WELDING Journal

April 2011

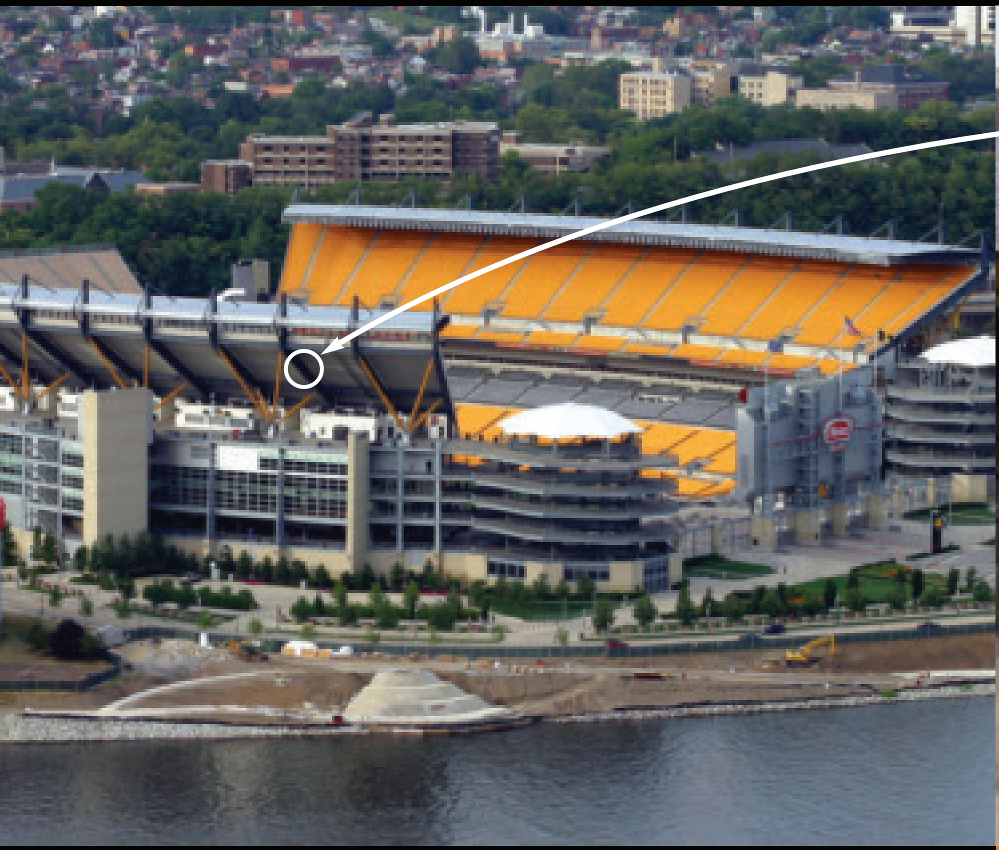
AWS

Become an Underwater Welder

YouTube and Welding

'Virtual' Skills Training

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



Raker Girders

133-ton Transfer Girder

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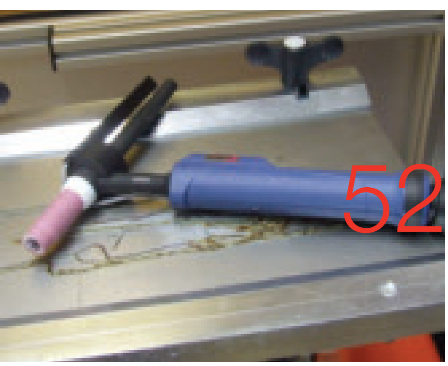

Features

Welding Research Supplement

On the cover: A student practices underwater welding at the International Diving Institute (IDI), LLC, North Charleston, S.C. (Photo courtesy of IDI.)

AWS Web site *www.aws.org*

Departments

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IIW 2012 — A World Welding Summit

It's not too early to spread the word about an international event in the world of welding that will soon be coming to the United States. The International Institute of Welding (IIW) will hold its 2012 Annual Assembly July 8–14, 2012, at the Hyatt Regency Hotel in Denver, Colo. It is an infrequent occurrence for IIW to meet in North America, and this upcoming meeting will provide a special opportunity for everyone involved in the welding industry to meet with their counterparts from all over the world.

Though it is held every year, the IIW Annual Assembly has only come to the United States three times in the past 63 years (New York City, 1961; Boston, 1984; and San Francisco, 1997). The 2012 event in Denver presents a special opportunity for welding experts throughout North America to attend what can truly be described as a world welding summit. In addition to meeting the world's most influential welding experts at the meetings, social events, and technical visits, you will have a chance to attend a major IIW International Conference on July 12 and 13, "Welding for Repair and Life Extension of Plants and Infrastructure."

Many of the participants will also take advantage of this chance to tour the beautiful state of Colorado, with its four National Parks: Rocky Mountain, Mesa Verde, Great Sand Dunes, and Black Canyon of the Gunnison. Combine the IIW Annual Assembly with Colorado's magnificent outdoors in mid-summer, the state's most welcoming time of year.

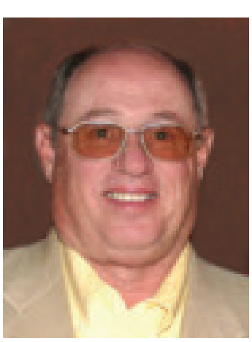
The International Institute of Welding was founded in 1948 by the welding institutes and societies of 13 countries (including the United States) to promote best joining practices on a worldwide level. Another goal was to provide an international platform for the exchange of evolving welding technologies and applications. Today, with 54 member countries, IIW has become a global reference, providing a respected forum for information exchange about welding technology. The scope of IIW interest, through its 25 Technical Commissions and Working Units, includes joining, cutting, and surface treatment of metals and nonmetals by means of welding, brazing, soldering, thermal cutting, thermal spraying, adhesive bonding, and microjoining. Allied fields covered by IIW work include quality assurance, nondestructive testing, standardization, health and safety, training, qualification, and design.

The 2012 IIW Annual Assembly will be officially hosted by the IIW American Council, which consists of the American Welding Society, Edison Welding Institute, and the Welding Research Council. AWS has put together a dedicated planning committee of American Council members and other welding experts who are working hard to ensure the event will be an outstanding success. The planning committee is cochaired by Damian Kotecki and Tom Mustaleski, both of whom are AWS past presidents. Dr. Kotecki is also IIW treasurer, and AWS Executive Director Ray Shook currently serves as IIW vice president.

My personal role on the planning committee is to raise funds to support the 2012 IIW Annual Assembly. Your role, or your company's, can be to become known internationally as a Bronze, Silver, Gold, or Platinum sponsor of the event. Even greater exposure is available by advertising your company's products or services in a special promotional magazine on the 2012 IIW Annual Assembly that will be sent with the AWS *Welding Journal* to its more than 67,000 subscribers all over the world. For more information on either of these opportunities, please contact me directly at *brice@oki-bering.com*.

Further information about the 2012 IIW Annual Assembly is available online at *www.iiw2012.com*. Under continuous development, this Web site will be the place to go for sponsorship information, to learn about accompanying tours and social events, and to register to attend the Annual Assembly.

The 2012 IIW Annual Assembly will truly be a world-class event in welding. Please plan now to be there, and to support it in every way you can. We hope to see you in Denver in July 2012.



William A. Rice
AWS Vice President

BY HUGH K. WEBSTER
AWS WASHINGTON GOVERNMENT AFFAIRS OFFICE

New White House Manufacturing Position Created

The new position of assistant to the president for manufacturing policy was recently announced by the White House. This position is within the National Economic Council, which advises the president on U.S. and global economic policy and is considered part of the executive office of the president. It's unclear whether this position is in addition to, or replaces, the senior adviser for manufacturing policy job within the Treasury Department that was created in late 2009 and has been generally known as the "manufacturing czar." There is also an assistant secretary of manufacturing and services within the Commerce Department. Regardless, it's assumed that an assistant to the president post will have enhanced influence and greater access to the president.

Administration Seeking to Establish 'Public Engagement Platform'

The White House is developing a draft concept for what it's calling a "next-generation citizen consultation," namely a government-wide software tool and process to elicit expert public participation. Tentatively named *ExpertNet*, this effort is intended to tap the expertise of the public in a manageable and structured format. The goal of *ExpertNet* is to enable government officials to search for and communicate with citizens who have expertise on a topic, giving them the opportunity to participate in a public consultation relevant to their areas of interest and know-how, and pose questions to and interact with the public to receive useful, relevant, and manageable feedback.

More information is available at the White House blog, *www.whitehouse.gov/blog*.

'Read the Bill,' Other Transparency Rules Adopted by Congress

The U.S. House of Representatives has adopted a new rule that no bill may be voted on without being available online for at least three calendar days. The rule reads, "it shall not be in order to consider a bill or joint resolution which has not been reported by a committee until the third calendar day…on which such measure has been publicly available in electronic formhttp

Similar transparency rules have been approved for House Committees, such as requiring that the text of legislation to be marked up must be made public no less than 24 hours before the markup, and all committee hearings and markups must be webcast and made available online.

In the U.S. Senate, the long-standing practice of "secret holds" has been barred. This tactic allowed individual senators to anonymously block any bill from proceeding. Under the new rule, senators are required to publish their holds in the *Senate Calendar* and *Congressional Record* within two legislative days. In addition, so-called "truth-in-testimony" forms, which disclose sources of federal funding for witnesses in committee hearings, must be posted online within a day after a hearing.

Two Proposed Regulatory Actions Withdrawn by OSHA

The U.S. Occupational Safety and Health Administration (OSHA) has recently withdrawn, temporarily, two proposed regulatory actions because of concerns about the potential impact on businesses.

The more controversial is a proposal to restore a column for work-related musculoskeletal disorders (MSDs) on OSHA Form 300, *Log of Work-Related Injuries and Illnesses*. While many employers are already currently required to keep a record of workplace injuries and illnesses, including work-related MSDs, the vast majority of small businesses are not required to keep such records. According to the Bureau of Labor Statistics, MSDs accounted for 28% of all reported workplace injuries and illnesses requiring time away from work in 2009.

OSHA also has withdrawn a proposed new interpretation of its existing Noise Standard. Late last year, OSHA proposed to require more employers to effect "administrative or engineering controls" to maintain noise at acceptable levels, rather than relying on personal protective equipment, such as ear plugs and earmuffs.

USCIS Reaches H-1B Limit

H-1B visa petitions reached the statutory cap of 65,000 for fiscal year 2011 earlier this year, according to the U.S. Citizenship and Immigration Services (USCIS). This is several months later than previous years and is presumed to be a result of unfavorable economic conditions. H-1B visas are used by U.S. businesses to hire skilled foreign workers.

NIST Outlines Future R&D Grant Directions

The National Institute of Standards and Technology (NIST) has issued a "Three-Year Plan" outlining the topics of possible future competitions for R&D funding under the agency's Technology Innovation Program (TIP). The research funding roadmap, which looks three years past the current fiscal year, proposes a range of TIP competitions in the fields of civil infrastructure, manufacturing, energy, health care, water resources, complex networks, and sustainability.

The TIP provides cost-shared funding, on a competitive basis, for high-risk technology R&D that offers solutions to specific critical national needs.

The TIP Three-Year Plan is available at *www.nist.gov/tip/upload/tip_programmatic_plan_fy2011_fy2014_01_25_2011.pdf*.

Regulatory Impediments to Manufacturing Cited

In response to a request from the House Oversight and Government Reform Committee, several manufacturers and manufacturing trade associations have identified those ongoing or pending regulatory programs they believe have the potential to create the greatest burden on U.S. manufacturers. Among those listed are Environmental Protection Agency initiatives to regulate greenhouse gases, tighten regulation of industrial and commercial boilers, and reconsider the National Ambient Air Standards. A current effort by the Occupational Safety and Health Administration to mandate a standard for employer safety and health programs was also highlighted.

The salutary effects of these initiatives will also be weighed by the House Committee to determine if the burden on manufacturing is unnecessarily high.◆

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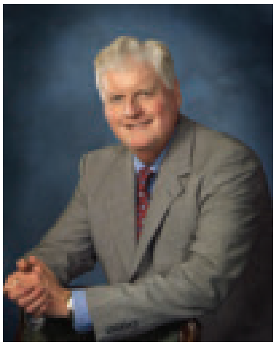
Seif Joins American Welding Society



Richard Seif

The American Welding Society, Miami, Fla., has engaged Richard Seif, recently retired from The Lincoln Electric Co., Cleveland, Ohio, as special assistant to the executive director. Seif will work on behalf of AWS to expand and facilitate international growth for the Society's products and services; assist the AWS Foundation in its welding workforce development activities; promote and develop the AWS Certified Welding Sales Representative program; and other related responsibilities.

"We are extremely pleased to have Dick Seif join us," said Ray Shook, AWS executive director. "He is well known and highly respected throughout the welding industry, and he brings a proven background in marketing innovation to the position."

Seif served The Lincoln Electric Co. for 40 years, most recently as senior vice president, global marketing and product development. Joining the firm in 1971, he held several positions of increasing responsibility, including vice president of sales and marketing, Lincoln U.S., and president, Lincoln Canada. He holds a bachelor of science degree in electrical engineering and master of business administration from Michigan State University.

Ohio State Researchers Invent Chromium-Free Alloy

A new nickel alloy consumable invented by Gerald Frankel and John Lippold, professors of materials science and engineering at The Ohio State University, was developed to lessen welders' risk of breathing toxic fumes on the job. It was developed to aid military and commercial welding personnel who work in tight spaces.

During tests, welds made with the consumable proved just as strong and corrosion resistant as welds made with commercial stainless steel consumables. When melted, the alloy does not produce hexavalent chromium fumes. Frankel and Lippold have begun further testing of their alloy with Euroweld, Ltd., Mooresville, N.C. The university will license the alloy and its applications.

The university has three issued U.S. patents and a pending European patent application covering a series of alloys, based on nickel and copper but with no chromium.

The research was funded by the Strategic Environmental Research and Development Program, a partnership of the Department of Defense, the Environmental Protection Agency, and the Department of Energy.

For more information, read "A New Chromium-Free Welding Consumable for Joining Austenitic Stainless Steels," on page 63-s of this *Welding Journal*.

Matheson K-Air India to Invest $100 Million, Build Plant

Matheson K-Air India Private Limited, a joint venture between Matheson Tri-Gas, Inc., an American Welding Society Sustaining Company Member, and K-Air India Private Limited, will undertake a series of investments totaling in excess of $100 million. This includes constructing a new, 200 ton per day air-separation plant in Pune, India. Expected to be fully operational by December 2012, it will produce liquid oxygen, nitrogen, and argon for delivery to end-user customers and distributors located primarily within a 300-km radius of the facility.

Genesis Plastics Welding to Expand Facility, Create Jobs

Genesis Plastics Welding will expand its operations in Fortville, Ind., creating up to 54 new jobs by 2014. The company plans to invest more than $3.3 million to add 50,000 sq ft of production space at its existing facility. Currently, Genesis is accepting applications for production workers and plant supervisors; visit *www.genesisplasticswelding.com* for contact information.

In addition, the Indiana Economic Development Corp. offered the company up to $340,000 in performance-based tax credits based on its job creation plans. Construction is scheduled to be completed by December.◆

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What's Happening in Welding Education

Mohave Community College's Welding Program Upgrades Equipment, Facilities

Buddy May, Mohave Community College's resident welding faculty member, poses in front of new welding booths at the Neal Campus-Kingman, Ariz., location. There are 12 dual work stations with ventilation systems, creating a student capacity of 24. (Photos courtesy of Mohave Community College.)

A student practices welding techniques using energy-efficient equipment available in the college's renovated welding lab.

Welding students at Mohave Community College (MCC), Neal Campus-Kingman, Ariz., will soon be able to take American Welding Society (AWS) qualification tests in addition to earning their degree.

Buddy May, formerly a welder in the U.S. Navy, is the new full-time welding technology faculty member. He's an AWS Certified Welding Educator and Certified Associate Welding Inspector. By this spring, he's expecting to achieve the AWS Certified Welding Inspector status that will enable MCC to establish a welding qualification testing center at the campus.

Welding program revisions for the current spring semester include upgraded equipment and facilities where hands-on instruction takes place. Also, starting with its upcoming fall semester, there will be curriculum changes to fit the requirements of AWS standards.

"By aligning the curriculum at MCC with the AWS certifications, students will earn a certificate from the college and increase their probability of passing the exam for an AWS welding certification that is accepted worldwide," said MCC President Michael Kearns.

The program is also designed to build on tech prep and dual-enrollment credits earned in high school for transfer into community college career and technical education pathways.

Facilities and equipment improvements were made possible by Perkins Grant funds and an Intergovernmental Agreement between the college and Western Arizona Vocational Education Joint Technological Education District.

All students currently enrolled in the welding program have an option of completing it as originally outlined or transitioning into the new program and testing for AWS qualifications.

"Students who enter the program this fall will be able to complete a welding certificate in two semesters or an associate of applied science degree in four," said Andra Goldberg, career and technical education coordinator for MCC's Neal Campus-Kingman. Both will incorporate AWS qualification preparation.

University of Texas Receives $2-Million Gift for New Engineering Program

The University of Texas at El Paso (UTEP) is expected to launch its Leadership Engineering Program by fall 2012. It includes a broad-based curriculum of engineering design, project management and innovation, along with an emphasis on business, communication, ethics, and social science.

A combined $2-million gift — from UTEP alumni Bob Malone, president and CEO of First National Bank of Sonora, Tex., and his wife, Diane, and Halliburton, a provider of products and services to the energy industry — will fund the program's development and scholarships for engineering students.

"The overarching goal is graduation of a new pedigree of qualified engineers with the professional skills, business acumen and strategic foresight, in addition to engineering prowess, to meet the needs of industry in the 21st century," said Dr. Richard Schoephoerster, dean of the College of Engineering.

The program will educate engineers with a liberal-technical approach, featuring a curriculum to capture the interest and imagination of talented, young leaders to turn their ideas into reality.

Genesis Systems Group Establishes Robotic Welding, Engineering Scholarship

Genesis Systems Group, Davenport, Iowa, an independent U.S. robotic workcell integrator, recently announced a new scholarship through an agreement with Western Illinois University (WIU)-Quad Cities Engineering Program and Scott County Schools.

The Andy Zinn-Genesis Systems Group scholarship is designed to encourage, support, and award students interested in a robotic welding systems and engineering career. One $2500 scholarship will be awarded annually and is renewable for four years for a total of $10,000. It's intended the company will award one four-year scholarship each year for four years.

Requirements include the following: Students must be graduates of a high school in Scott County, Iowa; complete the job shadowing program with Genesis Systems Group before high school graduation; and be enrolled in Project Lead the Way courses or a vocational area of study, WIU's linkages program with Eastern Iowa Community College or Black Hawk College for the first two years of college, and WIU-Quad Cities for the third and fourth years.

Visit *www.genesis-systems.com* or *wiu.edu/scholarships* for more information.

Monroe County Community College to Build Career Technology Center

The Board of Trustees for Monroe County Community College (MCCC), Monroe, Mich., voted unanimously to make $8.5

million available, through funds held in reserve and gifts it has received, for the college's 50% match to construct a 71,300-sq-ft Career Technology Center.

The facility will provide infrastructure to support classrooms and lab space required to deliver instruction and skills necessary to secure high-demand jobs. It will allow updating and expanding existing programs now housed in the East and West Technology buildings, including welding, nuclear engineering, computer-aided drafting and manufacturing, electronics, and automotive engineering. Also, it will provide facilities and equipment necessary for developing advanced manufacturing, alternative energies, and sustainable/green technologies programs.

The facility's total authorized cost is $17 million, with $8,499,800 coming from the State Building Authority, $8.5 million from MCCC, and $200 from the state general fund. It's anticipated construction will begin in July with occupancy in September 2012.

Thermadyne® Starts Education Initiative, Sponsors Student Career Day Program

Thermadyne® Industries, St. Louis, Mo., is launching its "Carry the Torch" program in support of educators and their students.

"At Thermadyne, we are committed to helping build the future of this industry, not only to crafting better and safer equipment, but to the people who will use them...the next generation of welders," said Joe Mueller, vice president, sales and marketing. The program includes educational discounts on initial orders for products and consumables from all of the company's brands.

In addition, the company has become a sponsor of Student Career Day program at Autorama and World of Wheels events, which are part of Summit's Performance Equipment Show Car Series seeking to introduce high school, vocational, and college automotive students to the aftermarket hot rod industry.

Student Career Day events will take place in 25 cities during the 2010/2011 show season where students are exposed to opportunities in the specialty automotive aftermarket industry.

"Working on custom cars and hot rods is an exciting job that can be a fulfilling way to demonstrate your talents and creativity. And, in addition to being a fulfilling job, it is a very marketable one," added Mueller.

Worthington Industries, Gestamp to Form Venture for Wind Tower Manufacturing

The Energy Group subsidiary of Worthington Industries, Inc., Columbus, Ohio, signed a memorandum of understanding with Gestamp Renewables group to create a 50-50 joint venture. Gestamp Worthington Wind Steel, LLC, will focus on producing towers for wind turbines constructed in the North American market. The partners also identified 30 acres in Cheyenne, Wyo., as the site of the initial production facility and anticipate employing 150 people when fully operational.

The venture expects to begin shipments of 80–100-ft-long tower sections in the first quarter of 2012. The proposed facility will produce utility-scale towers for 2.0- to 3.0-MW wind turbines. Initial plans call for production of more than 300 towers per year.

Insituform Technologies Awarded Contract for Pipeline Coating and Welding Services

Insituform Technologies, Inc., St. Louis, Mo., recently announced its subsidiary, The Bayou Companies LLC, has been awarded a contract with Air Products and Chemicals, Inc., a hydrogen producer. The company will provide corrosion and concrete weight coatings, double joint welding, and logistic support

Insituform Technologies will provide corrosion and concrete weight coatings, plus double joint welding, on a new hydrogen pipeline in the Gulf Coast. Shown are the company's pipeline welding services in action. (Photo courtesy of Insituform Technologies, Inc.)

on more than 180 miles of 18-in. steel pipe for use on a new hydrogen pipeline in the Gulf Coast.

It's expected Bayou will begin work on the project by the end of the first quarter of 2011, continue work through the end of the third quarter 2011, and the pipeline will be in service by 2012.

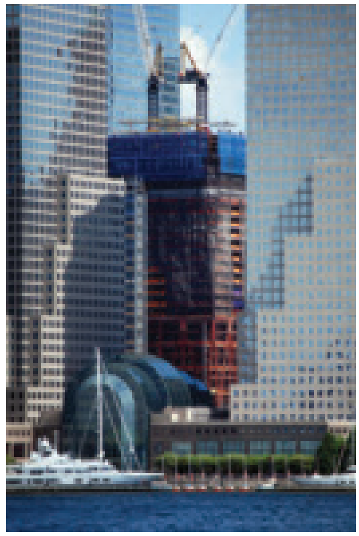
"With high-quality coating capabilities, more than 280 acres of storage, access to rail, truck and barge loading or unloading, and extensive experience in welding, Bayou is committed to the successful completion of this project," said Jerry Shea, president of The Bayou Companies.

ThyssenKrupp, Christian Pohl Supply Steel for One World Trade Center

The corners of the new One World Trade Center's facade will be edged with stainless steel made in Germany.

ThyssenKrupp Nirosta, Krefeld, produced the material at its Dillenburg plant using a rolling and heat-treatment process. Christian Pohl GmbH, Cologne, fabricated the material into facade elements for the center's corners, some 250 tons in total.

The 1 × 4 m facade elements are made from corrosion-resistant, chromium-nickel-molybdenum stainless steel Alloy Nirosta 4404 with a textured finish. Installment began recently.



The One World Trade Center, formerly named the Freedom Tower, is under construction on Ground Zero in New York. The corners of the skyscraper's facade will be edged with stainless steel. (Photo courtesy of emporis.)

The One World Trade Center's construction is managed by Tishman Construction Corp. of New York. The building's gross area will be 3.5 million sq ft. The total height of the structure, including antenna, will be 1776 ft.

The outer facade of the skyscraper will be made of glass. Above the 200-ft-high base, metal frames surrounding the glass panes will be clad with stainless steel panels. The building's edges rotate through an angle of 45 deg from the base upward. The final architectural design of the building now under construction was drawn up in the New York office of the international architectural firm Skidmore, Owings & Merill.

Industry Notes

- **Joining Technologies**, a laser cladding, electron beam, and laser welding applications innovator, launched a laser additive manufacturing division and entered into a cooperation agreement with **Fraunhofer Institute for Laser Technology**. The resulting partnership is the **Joining Technologies Research Center**.
- **Spitzer Industries, Inc.**, Houston, Tex., completed acquiring **Advanced Inspection Technologies**, also based in Houston, furthering the company's fabrication potential with deeper welding engineering and technology capabilities.
- **Northwest Pipe Co.** plans to expand its Atchison, Kans., mill facility that is home to one of three Tubular Products Group locations. Anticipated to be complete by the fourth quarter of 2011, this will enable product production up to 0.375 in. wall.
- **Murray Percival Co.**, a Midwest electronics distributor and process specialist that's a third-generation, family-owned business, is celebrating its 50th year as a supplier to the industry.
- **C. & E. FEIN GmbH**, Germany, a power tool manufacturer, is acquiring **Jancy Engineering, Inc.**, Davenport, Iowa, a core drilling tool firm. Jancy will remain under its current management.
- A partnership between manufacturer **Torchmate**, Reno, Nev., and retailer **4 Wheel Parts** is putting automated metal-cutting machinery into storefronts across the nation.
- **Precision Welding Supply**, Coatesville, Pa., is now the East Coast factory-authorized warranty repair station for the complete **MK Products** orbital welding supply line.
- **Seconn Fabrication**, Waterford, Conn., recently announced the latest addition to its family of companies, **Solar Fabricators**.
- **The Lincoln Electric Co.'s** virtual reality welding system, VRTEX® 360, has been recognized by the **International Institute of Welding** with its 2011 Heinz Sossenheimer Award.
- **ProlamsaUSA**, Houston, Tex., a tubular shape producer, has a new Web site at *www.prolamsausa.com* offering users registered to its LinkedIn section a flow of industry news.
- **Airgas, Inc.**, Radnor, Pa., signed a three-year agreement with **TDIndustries**, Dallas, Tex., for industrial gases, welding and safety products, leased safety equipment from Oilind Safety, and leased welding equipment, welder certification trailers, generators, and compressors from Red-D-Arc Welderentals.
- **Industrial Scientific's** primary design and commercial facility is now at its leased 35,000-sq-ft space within the Oncology Nursing Society Building in RIDC Park West, Pittsburgh, Pa.
- **Orbitform Group**, Jackson, Mich., received **ISO 9001:2008 Quality Management** certification for the design and manufacture of orbital forming, fastening, joining, conveyor systems, and assembly equipment.
- Plant engineering specialist **Kemper** is expanding automation activities with creating a new business for warehouse, automation, and control technology in Lünen, Westphalia, Germany.♦

BY TONY ANDERSON

Q: I have often heard aluminum described as a material that has very good corrosion resistance. What are the facts associated with aluminum and corrosion?

A: The corrosion behavior of aluminum and its alloys is a very broad subject. In this column, I will try to provide a brief overview.

The General Principles of Aluminum's Corrosion Resistance

Aluminum is described as having outstanding corrosion resistance because of the oxide film that adheres strongly to its surface and, that if damaged, re-forms immediately in most environments. On a surface freshly abraded and then exposed to air, the oxide film is only around 1 nm thick. The oxide film, even at this very limited thickness, is highly effective in protecting the aluminum from corrosion. The oxide film that develops on aluminum in ordinary atmospheres grows to thicknesses much greater than 1 nm and is composed of two layers. The inner oxide that is next to the metal is a compact, amorphous barrier layer whose thickness is determined entirely by the temperature of the environment.

At any given temperature, the limiting barrier thickness is the same in oxygen, dry air, or moist air. Covering this barrier layer is a thicker, more permeable outer layer of hydrated oxide. The natural film on aluminum can be visualized as the result of a dynamic equilibrium between opposing forces — those tending to form the compact barrier layer and those tending to break it down.

If the destructive forces are absent, as in dry air, the natural film will consist only of the barrier layer that forms quickly to the limiting thickness. If the destructive forces are too strong, the oxide will be hydrated faster than it is formed and little barrier will remain. Between these extremes, where the opposing forces reach a reasonable balance, relatively thick (20 to 200 nm) natural oxide films are formed.

The conditions for thermodynamic stability of the oxide film are expressed by the Pourbaix (potential vs. pH) diagram featured in Fig. 1. As shown, aluminum is passive (protected by its oxide film) in the pH range of about 4 to 8.5. However, the limits of this range vary somewhat with temperature, the specific form of oxide film present, and the presence of substances that can form soluble complexes or insoluble salts with aluminum.

Pitting Corrosion

Corrosion of aluminum in the passive range is localized, usually manifested by random formation of pits. The pitting potential principle establishes the conditions under which metals in the passive state are subject to corrosion by pitting.

For aluminum, pitting corrosion is most commonly produced by halide ions, of which chloride is the most frequently encountered in service. Pitting of aluminum in halide solutions open to the air occurs because, in the presence of oxygen, the metal is readily polarized to its pitting potential.

Generally, aluminum does not develop pitting in aerated solutions of most nonhalide salts because its pitting potential in these solutions is considerably more noble (cathodic) than in halide solutions and it is not polarized to these potentials in normal service.

Solution Potentials

Because of the electrochemical nature of most corrosion processes, relationships among solution potentials of different aluminum alloys, as well as between potentials of aluminum alloys and those of other metals, are of considerable importance. Furthermore, the solution potential relationships among the microstructural constituents of a particular alloy significantly

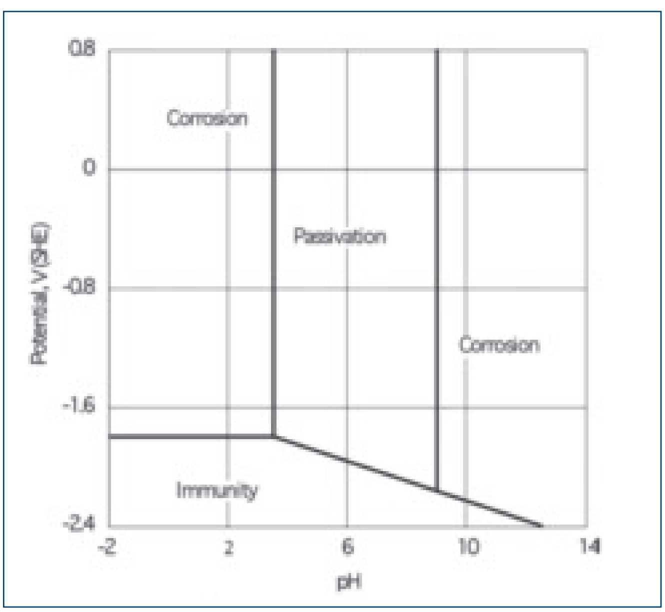


Fig. 1 — Pourbaix diagram for aluminum with an $Al_2O_3\ 3H_2O$ film at 75°F (25°C). Potential values are for the standard hydrogen electrode (SHE) scale.

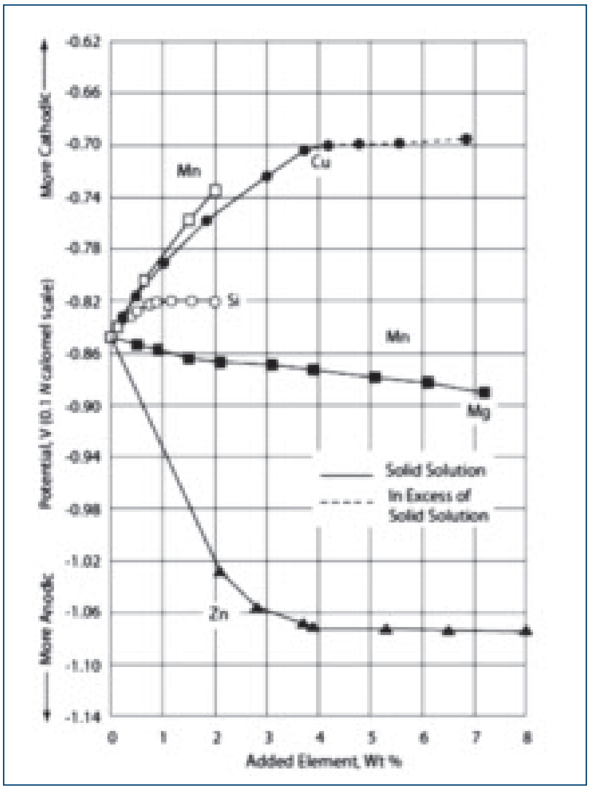


Fig. 2 — Effect of principal alloying elements on the electrolytic solution potential of aluminum. Potentials are for solution-treated and quenched high-purity binary alloys in a solution of 53 g/L NaCl plus 3 g/L H_2O_2 at 25°C (75°F).

affect its corrosion behavior. Compositions of solid solutions and additional phases, as well as amounts and spatial distributions of the additional phases, may affect both the type and extent of corrosion.

The solution potential of an aluminum alloy is primarily determined by the composition of the aluminum-rich solid solution, which constitutes the predominant volume fraction and area fraction of the alloy microstructure. Solution potential is not affected significantly by second-phase particles of microscopic size, but because these particles frequently have solution potentials differing from that of the solid solution matrix in which they occur, localized galvanic cells may be formed between them and the matrix. Since most of the commercial aluminum alloys contain additions of more than one of these elements, effects of multiple elements in solid solution on solution potential are approximately additive. The amounts retained in solid solution, particularly for more highly alloyed compositions, depend highly on fabrication and thermal processing so that the heat treatment and other processing variables influence the final electrode potential of the product. The effect of principal alloying elements on solution potential of high-purity aluminum are shown in Fig. 2.

Intergranular Corrosion

Intergranular (intercrystalline) corrosion is selective attack of grain boundaries or closely adjacent regions without appreciable attack of the grains themselves. Intergranular corrosion is a generic term that includes several variations associated with different metallic structures and thermomechanical treatments. Intergranular corrosion is caused by potential differences between the grain bodies. The location of the anodic path varies with the different alloy systems.

In the 2xxx series alloys, it is a narrow band on either side of the boundary that is depleted in copper. In the 5xxx series alloys, it is the anodic constituent Mg_2Al_3 when that constituent forms a continuous path along a grain boundary. In the copper-free 7xxx series alloys, it is generally considered to be the anodic zinc and magnesium-bearing constituents on the grain boundary. In the copper-bearing 7xxx series alloys, it appears to be the copper-depleted bands along the grain boundaries. The 6xxx series alloys generally resist this type of corrosion, although slight intergranular attack has been observed in aggressive environments.

Strain-hardened 5xxx series alloys that contain more than 3% Mg are rendered susceptible to intergranular attack (sensitized) by certain manufacturing conditions or by being subjected to elevated temperatures above 150°F. This is the result of the continuous grain boundary precipitation of the highly anodic Mg_2Al_3 phase, which corrodes preferentially in most corrosive environments.

Stress Corrosion Cracking

Only aluminum alloys that contain appreciable amounts of soluble alloying elements, primarily copper, magnesium, silicon, and zinc, are susceptible to stress corrosion cracking (SCC). For most commercial alloys, tempers have been developed that provide a high degree of immunity to SCC in most environments.

Atmospheric Corrosion

Most aluminum alloys have excellent resistance to atmospheric corrosion (often called weathering), and in many outdoor applications, such alloys do not require shelter, protective coatings, or maintenance.

Corrosion in Waters

Aluminum alloys of the 1xxx, 3xxx, 5xxx, and 6xxx series are resistant to corrosion by many natural waters. The more important factors controlling the corrosivity of natural waters to aluminum include water temperature, pH, and conductivity, availability of cathodic reactant, presence or absence of heavy metals, and the corrosion potentials and pitting potentials of the specific alloys.

Conclusion

The above is a limited description of some issues associated with this very broad and complex subject. There are many other areas associated with aluminum corrosion behavior.♦

Acknowledgment

I would like to thank ASM International for permission to use information from the corrosion behavior section of its publication *ASM Specialty Handbook — Aluminum and Aluminum Alloys*.

TONY ANDERSON is director of aluminum technology, ITW Global Welding Technology Center. He is a Fellow of the British Welding Institute (TWI), a Registered Chartered Engineer with the British Engineering Council, and holds numerous positions on AWS technical committees. He is chairman of the Aluminum Association Technical Advisory Committee for Welding and author of the book Welding Aluminum Questions and Answers *currently available from the AWS. Questions may be sent to Mr. Anderson c/o Welding Journal, 550 NW LeJeune Rd., Miami, FL 33126, or via e-mail at* tony.anderson@millerwelds.com.

American Welding Society

Friends and Colleagues:

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

For specifics on the nomination requirements, please contact Wendy Sue Reeve at AWS headquarters in Miami, or simply follow the instructions on the Fellow nomination form in this issue of the *Welding Journal*. Please remember, we all benefit in the honoring of those who have made major contributions to our chosen profession and livelihood. The deadline for submission is July 1, 2011. The Committee looks forward to receiving numerous Fellow nominations for 2012 consideration.

Sincerely,

Thomas M. Mustaleski
Chair, AWS Fellows Selection Committee

We would like to thank the following Major Donors who have supported the Foundation:

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Forging the future in welding

Your Career in Welding

A guide for students, parents, teachers, and career-changers

Miller Electric Mfg. Co. – Sponsor of the World Skills Competition Scholarship

The Miller Electric Manufacturing Company established this $40,000 scholarship in 1995 to recognize and provide financial assistance to contestants representing the United States in the World Skills Competition. To qualify, an applicant must advance through the national SkillsUSA Competition. The 3 SkillsUSA competitors qualifying the highest advance on to the next phase of the selection process that culminates at the SkillsUSA Championships in Kansas City, MO. The SkillsUSA winner at the US Open Weld Trials represents the United States at the World Skills Competition held worldwide every other year.

2009	Joe Young	1999	Ray Connolly
2007	Chance Pollo	1997	Glen Kay III
2005	Joel Stanley II	1995	Branden Muehlbrandt
2003	Miles Tilley	1993	Nick Peterson*
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*1991 and 1993 recipients received alternate scholarship funds, which were prior to the start of the Miller Electric Mfg. Co. Scholarship.

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The Mission of the AWS Foundation is to meet the needs for education and research in the field of welding and related joining technologies.

We greatly appreciate the hundreds of individuals and companies who support the industry's future by contributing to the Foundation's educational programs, which provide scholarships and fellowships to students pursuing a career within welding or related materials joining sciences.

BY DAN KAY

Q: I am thinking about using a Ni-Cr-P braze alloy, such as AWS BNi-6, BNi-7, or BNi-12, in order to join some Ni-based Inconel® superalloys, as well as for brazing some stainless steels such as Hastelloy® X and 410 stainless steel. Their low melting temperatures are attractive to me. Could such brazing be performed in a vacuum furnace? Is partial pressure required?

A: First of all, you mention the joining of Ni-based superalloys, and then also mention joining "stainless steels such as Hastelloy X and 410 stainless steel."

The nickel-based brazing filler metals (BFMs) containing phosphorus (BNi-6, BNi-7, and BNi-12) are very well suited for joining the nickel-based superalloys, such as any of the Inconels, etc., in which the base materials are primarily nickel and chromium. The phosphorus-containing Ni-BFMs have been used for many years in such applications (such as for nuclear grids, etc.) and have performed very well.

However, when ferrous-based metals are involved, such as stainless steels, it is strongly recommended (from my own experience as well) that you NOT use any phos-containing BFMs when you are trying to join them. The automotive people found this out when they tried to use phos-copper BFMs to join carbon-steel fuel rails back in the 1960s and 1970s. Field failures came fast! Phosphorus-containing BFMs have been banned from such ferrous brazing for many years now.

Metallurgically, phosphorus loves to react with the iron in these ferrous materials to form iron-phosphides in the reaction zone in and near the brazed joint, and cross sections of joints (if very carefully made) can look great. The problem is that these iron-phosphides have no meaningful ductility, and can thus result in cracks through the brazed joint if the parts are subjected to any kind of service stresses due to thermal cycling, fatigue, shock, vibration, etc. Thus, phosphorus-containing BFMs are not to be recommended for use on any ferrous metals.

The rare exception to this rule is when very thin, flexible sheet metal is involved, such as when brazing honeycomb materials. Because the sheet metal is very thin, the base metal sheet itself may be able to move, bend, etc., carrying the brazed joint along with it, and thus the joint would not have to directly handle all that movement and "abuse." But, when the base metals are thicker and much more massive, the brazed joints have to directly absorb all that shock. If any phosphides are present they could cause some real service problems.

Let me also comment about atmospheres. Yes, brazing these materials in a vacuum is fine, and the use of an argon partial pressure is an acceptable option, but only if needed. Remember that the reason you are using a vacuum is to exclude a lot of the problems encountered with atmospheres, such as oxygen content (dewpoint issues), for example. Whenever you put a partial pressure of atmosphere into the furnace, you may also be "throwing water" into the chamber unless you carefully monitor the partial-pressure gas at the inlet to the vacuum furnace to be sure that its dewpoint is very low (usually –60°F or drier, when measured at the furnace). Piping the argon through a gas drier that is placed right at the furnace could also be very helpful.

Another reason people use a partial pressure atmosphere in their vacuum furnaces is to prevent some metallic constituents of the base metals or BFMs from outgassing in the furnace vacuum. This is often true when using a silver-based BFM in a vacuum furnace, or if the base metals being joined contain relatively high vapor-pressure metals such as copper, silver, etc. Very high vapor pressure metals such as zinc should never be brazed in a vacuum furnace. The use of a partial pressure of argon, for example, may then be helpful in suppressing any outgassing of those high-vapor pressure materials. However, for most stainless steel brazing, or Inconel brazing, no added atmosphere is really needed when using standard BNi-type BFMs.

One final thought regarding the use of any phosphorus-containing BFMs. Some people believe that using these low-melting BFMs is a way to keep their furnace brazing costs down. Be careful! Remember, metals will oxidize on their way up to brazing temperature, and this can be a real problem with any metals containing chromium (such as Inconels and many stainless steels). When brazing chromium-containing metals, you will need to go above approximately 1900°F/1050°C in order for any chromium oxides to be reduced (dissociated) in a vacuum or atmosphere furnace. Therefore, if you were to use a BNi-6 BFM (eutectic at 1610°F/880°C) and use the standard guideline of brazing at approximately 100°F/50°C higher than the published liquidus of the BFM, you might be tempted to braze at temperatures just above 1700°F/930°C in your furnace. At such temperatures, the chromium oxides will not have been reduced, and very poor brazing may result. In such cases, it would usually be necessary to pre-plate the chromium-containing metals with electrolytic nickel prior to brazing, so that the chromium oxides would not be able to form inside the joint between the faying surfaces.♦

This column is written sequentially by TIM P. HIRTHE, ALEXANDER E. SHAPIRO, and DAN KAY. Hirthe and Shapiro are members of and Kay is an advisor to the C3 Committee on Brazing and Soldering. All three have contributed to the 5th edition of AWS Brazing Handbook.

Hirthe (timhirthe@aol.com) *currently serves as a BSMC vice chair and owns his own consulting business.*

Shapiro (ashapiro@titanium-brazing.com) *is brazing products manager at Titanium Brazing, Inc., Columbus, Ohio.*

Kay (Dan@kaybrazing.com)*, with 40 years of experience in the industry, operates his own brazing-training and consulting business.*

Readers are requested to post their questions for use in this column on the Brazing Forum section of the BSMC Web site www.brazingand soldering.com.

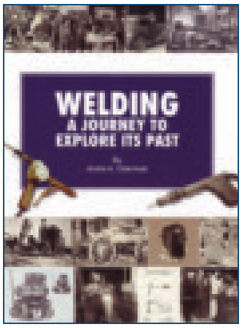
LETTERS TO THE EDITOR

Reader Expands on Mendoza's Editorial

I enjoyed AWS President John Mendoza's editorial in the January 2011 issue ("Recapturing the Spirit of '76," on page 6, which focuses on the history and importance of the AWS Certified Welding Inspector program). No doubt he didn't know that Butch Sosnin was the father of the qualification program. He was the instigator and driving force, being chairman of the Pipe Welding Committee at the time. He later became AWS president.

Harry E. Broadbent
Fort Lauderdale, Fla.

BY A. F. MANZ



Welding: A Journey to Explore Its Past is a wonderful book about the history of welding written by André A. Odermatt, president and chairman of the board of Hobart Institute of Welding Technology. It takes us on a trip through time, in an easy-to-read text.

It took a vast amount of research to write this book. There are more than 600 photographs, many of them in color. It is printed on high-quality paper with an easy-to-read type and font size. The proofreaders did a very good job. I found only a few typos, of which I informed the author privately.

The text is presented in 11 major sections: 1. Brazing, Soldering and Cutting; 2. Gas Welding and Cutting; 3. Electric Welding; 4. Electroslag Welding; 5. Automatic Welding Processes; 6. Arc Welding Power Sources; 7. Resistance Welding; 8. Solid-State Welding; 9. Thermit Welding; 10. Training of Welders; and 11. Welding Contributes to Society. The front matter includes a color chart of "Welding and Joining Processes," and another color chart of the "Historical Development of Welding Processes." The end pages of the book include "A Selected Chronology of Welding," a listing of "Historical Electrode Patents," and a reproduction of the New York Public Library's 1913 "List of Works Relating to Welding" as well as an extensive list of references.

Inside the front and back covers is a time line chart of significant events in the history of welding. The time line runs from 8000 BCE to 2003 CE. (For you old timers that is from 8000 BC to 2003 AD.) The chart also includes a few events in the history of the Hobart Brothers Co.

Its use as a reference text is severely hampered by the lack of an index. It also is hampered by the lack of individual identification of the sources of the many photos and figures. These omissions should be corrected if there is a reprinted edition. These changes will make the text much more useful as a reference.

There is extensive and helpful use of patent exhibits. Patents are a valuable source of historical data. In addition, American Welding Society (AWS) definitions of the various welding and cutting process terms are presented at the beginning of each chapter and subsection. It would be helpful in the future to add the AWS abbreviations for each of these definitions.

Section 3.2, The Battle of Currents, shows a "Figure 3.2.1: Hippolyte Pixii AC generator 1832." This in fact is Pixii's machine for generating DC. The rotating magnet induces an alternating current in the coils shown at the top of the figure. The current is converted to pulsating direct current by the commutator shown, just below the U-shaped magnet. (See *A History of Electricity and Magnetism* by Herbert W. Meyer, The MIT Press, Cambridge, Mass., ©1977, pages 71, 72.) This correction is an example of how the inclusion of reference information, in future printings, would be helpful to historians.

Section 3.10, Gas Metal Arc Welding, makes a subtle case for some Hobart employees' role in the invention of gas metal arc welding (GMAW) at the Battelle Memorial Institute of Columbus, Ohio, in the 1940s. Over the years, many people played a part in the events that eventually led to the invention of GMAW. For example, H. D. Morton, U.S. Pat. 1,278,982, September 17, 1918, had most of the elements needed to practice GMAW. However, he did not have the critical knowledge that at certain current levels and with certain wire diameters there is what we now call spray transfer or spray arc. The same is true of the work done at Battelle. It was the work of Muller, Gibson, and Anderson at Airco (Air Reduction Co.) that resulted in U.S. Patent 2,504,868, April 18, 1950. That patent is recognized as when GMAW, as is practiced around the world, was first described.

This book will be a welcome addition to any welding library. If you enjoy welding and history, this book will give you many hours of pleasant reading. It is written in a readily understood manner and is loaded with interesting tidbits of welding lore.♦

Welding: A Journey to Explore Its Past, *by André A. Odermatt, ©2010. Published by Hobart Institute of Welding Technology, 400 Trade Square East, Troy, OH 45373,* www.welding.org, *(800) 332-9448. Price for hardcover (EW-807) $39.95, softcover (EW-806) $24.95 plus a shipping fee of $8. ISBN 978-1-936058-29-7.*

A. F. MANZ is a Fellow of the American Welding Society, Miami, Fla.

Welding Booths Improve Workspace Management

A fabricated welding booth features workspace management for training, educational, and vocational centers, as well as other stationary production welding applications. It comes in two sizes, 5 × 5 ft and 6 × 6 ft, which meet AWS guidelines for booth width and depth. The steel-constructed booth can be used as a stand-alone unit, or placed side by side and/or back to back in a multiple booth installation. As an option, source capture weld fume control is available with a telescopic extraction arm made from scratch- and dent-resistant material that extends 40–80 in. in length and includes a 360-deg rotatable hood. The following options are available: worktable with adjustable overhead welding bracket, welding curtain, tool shelves with torch holders, and lock box for personal items.

The Lincoln Electric Co.
www.lincolnelectric.com
(888) 355-3213

Pipe Beveling Machine Reduces Fit-Up Time

The PRO 10PB/PBE portable pipe beveling machine, available in pneumatic or electric versions, bevels pipe diameters from 1.5 to 10 in. Its lightweight, compact design allows setup and operation by a single user. Using a self-centering, ID-mounted mandrel, it performs beveling, facing, counterboring, and J-groove weld preparation. Producing machined pipe ends allows for rapid fitup and welding. Consistent machined beveling provides a foundation for high-quality welds and helps reduce weld defects. The tool holders open design allows viewing of machine operations for simultaneous facing, beveling, and counterboring operations.

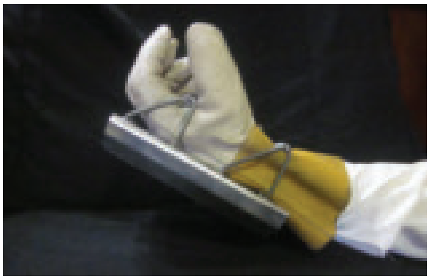
Steelmax Tools LLC
www.steelmax.com
(877) 833-5629

Robot Protects Cables and Hoses in Its Upper Arm

The IRB 2600ID, an arc welding robot that features an integrated dress pack design, has a 2-m reach and 8-kg payload. It also offers a flexible conduit in its upper arm/wrist for routing the cables and hoses. The design provides 15% shorter cycle times and easier programming. In addition, the time required for fine-tuning programs is minimized by up to 90%, enabling faster transitions from weld to weld. It works in narrow spaces and has a swing base radius of 337 mm and base width of 511 mm. For arc welding, the reduced risk of interference with other robots allows for high-density installations with 50% more robots, and up to 50% higher output from a production cell. It's available with the company's IRC5 robot controller.

ABB Robotics
www.abb.com/robotics
(248) 391-9000

Hand Shield Provides 1-in. Barrier above Gloves



The welding Gauntlet Glove, invented by AWS member Rick Dawson, provides hand protection by deflecting welding slag, molten steel, and hot embers. The aluminum shield dissipates heat, provides a 1-in. barrier above your gloves, and can be worn on either hand. It weighs less than 10 oz, with stainless steel flexible springs. The rectangular shape and ridges help guide your welding holder in horizontal or uphill positions. While wearing the product, users can better concentrate on controlling weld pool movement, bead width, and penetration. When welding in structural steel, with hot flux 232 core welding wires, it protects from excessive heat and ultraviolet light. Replacement shields are available as well.

Tuff Mats
www.weldinggauntlet.com
(707) 462-1232

Wheels Maintain Speed of Weld Cleaning Brushes

The DUALLY™ stringer-bead wheels feature a dual-hex nut to eliminate interference issues that might force users to remove guards from their angle grinders. The patent-pending design features a nut with a hex on each side of the wheel that's tall enough to ensure adequate clearance on the tool. A stringer-bead twist puts the sharp wire tips at the end of the knot, so the wheels cut through slag, spatter, and oxidation. By utilizing heat-treated steel wire and a construction that virtually eliminates knot movement, the product delivers smooth operation and long life.

Weiler Corp.
www.weilercorp.com
(800) 835-9999

Blast Machine Utilizes Abrasive Recycling System

The SH 1545 indexing spinner hanger removes scale, flashing, corrosion, rust,

— continued on page 29

— continued from page 27

and paint by indexing two, 15-in.-diameter × 45-in.-high work envelopes on a continuous basis. As the chambers rotate, one compartment is blasted while the other is loaded with parts. These parts are presented on a manganese rotating parts tree with a 185-lb capacity that exposes them to the two, 7.5-hp, VC9 blast wheels. The machine is durable with each blast chamber constructed of manganese chrome alloy steel and lined with ¼-in. manganese alloy liners. It also utilizes an abrasive recycling system with an air wash separator that cleans the abrasive prior to blasting.

Viking Blast & Wash Systems
www.vikingcorporation.com
(800) 835-1096

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The PalletPal level loader has been redesigned. A smaller base makes loading and unloading pallets faster, safer, and easier because it lets the user step closer to the unit's platform. Heavy-duty springs automatically lower or raise a pallet as weight is added or removed, maintaining the top layer of stacked containers at a convenient height. The turntable ring or optional turntable platform at its top allows the user to spin the load. It can accommodate loads from 400 to 4500 lb, depending on which of five spring packages the user chooses.

Southworth Products Corp.
www.southworthproducts.com
(207) 878-0700

Flow Meters Withstand 10–300 lb/in.^{2} Pressures

The Vortex shedding flow meters are useful for applications utilizing water, water/glycol coolant, and other low-viscosity fluids. They feature no moving parts to clog or wear out; operate with NPT ports ranging from ¼ to 2 in. in size; handle flows from 4 to 200 gal/min, with occasional overranging up to 125% of capacity without damaging the product; offer 4–20 mA flow rate transmitters; and withstand working pressures from 10–300 lb/in.^{2} In addition, the meters are designed to operate at fluid and ambient temperatures from 35° to 150°F. They are built with a stainless steel or bronze body. The company supplies standard units equipped with a solid-state relay. They also require 10–30 VDC @ 80 mA input power, attached via pin connectors.

Parker Fluid Control Division
www.parkerfluidcontrol.com
(800) 825-8305

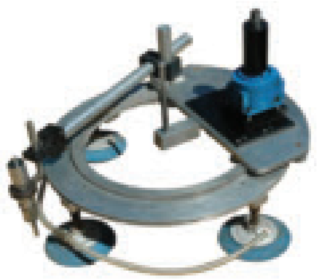
Helmet Switches from Clear to Dark in 0.22 ms

The Fazor 1000 automatic welding helmet features a continuously adjustable autodarkening filter (9–13) and a switching time (clear to dark) of 0.22 ms. The sensitivity can be adjusted between active and inactive catering to all welding tasks. It weighs 1.3 lb and features a multiadjustable headband. The helmet is useful

for do-it-yourself enthusiasts and welder training institutes.

Fronius USA, LLC
www.fronius-usa.com
(877) 376-6487

Water Jet Cutting System Makes Radiuses, Circles



The Spyder abrasive jet radius and circle cutting system is designed for use in potentially hazardous environments. It can be set up on the side of tanks, small vessels, and large-diameter piping. The system's held in place by vacuum cups. Motion components are made from nonferrous materials, and cutting head manipulators are powered by pneumatic motors. A master control panel allows users to control the cutting head manipulators, direction, travel speed, abrasive delivery, and vacuum components. It's available in 1–6.5 in. inside diameter/16–48 in. outside diameter and 3–12.5 in. inside diameter/27.5–56 in. outside diameter sizes. The system is powered by the company's 60,000 lb/in.^{2} water jet intensifier pumps.

Jet Edge
www.jetedge.com
(800) 538-3343

GMAW Guns Designed for Nonindustrial Welders

The WeldSkill product line includes GMA guns that accommodate the welding practices of nonindustrial users. They feature a patent-pending design and include 125-, 140-, 180-, and 220-A models. The ergonomic handle has a slight curvature to maneuver easily in different welding positions. There are no brass blocks inside the handle, so they are light weight,

cooler for operator comfort, and easier to control for various applications and welding positions. The guns feature a jacketed, durable brass tube to protect the patented through-the-tube Cablehoz™, and the steel spring strain relief at the base of the guns adds durability. Long-life triggers on the guns have been tested to provide more that 1.2 million cycles without failure.

Tweco®
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Material Prep Bundles Prepare 100 Specimens

To simplify ordering and purchasing, the Sum-Met Bundles contain all the grinding and polishing consumables required to prepare 100 specimens. Using one part number, laboratory, medical, quality control, university, and other material analysis and preparation facilities can order these for the following applications: Fe and Ni alloys; Al and Cu alloys; Ti alloys; electronic and polymer (especially components such as wiring boards); and ceramic and refractory (nonmetallic materials common in high-heat applications). Typical contents include a combination of CarbiMet2 or Apex grinding discs in 8, 10, or 12 in. diameter, polishing pads/cloths, MetaDi diamond suspensions or pastes, and MasterMet final polishing suspensions.

Buehler
www.buehler.com
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Jessi Combs - Metal fabricator and television personality.

American Welding Society

Friends and Colleagues:

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

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

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

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

For specifics on the nomination requirements, please contact Wendy Sue Reeve at AWS headquarters in Miami, or simply follow the instructions on the Counselor nomination form in this issue of the *Welding Journal*. The deadline for submission is July 1, 2011. The committee looks forward to receiving these nominations for 2012 consideration.

Sincerely,

Alfred F. Fleury
Chair, Counselor Selection Committee

Exploring Welding through YouTube

You can tap into an amazing number of welding videos through this Internet video-sharing community

BY ANDREW CULLISON, MARY RUTH JOHNSEN, HOWARD WOODWARD, AND KRISTIN CAMPBELL

It seems there's a lot more to YouTube than silly pet videos, people who can't sing but who are doing so anyway, and cute kids. It turns out there's a wealth of informational welding videos on the site. In fact, when we visited *www.youtube.com* and typed in "welding," we got 5460 results. "Welder" brought up nearly as many, with 5240 results.

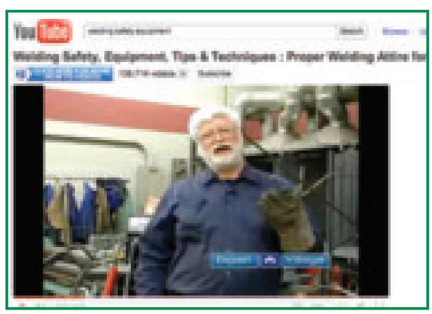
The editors of the *Welding Journal* thought we would browse through YouTube and tell you about some of the videos available. We can only touch on a few of the welding-related categories and videos, and although we've kept an eye out for safe practices, these write-ups are not an endorsement of the videos. You'll have to decide for yourself whether the information presented is useful. We watched many videos before selecting the ones we present here, and can tell you that while there is plenty of really great information on YouTube, many videos also show a lot of questionable practices. Use your best judgment.

The major welding equipment manufacturers all offer a variety of professionally produced videos. They are all good. You can access those in two ways: either go to the company's Web site and click on the YouTube logo or go to YouTube and type in the company name in the search box.

The editors chose to view videos from lesser known sources. The names of the videos are in bold-face type at the beginning of each writeup and the URLs are at the end. Either of those will get you to the video you want to watch.

Welding Safety

Welding Safety, Equipment, Tips & Techniques: Proper Welding Attire for Welders

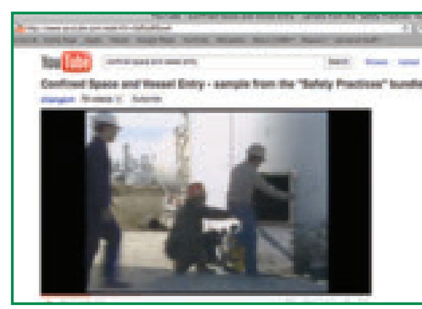


According to his bio, Malcolm MacDonald has been involved with welding since 1968 when he graduated from the welder/fitter program at Conestoga College. In this 2-min video, produced by expertvillage.com, he stresses proper clothing, including what welders need to wear and the materials the clothing and footwear should be made of. Mack, as he introduces himself in the video, is dressed for the part. In other videos, he discusses additional safety concerns including proper eye protection, electric shock, welding fumes, welding on closed vessels, and proper handling of gas cyclinders. *www.youtube.com/watch?v=5rw2hwqZ5LQ*

Safety Factors in Arc Welding Operations

The narrator of this 3-min video from SafetyInstruction.com stresses it is a presentation of basic safety measures and not a complete nor comprehensive program. The video predominantly focuses on fire hazards and warns against welding in the presence of combustibles, discusses keeping the welding area clean, and talks about heat transfer from the workpiece to nearby flammable items. It warns that you should never weld near vapor degreasing operations or spray booths, and that it is necessary to follow all printed rules and safety instructions. *www.youtube.com/watch?v=nGlsqp 5kKUk*

Confined Space and Vessel Entry



This 3½-min video is the second section of a four-part module on recognition of what are confined spaces and an understanding of safe operation practices. This video deals with the preparations necessary before entering a confined space. It discusses lockout and tagging as well as cleaning and purging prior to entry. It recommends using a "preparation for entry" checklist and encourages people working in confined spaces to be aware of federal

ANDREW CULLISON (cullison@aws.org) *is publisher, MARY RUTH JOHNSEN* (mjohnsen@aws.org) *is editor, and HOWARD WOODWARD* (woodward@ aws.org) *and KRISTIN CAMPBELL* (kcampbell@aws.org) *are associate editors of the* Welding Journal.

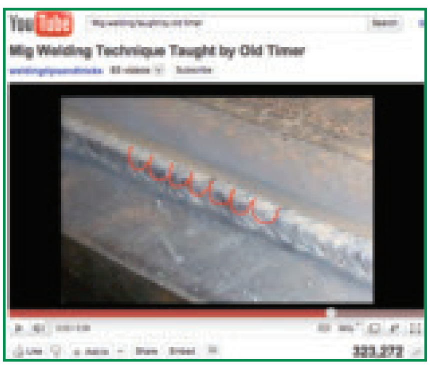
and local regulations. *www.youtube.com/watch?v=0affyoR0cw4*

OSH 141 Project Final: Welding Safety and Health Quantitative Methods

Scott Neal, company safety coordinator at Delta City Power, developed this 4-min video to describe the quantitative methods used at the company's welding center to ensure proper ventilation for its welders. He shows the ventilation systems in place, and discusses the fumes they are dealing with and their potential hazards, especially those of hexavalent chromium. He shows the calculations they used to determine the amount of airflow the company needed through its fans and ventilation system and the results of the calculations. *www. youtube.com/watch?v=944NL_OXuY*

Welding Tips

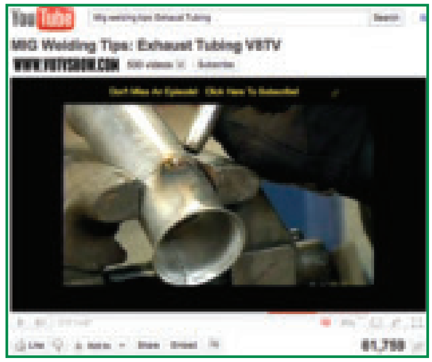
Mig Welding Technique Taught by Old Timer



The instructor on this 2½-min video is not the old timer, but he tells of tricks an old timer told him 20 years ago. The tips are hand-motion techniques that control the weld pool to produce a smooth and even weld bead. The video shows the weld in progress, as well as the finished weld bead with a schematic of the hand motion superimposed over it to give the viewer a better idea of what is happening. A tip on improving weld speed without detriment to the weld bead is also given. The motion gives good results with either a push or pull progression. *www.youtube.com/watch?v= w4RrDeUKcH4*

Mig Welding Tips: Exhaust Tubing

This video, geared to car enthusiasts, gives tips on joining exhaust tubing. The instructor explains his approach to this particular application, and shows his machine's settings. He demonstrates how to join the tube with a series of tack welds that stitch the joint closed. This technique flattens out the weld beads, which then can be ground down for a smooth, seamless joint (4:27 min). *www.youtube.com/watch?v=Joh BHzhOyPg*

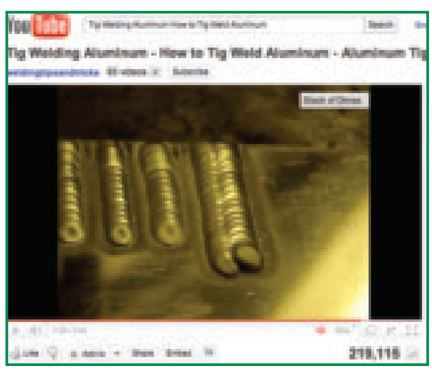


Welding with MIG Welders vs. TIG Welders

This is a very basic informational piece on the pros and cons of a gas metal arc welding machine vs. a gas tungsten arc welding machine. A narrator explains the differences between the two processes. During the narration, bullet point advantages and disadvantages of each type of machine appear on the screen to help reinforce what is being said. Over all, good advice is given to those who are just beginning to get into welding (8:25 min). *www.youtube.com/ watch?v=B-f25N7zJeI*

Welding Aluminum

How to TIG Weld Aluminum



This short video shows a technique for making a nice rippled bead on aluminum that the welder calls "a stack of dimes." The hand movement is explained as a step-and-pause technique while adding the filler metal. The end result is very professional. There are helpful answers to questions given in the comments section (0:46 min). *www.youtube.com/ watch?v=rR8Rlpf0ELQ*

Aluminum Welding Tips: How to Fill Large Holes in Aluminum

This 1-min video gives a demonstration of filling a hole about the size of a dime in an aluminum air-conditioning line. The process is oxyfuel with filler metal added. No information is given on setup prior to welding, but as the individual fills the hole, he describes his technique. *www.youtube.com/watch?v=6fOOI9ferCY*

Weld Aluminum Bracket for Tool Post Grinder

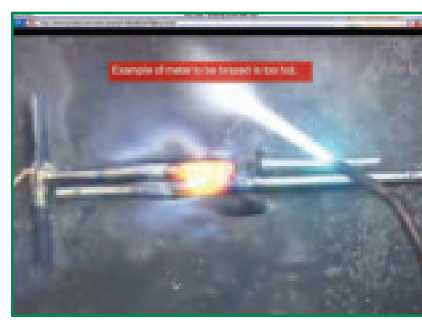
This video is an example of all that is bad with YouTube. It shows an individual who admits he is not a good welder, and then shows him welding aluminum without gloves and with bare arms. He can barely sustain an arc and his multiple strikes in the attempt give new meaning to "stick" welding. Although there are good examples of welding on YouTube, this is a reminder that the Internet is an unregulated territory that must be approached with caution and common sense (2:48 min). *www.youtube.com/watch?v=xU7CuxKMO1o*

Soldering and Brazing

Brazing Aluminum

Kent White demonstrates in 8 min his method for repairing a severely damaged aluminum part using a flux cored brazing rod and acetylene torch. White delivers an interesting dialog to accompany the close-up visuals of the work in progress. First, he demonstrates the brazing operation, then explains his techniques for sanding and shaping the part using an air tool with a 320-grit disc, followed by a polishing operation. *www.youtube.com/ watch?v=RRWmpSE-Xk*

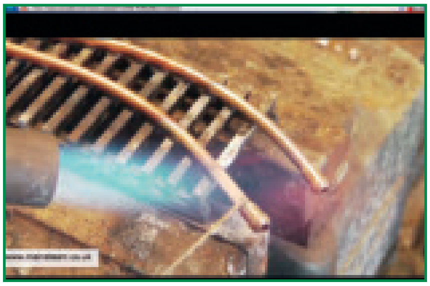
Brazing Hints and Tips



This interesting 5-min-long video targeted for beginners discusses brazing with a flux-covered rod. Tips are offered on what to do when the rod sticks to the workpiece, and how to smooth "globs" of filler metal when they form on the joint. *www.youtube.com/watch?v=ZojIpKCo4TQ&feature=related*

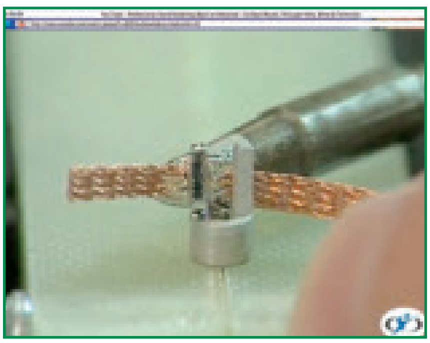
How to Silver Solder for Beginners

This video offers in less than 4 min a number of tips on how to get started soldering nipples to copper tube and pipe. It details the initial cleaning of the surfaces to be soldered through to the final



polishing operation combined with a safety heads-up. The highlights of this presentation are good visuals with clear close ups of the work in progress. *www.youtube.com/watch?v=kIKQFL96uU&feature=related*

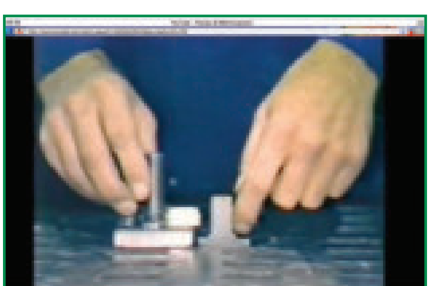
Professional Hand Soldering (basic to advanced)



This high-quality 4-min video shows a number of professional techniques for hand soldering printed circuit boards. Also demonstrated are techniques for soldering connector leads and copper braid to several common terminals. Other topics presented are inspection information, tinning terminals, through-hole part soldering, and mounting microchips to a printed circuit board using the drag soldering method. *www.youtube.com/watch?v=Ql6Vkw5wswU&feature=fvw*

Inspection

Stud Welding and Inspection Training



In this video, stud welding inspection is presented along with a meaningful discussion of what causes various defects. Highlighted in this 9-min presentation are the effects of amperage setting, plunge setting, dampening rate, and the length of the stud before and after the welding operation. A good weld is detailed for what makes it satisfactory and what factors make welds unacceptable. *www.youtube.com/watch?v=OpNkGqYNe7k&playnext=1&list=PL6274019473D885AD*

Welding Inspection and QC

This 6-min video offers a general overview of numerous weld inspection techniques. The testing methods include magnetic particle, liquid penetrant, ultrasonic, guided bend, hydro, Charpy V-notch, hardness, and tensile. Other topics include code review, visual inspection, and the use of assorted measuring tools, X-ray film review, polishing, and etching. *www.youtube.com/watch_popup?v=aUbhrbbA_8k&vq=medium*

TomB Welding Assessment

This video is just 2 min long, but that is enough time for Tom Baldwin, a personable welding instructor, to relate how he evaluates welds for his beginning welding students and inspires them to learn from their mistakes. He shows several good and bad welds and how he helps his students organize their work in a folder for future reference. *www.youtube.com/watch_popup?v=dMq7hX0xm80&vq=medium#t=71*

Using Electromagnetic Magnetic Particle Inspection to Detect Cracks in an Automobile Cylinder Head

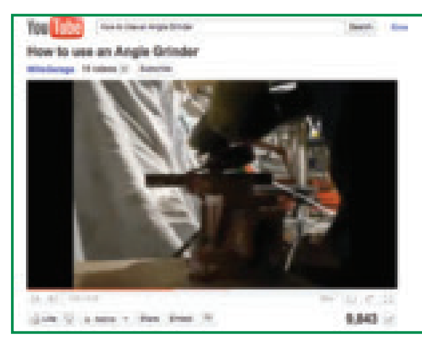
In this 3-min video, John Edwards from Costa Mesa R&D Automotive Machine Shop demonstrates how the experts employ magnetic particle inspection to quickly and clearly define cracks in an automotive cylinder head. The technique, using an electromagnet and iron dust, is equally applicable to other projects where cracks in metal are suspected. *www.youtube.com/watch_popup?v=0o1Usf3hc5c&vq=small*

Grinding and Finishing

SMAC Tutorial Grinding Part 1

Holly Fisher, executive director of the now-closed Smartshop Metal Arts Center in Kalamazoo, Mich., goes over the basics of grinding and metal finishing in this 7½-min video. She details grinding safety, going over personal protection equipment including eye and hearing protection, and hazards from flying sparks. She also discusses proper clamping of the metal for safe, productive, and efficient metalworking. The various types of grinding discs are detailed. While she's talking, she's demonstrating grinding techniques. *www.youtube.com /watch?v=oxR2G9vntnA*

How to Use an Angle Grinder



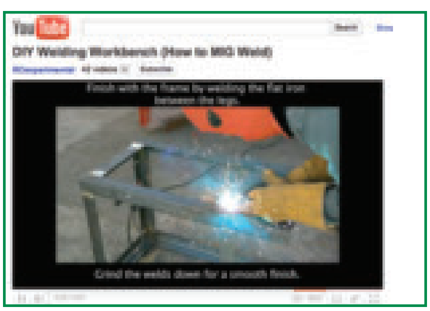
The basics of using an angle grinder are covered in detail in this 10-min video from Willsgarage. It begins with the safety gear and tools needed for grinding. Part 1 covers grinding and Part 2 gets into using a cutting disc. In Part 1, he shows viewers how to insert the disc, the angle at which to grind, and how to adjust the tool for right- or left-handed workers. He cautions viewers to ensure the workpiece is secure and tells them to check to see which direction most of the sparks will fly to in order to take care of any potential fire hazards. He shows how to prepare a flat piece of metal prior to welding and how to finish a weld. In the cutting section, he demonstrates how to rotate the wheel guard and move the handle for safe, accurate cutting. *www.youtube.com/watch?v=6bA4pQQ4i2I*

Welding Projects

A Little Welding Project

In a 9-min video by farmall1938, a man improves a frame to enclose and protect his plastic mailbox. He cuts down a caster wheel, uses shielded metal arc welding to attach this to the frame's bottom, and inserts a screw eye in the frame's back center portion, which has large springs down each of its sides. With a cordless drill, he mounts this structure to a cut off telephone pole, and it's now about 1½ in. higher than before. The finished mail frame is self centered, well balanced, and spins from side to side. *www.youtube.com/watch?v=Aw8YNNvuHSA*

DIY Welding Workbench



Viewers are taught how to make a do-it-yourself welding workbench in RCexperimental's 4-min video. The materials for the project include $\frac{3}{8}$-in. steel for the tabletop, 2-in. angle iron for the frame and legs, and $\frac{3}{16}$-in. flat steel for the struts. In addition, the frame requires four angle iron pieces cut about 3 in. shorter than the table's dimensions, four pieces of angle iron for the legs, and $\frac{3}{16}$-in. flat iron that can be welded for struts between the table's legs. These materials are gas metal arc welded to create the workbench. Helpful instructions, such as using a T-square to make sure the frame's pieces are at right angles and grinding down the welds, are listed on-screen. *www.youtube.com/watch?v= Xn0kIaY3CcY*

Zann Jones' Welding Project — Jack in the Box

Making a colorful, 41-in.-high jack-in

-the-box kinetic metal sculpture is shown by Zann Jones during a 4-min video. The figure's face, upper body, and arms are fused glass, but this part could be cut out of steel plate and painted. The vertical portion is kept in a slender profile, and its bottom box is a flat, rectangular shape. The spring portion is elliptical to not cause problems with the vertical stand; it's made with a $\frac{3}{8}$-in.-diameter steel rod bent around two, 1-in.-diameter pipes that are tack welded. This rod is later expanded to create the spring. Also, the horizontal rod located at the spring's top, which holds it to the vertical stand and allows swinging, is welded on both sides. A $\frac{1}{4}$-in. plate serves as a counterweight for the sculpture's top portion and provides support for the fused glass. *www.youtube.com/watch?v= 3vQXROiRubg*

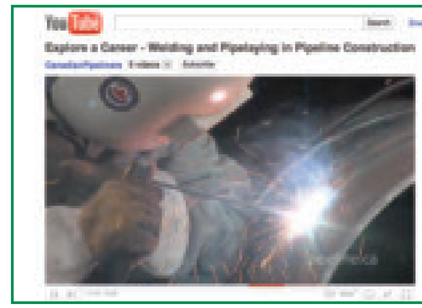
Welding Career Paths

Structural Metal Fabricators and Fitters Job Description

The various tasks structural metal fabricators and fitters perform are featured in a 2-min video by GadBaller. The metal objects they construct range from tanks and water towers to frames for buildings and bridges. The intricate work includes reading blueprints and using machinery to cut metal. Additional equipment is used to punch, roll, or straighten pieces before fastening; these metalworkers weld, bolt, or rivet units into full or subassemblies. They work both indoors and out. A good physical condition is needed for heavy lifting and climbing. "Fabricators and fitters take pride in knowing what they create today will no doubt still be in use for generations," the video concludes. *www.youtube.com/watch?v= x1qYzCYi8oI*

Explore a Career – Welding and Pipelaying in Pipeline Construction

A 5-min review of the work pipelayers and welders do is offered by Canadia Pipeliners. Pipelines can run thousands of miles and typically range 24–48 in. in diameter. Once individual pipes are set up on timber cribs, crew members preheat the steel pipe in preparation for welding. When pipe can't be laid straight, pipelayers work with laborers using bending machines; stabbers provide direction to a side boom operator for final alignment of two pipes; and a clamper locks a set of clamps in place to hold two pipe sections in preparation for welding. Automatic welding via a remote control at the far open end of the pipe is shown along with fill and cap welds. When welders complete a pass, a control number is noted that's used for inspections. During manual welding, welders often work in teams of two. Tie-ins for connecting finished pipeline sections are also mentioned. *www.youtube.com/watch?v=HGTASZE9aMk*



How to Become a Mechanical Engineer

A 1-min rundown by Edu411, shows what mechanical engineers do. These individuals design many items, including engines, robots, generators, kitchen appliances, and power tools. "Whatever the device, if it has moving parts, mechanical engineers were almost certainly involved in its creation," the video states. It's cited as the broadest of all engineering disciplines; in regard to products, some do research, others design or make the machines, and some help sell technical products. Also, it's important to have good math and science skills, the ability to think analytically, handle abstract ideas, and solve problems creatively. A satisfying reward for mechanical engineers is to see their designs turned into new products or machines. *www.youtube.com/ watch?v=nGL-Pj81-Wo*♦

Dear Readers:

The *Welding Journal* encourages an exchange of ideas through letters to the editor. Please send your letters to the Welding Journal Dept., 550 NW LeJeune Rd., Miami, FL 33126. You can also reach us by FAX at (305) 443-7404 or by sending an e-mail to Kristin Campbell at *kcampbell@aws.org*.

Not only do underwater welders need to be good divers who are proficient in performing shielded metal arc welding, but they also must meet certain health requirements, wear the proper gear, and pay attention to safety at all times.

What It Takes to Be an Underwater Welder

Diving work is demanding and requires both physical and psychological endurance, but the opportunities this field offers are available worldwide

BY KRISTIN CAMPBELL

Imagine being deep underwater, perhaps in the Atlantic or Pacific Ocean, welding a new structure or repairing an old one while exotic sealife swims around and you know your job is critical to completing a project. Sounds pretty adventurous, doesn't it?

Underwater welding requires learning how to dive, being in good health, performing shielded metal arc welding in the water, wearing the proper gear, and keeping safe. When these elements combine, exciting career paths can be established that lead to worldwide travel working in various oceans, seas, lakes, and rivers.

Here's a look at the training provided by the International Diving Institute (IDI), LLC, North Charleston, S.C., representing what's required for this specialized field. Its mission is to provide and prepare graduates for a career in the commercial diving industry as entry-level divers/tenders who excel in knowledge, skills, and safety.

Fig. 1 — The International Diving Institute faces the Cooper River, giving direct access for students to practice diving and welding underwater in low-visibility conditions.

What's Offered On-Site

The institute's waterfront location faces the Cooper River, which offers 8–40 ft depths — Fig. 1. This enables diving practice along with welding, cutting, and mechanical projects from several locations in little-to-no visibility conditions.

"We're getting an influx of certified welders who want to do underwater welding. We have a true working environment, so it's real world," said Kim Gissendanner, a diving instructor/supervisor at the institute.

International Diving Institute's brick central facility has a welding fabrication shop on the first floor — Fig. 2. Many supplies are available, including steel; 6013 electrodes; welding machines; booth space for welding on land, known as topside; oxyacetylene cutting stations; and shop tools.

Two classrooms, divided by a hallway lined with safety posters and job opening notices, as well as a library and computers are on the second level — Fig. 3.

Walkways provide access to three above-ground wet tanks. The 17-ft-deep main tank holds 48,000 gal of water and features observation windows, a penetration tube, and an overhead crane. Diver training takes place here as does "Christmas tree" projects where valves and fittings are assembled to be leak-tight, including bolting valves on pipes, representing about 100 lb of lift — Figs. 4, 5.

The main wet tank sits between a new underwater welding-dedicated, 20-ft-deep tank that holds 9330 gal of water and a 30-ft-tall confined space tank holding 9000 gal of water.

Also offered at the institute is a large "bathtub" filled with water for cutting practice; a main dive platform extending 8 ft over the water; a 30-ft-long floating T-dock; a portable diver's stage area operated with an electric hoist; a mixed-gas

Fig. 2 — In the institute's welding fabrication shop, 6013 electrodes are coated in molten paraffin wax to protect the flux from water before the diver/welder strikes an arc.

Fig. 3 — Linn Boughamer (standing), a physics, physiology, and dive medicine instructor, teaches a group of students.

KRISTIN CAMPBELL (kcampbell@aws.org) *is associate editor of the* Welding Journal.

All photography in this article is courtesy of the International Diving Institute, LLC (www.internationaldivinginstitute.com *or (888) 728-3483*)*, North Charleston, S.C.*

Fig. 4 — A student jumps into the institute's 17-ft-deep main wet tank.

facility to fill diving bottles; changing rooms; and the Dive Locker, a retail shop featuring sport/commercial diving equipment and other gear.

The Association of Diving Contractors International (ADCI) assesses and verifies the competency of the institute's students and staff, plus audits its training programs.

Physical Requirements for Diving

Before starting at IDI, students must, at the minimum, undergo a basic physical with an electrocardiogram, pulmonary function and urinalysis tests, complete blood count, and chest X-rays. Students must also be fit for diving and hyperbaric activities. It's highly recommended they get an ADCI physical by a licensed physician in their area who is qualified by experience or training to conduct commercial diver physical exams. This includes X-rays and tests appropriate for working commercial divers exposed to rigorous conditions.

To stay in shape, students participate in daily physical training activities, including swims in the Cooper River, jumping jacks, and push-ups.

According to the ADCI, a person having any of the following conditions will be disqualified from engaging in diving or other hyperbaric activities: a history of seizure disorder other than early childhood febrile (high fever) conditions; cystic or cavitary disease of the lungs, significant obstructive or restrictive lung disease, or recurrent pneumothorax; chronic inability to equalize sinus and middle ear pressure; significant central or peripheral nervous system disease or impairment; chronic alcoholism, drug abuse, or history of psychosis; significant hemoglobinopathies, malignancies, or osteonecrosis; grossly impaired hearing; chronic conditions requiring continuous control by medication; and pregnancy.

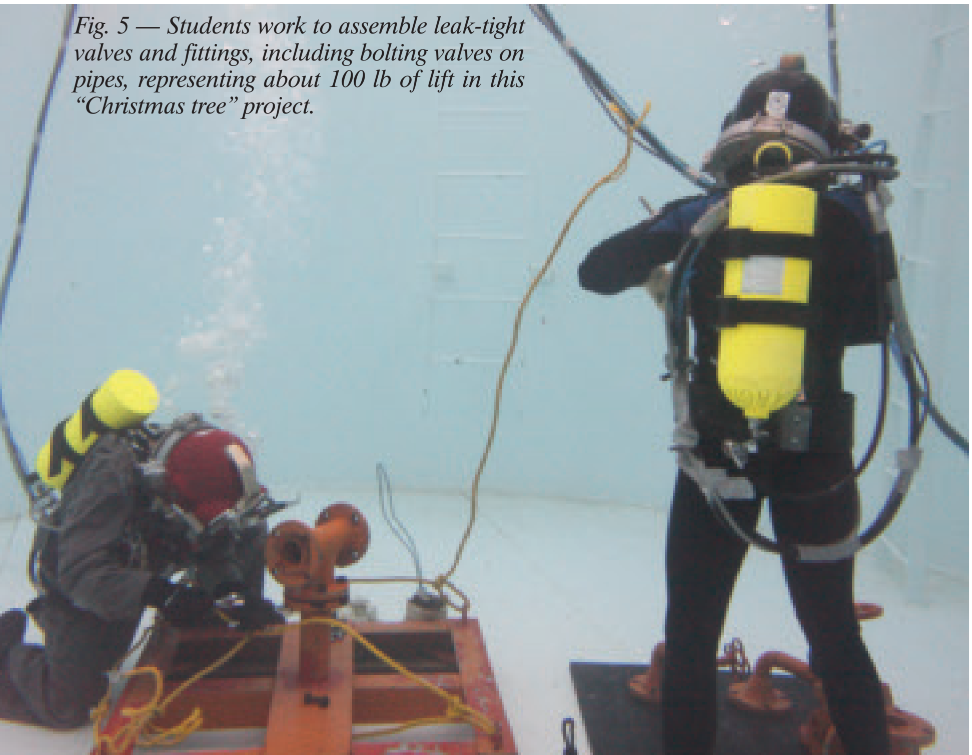


Fig. 5 — Students work to assemble leak-tight valves and fittings, including bolting valves on pipes, representing about 100 lb of lift in this "Christmas tree" project.

Learning How to Dive

Once you're deemed physically fit to dive, training can start. Students must know how to swim, and although prior diving and welding experience is not required to enroll, it's recommended they have basic open water SCUBA certification by a recognized certification agency.

Life-supporting diving equipment and gear must be worn. This includes a surface-air-supplied diving helmet; neck dam with a seal that clamps to the helmet so it can't come undone; full-body wet suit that's buoyant, or if there's cold, icy weather, a thicker wet or hot-water suit where warm water is pumped in; weight belt that typically handles 40–50 lb, along with a knife strapped to it for practical use; harness; safety shackle that goes to the umbilical hose supplying air; and heavy-duty industrial rubber gloves tucked into the wet suit and duct taped to stay in place; a main tank, along with a bail-out bottle as an emergency supply that both contain compressed air (mixed gases are used for deeper dives); a pneumo line that serves as a third supply of air and measures depth; and fins.

Once suited up, students learn to jump, move around, and breathe underwater.

Getting Used to Performing Tasks Underwater

Shielded metal arc welding is the process that's performed underwater. Cutting consists of oxygen that's passed through a magnesium electrode. It's best to perfect skills topside first, then try underwater use.

On land, working areas are clean, wires are tied down, and the power source is placed on an insulated surface. The direct current (DC) welding and cutting machines, typically at 300 A, are grounded in sheltered areas and must be monitored. Any cable splices are waterproofed with rubber tape.

Staying Safe

Taking safety precautions during underwater activities is important. Generally, trained divers shouldn't have accidents; there's probably a bigger chance of getting injured from barnacle cuts or something happening on land.

The gear underwater welders and cutters wear is similar to what was listed previously, but they are also connected to an umbilical that contains a communications wire that allows the diver/welder to speak with a person on the surface — Fig. 6. Their diving helmets have autodarkening filters and steel-toe boots are worn. It's useful to keep a plastic holder for extra electrodes. Head-to-toe insulation, with no skin exposed to the water, prevents shocks.

Electric shock is avoided in additional ways as well. Unlike topside welding where the ground clamp is negative, in underwater welding there's a "positive is always ground" rule where the electrode holder is negative, and a knife switch between the power supply and circuit can be turned on or off — Fig. 7. Another rule is to never place yourself between the electrode and ground to avoid a shock.

Welding Work

Covered electrodes for underwater welding are dipped in wax a few hours before use to protect the flux. Some companies manufacture these, but they can be expensive, so it's useful to make your own.

A welder inserts the electrode in the holder made for underwater use, then strikes the arc. Horizontal, uphill, and downhill welding positions are practiced. It's good to keep the electrode at about 30 deg to the line of work. The ultraviolet light is filtered out by water.

It's mostly steel that's welded underwater. Welds achieve 80% of tensile strength and 50% of the ductility of similar topside welds.

Twenty to thirty electrodes may be taken underwater at a time. Each electrode only lasts about 30–40 s.

Cutting Details

For cutting various objects underwater, the diver controls an insulated torch designed for underwater use. Oxygen is sent through a hollow magnesium electrode from 14 in. to 2 ft long. Once the arc is struck, a flame is created that burns extremely hot at 10,000°F.

The current passing through water dissociates the water into H_2 and O_2, posing an explosion danger in closed compartments or corners where bubbles accumulate. To avoid gas buildup, the space needs to be vented first, then the material can be cut.

Positions Essential to Help Underwater Personnel

On the surface, tenders and dive supervisors support underwater workers. Thanks to a dive station communication box that runs off a car battery, divers can

Fig. 6 — David Sharpe (center), a diving supervisor/instructor at the institute, makes sure that students wear the proper gear for underwater welding.

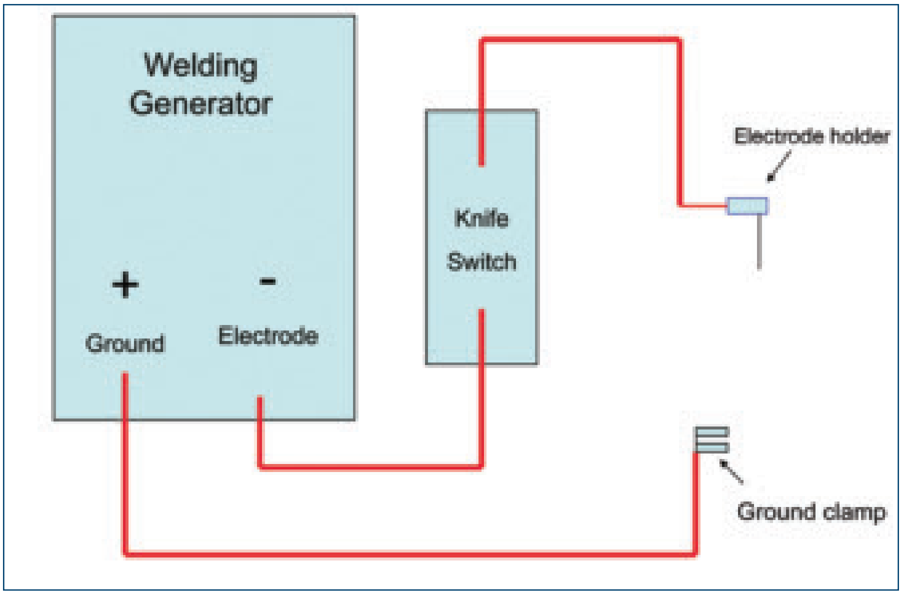


Fig. 7 — This schematic for underwater welding shows the welding generator, knife switch, electrode holder, and ground clamp. A "positive is always ground" rule dictates the electrode is negative, so electron flow is away from the user.

Determining if Underwater Welding is Right for You

Kim Gissendanner (pictured above) has been diving for 36 years. His vast experience includes heavy underwater construction with welding and concrete encasement.

Kim Gissendanner, a diving instructor/supervisor with the International Diving Institute, offers these tips to help individuals decide if underwater welding would suit them.

- If you'd like to use diving, welding, and cutting skills while working in dark, confined spaces underwater in oceans, seas, lakes, and rivers. Typically, mechanically inclined people are great for this field because they have dexterity and can handle many responsibilities.
- "It's a great lifestyle if you like to travel," he said. If you're single, it's a good opportunity to travel all over the world. However, if you're a homebody, this field will probably not be good for you.
- You've got to like the water, marine environments, and be able to handle extreme weather from cold, icy conditions to heat with heavy humidity.
- Being a diver has nothing to do with physical size; rather, it has a lot to do with using your knowledge, staying calm and collected, and managing potential danger (fight vs. flight syndrome).
- If you'd enjoy participating in a variety of tasks underwater, including cofferdam, pipeline, construction, and salvage projects.
- If you're up for working long hours, on barges for instance, to make up a possible 60–70 h work week with good overtime pay.
- An added benefit is sharing good camaraderie with your colleagues.

be talked to underwater; this is important for getting progress updates and making sure everything is going well. A rack box is a manifold that controls the air supply and has pressure gauges to monitor lb/in.^{2}

A standby diver waits above who is responsible for rescuing the diver if a problem occurs. At the institute, students acting in this capacity need to get in the water quickly — 15 s for the wet tanks and 30 s for the river.

Treating Decompression Needs

Divers need to know how long they can safely stay underwater. Decompression table requirements, determined by depth and time, must be followed. To finish a project, multiple divers may be used on a rotational basis.

In emergency medical situations, hyperbaric chambers provide vital oxygen treatment for decompression sickness. The institute's outdoor quarterdeck space features two, 54-in. hyperbaric chambers large enough to hold several people — Fig. 8.

Diver Program Details

The institute's Air/Mixed Gas Surface Supplied Diver program lasts 16 weeks, comprises 640 h, and has a maximum of 10 students per class.

The commercial diving certification program includes the following classes: safety operations for surface-air-supplied diving; diving physics; dive medicine; decompression and treatment tables; hyperbaric chamber operations; underwater use of tools and equipment; rigging fundamentals/practical application; topside welding/cutting; underwater welding and cutting; dive operations planning; and mixed gas-surface supply and saturations diving.

Texts include the *Commercial Diving*, *U.S. Navy*, and *National Oceanic and Atmospheric Administration Training Manuals*; *ADCI Logbook*; and *Handbook for Riggers*.

Experienced Teachers

Sergio Smith, IDI's president and owner, has been diving for more than 35 years. "I've been all over the world. I wouldn't trade it for anything," he said of his career. Smith is the east coast regional director for the National Association of Scuba Educators Worldwide; has been a diving instructor in Jordan, Greece, and the Mediterranean Sea; and served with the Navy Special Warfare Group as a Seabee.

"A commercial diver will never be out of a job," Smith said. Wind tower production will open up jobs with more towers placed in the water, he added.

Additional staff members include Michael Hielscher and Edward Lee Spence, vice presidents; David Sharpe, Kim Gissendanner, and Jason Pope, diving instructors/supervisors, who have a combined diving experience of more than 75 years; Janilee Chesky, head of administration; Debbie Gregory, manager of the Dive Locker; and Linn Boughamer, John Stoddart, John Chalfin, Johnny Cercopely, and Carl Whitaker, contract instructors.

Rewarding Careers

After finishing the program, IDI students are awarded a certificate for Air/Mixed Gas Surface Supplied Diver. In addition, they receive an ADCI entry-level tender/diver card, which is a requirement for working in the commercial diving industry.

Assistance is provided with résumé preparation and job placement. However, while many companies contact the institute looking for divers, the institute does not guarantee job placement.

Offshore vs. Inland Work

When working offshore, you'll be on large diving vessels or platforms in the ocean. Most people work as a tender before breaking out as a diver. This can take several years depending on an individual's skills and abilities. Offshore, you live and work on-site.

When working inland, you may be in intercoastal waterways, power plants, water treatment plants, bridges, and piers. Inland divers can break out much faster. Most of IDI's students who go into inland work start diving within a few weeks of being hired. Inland dive teams travel frequently either in the United States or overseas.

Earnings Potential and Benefits

The money an underwater welder makes varies depending on the location; whether you're working inland or offshore; for a small or large company; if you are in the divers' union; and job duties. The benefits offered depend on the employer. Some companies have sign-on bonuses, tuition reimbursement, continuing education, medical/dental/vision insurance, vacation time, 401K plans, and stock options; others even feature dive and depth pay in addition to standard pay.

Thoughts from Past Students

Chad Burleson of Half Moon Bay, Calif., took a leave of absence from DRS Marine, Inc., Vallejo, Calif., to attend the institute — Fig. 9.

"I worked for them for two and a half years learning as a dive tender, and when they approached me about going to school to become a ADCI certified diver, I jumped all over it," Burleson said. "Being a surfer from the north coast of California and an avid boater, my love for the water is immense, so why not get paid for working in the water?"

What he learned at the institute helped refine previous knowledge. After graduating last September, he drove to California and immediately returned to work for DRS Marine. Burleson has now been a foreman on several jobs and a diver on a regular basis. He has worked on dams, ships, potable water tanks, water towers, inspections, and general construction.

He plans to continue a career with DRS Marine, performing the duties he does now until retiring, and to learn as much as possible.

"It's a small brotherhood," Burleson said of the industry's makeup, adding a hard work ethic must be displayed. "There's no margin for error because you're dealing with someone's life."

Bob Salter of Winder, Ga., a licensed SCUBA instructor with 12 years of diving experience, wanted to participate in a more advanced program — Fig. 10. "This is taking it to a new level," he said about performing underwater welding on top of diving and merging the two. He graduated from the institute last November.

Currently, Salter works for an underwater construction firm that has been awarded a government contract for an inland job in Lake Lure, N.C. He unearths pipe, uses a 5-ft-long jet machine to clean various sections, and wraps pipe joints in a sealing material. It's estimated the project is saving 500,000 gal of water a month. He expects to be working on it for another 1½ years.

Salter describes his job as intense and unique, and he likes the adventure of a dive because no two are the same. "It's definitely challenging," he said about working in claustrophobic, black water. At work, he's mentally strong, reliant on touch and feel, and wears a hot-water suit

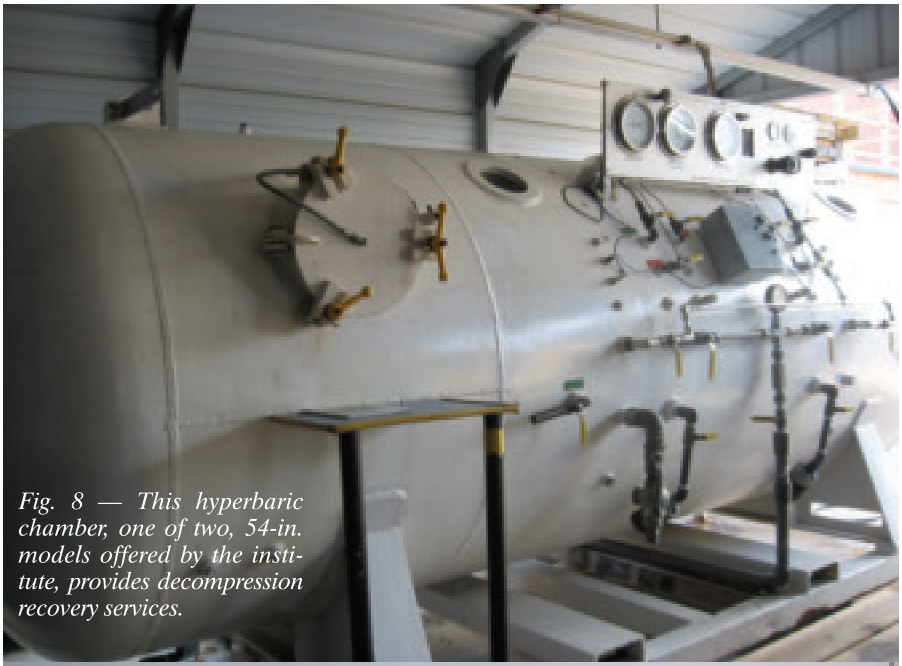


Fig. 8 — This hyperbaric chamber, one of two, 54-in. models offered by the institute, provides decompression recovery services.

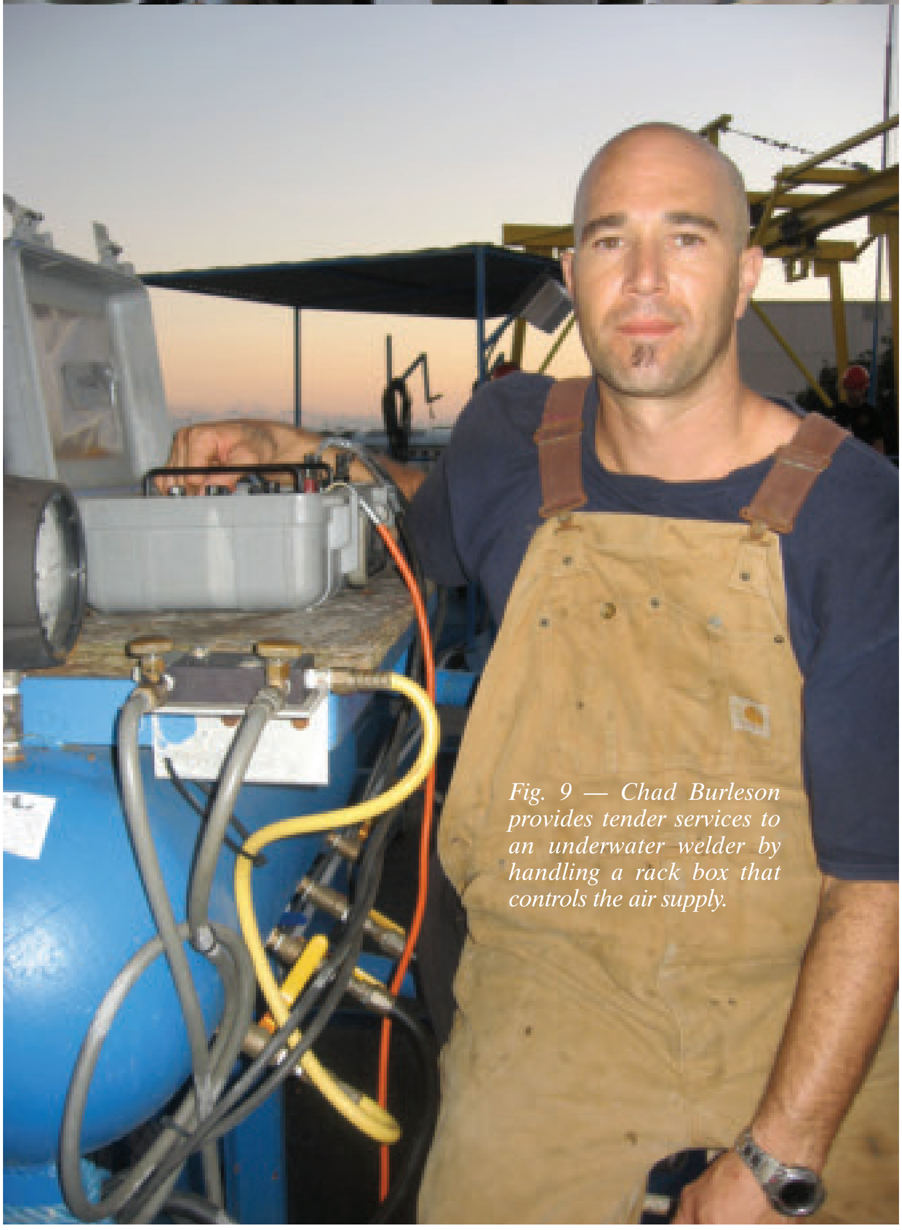


Fig. 9 — Chad Burleson provides tender services to an underwater welder by handling a rack box that controls the air supply.

Fig. 10 — Sergio Smith (center), president and owner of the International Diving Institute, poses with Katie Setliff and Bob Salter.

Fig. 11 — Chris Stapp practices standby safety diver skills. He is ready to get in the water and save an underwater diver in a matter of seconds should an emergency occur.

because the water is 30°F. Salter also pointed out getting to the pipe requires decompression diving to more than 100 ft and staying there more than 2 h; while coming up to the surface, he uses his physical strength and takes timed stops along the way. On land, he gets into a hyperbaric chamber to decompress for about 1 h and 15 min.

"Welding is a huge part of underwater commercial diving," Salter added. During a previous job, he performed topside welding on a barge. He added potential divers need to be careful and learn as much as they can to ensure when they're on the job they'll make it home each night.

This summer, Salter hopes to start an emergency medical technician course at the Divers Alert Network in Durham, N.C., and ultimately would like to be a dive medical technician.

Katie Setliff of Danville, Va., also pictured in Fig. 10, enjoys combining welding and diving. "I've always wanted to do underwater welding. It looked like such a cool job," she said.

Setliff started welding at a vocational high school. She had no previous diving experience before coming to IDI, but loves being in the water, and quickly learned what to do.

Setliff graduated last November. She has career aspirations of working inland, traveling and meeting new people, plus performing underwater welding, rebuilding structures, and doing ship work. "The door is open to so many opportunities," she said of the different diving paths available. Setliff is now waiting to see if the Florida Department of Transportation will hire her for a position to do underwater inspection work on piers and bridges.

Being a female in this male-dominated field, Setliff hopes she may inspire or open doors for other women to feel they can do it, too. "I've never been intimated by the guys," adding she would like to open men's minds to the fact women can succeed in this career.

Chris Stapp, also of Danville, Va., enjoys hands-on work — Fig. 11. He learned how to weld during high school and through his father's welding business. Stapp later used his skills at a tank manufacturing company performing pressure vessel welding. "It's a field of self accomplishment," he said.

Stapp decided to study at the institute to learn underwater welding, which he considers an elite trade, and drove himself to get better at it. "Welding is part of the tool to get the job done," he added, and explained that the knowledge to completely fabricate an item is essential.

Stapp graduated from the institute last November. He has turned down a few inland dive offers as he wants an offshore diving position with international travel. In the long-term, he would like to have a career in saturation diving for welding pipeline sections.

Conclusion

If you have an interest in diving, why not combine that with additional skills and techniques? Learning how to do various types of work underwater will help you make the most out of both worlds.

It could even lead to a worthwhile career where diverse paths — including underwater welding, construction projects, salvaging and repairing structures, inspection using remotely operated vehicles, or medical life-saving operations — can be pursued worldwide.♦

Developing Guidelines for Numerical Welding Simulation

Simulation of the welding process offers great potential for optimizing the processes and reducing fabrication costs

BY CHRISTOPHER SCHWENK

A goal of industry is to fully map the fabrication process — from the blank metal through the individual fabrication steps all the way to the end product — in a so-called "virtual process chain." The concept of continuous simulation of all relevant fabrication segments is intended not only to achieve a reduction in development and fabrication costs, but most of all to optimize products and fabrication procedures. An essential link in this virtual process chain is welding simulation.

Welding simulation permits statements to be made at an early stage about welding-specific phenomena such as component distortions and residual stresses, and thus helps to minimize through simultaneous engineering the number of iteration loops in the development process. Additionally, it provides information such as the time-dependent evolution of thermal stresses during the ongoing process that can be gained experimentally only with disproportionately high expenditures or possibly not at all. This implies, for instance, that the causes of welding-specific quality aspects can be deliberately identified and, therefore, a target-oriented optimization becomes possible (Ref. 1).

From the perspective of its economic potential, welding simulation should be prized as highly as forming simulation. Today, hardly any formed component is developed without simulation, which helps cut component, tool, and equipment costs. The state of the art of welding simulation today corresponds to the beginnings of forming simulation in the 1980s. The error potential of welding simulation, however, is very high due to the involved physical phenomena and couplings (e.g., weld pool fluid flow around a keyhole during laser beam welding) in combination with pronounced nonlinearities challenging the simulation technology (e.g., temperature-dependent material properties). Special requirements such as prior user knowledge and experience must also be mentioned. Both of these facts are frequently conducive to avoidable application problems, namely when users get freshly into this subject matter, which emphasizes the need for an appropriately structured and defined approach.

A particularly great application potential of welding simulation can be seen in the engineering services market. Big corporate groups such as original equipment manufacturers put the development of individual components more and more in charge of industry suppliers (small- and medium-sized enterprises). One study examined the current state of production simulation in small- and medium-sized companies and identified future trends (Ref. 2). In addition to simulation-assisted analysis of components and fabrication processes, which in many instances is mandatory based on customer specifications, a time-saving and cost-efficient development process is of vital interest to many enterprises. Welding simulation can make valuable contributions to assist them and to counteract rising product development costs.

For trouble-free communication between customer and tenderer, a defined guideline for executing the calculations and assessments as well as displaying the results is imperative to ensure reliability and relevance of the calculation results. Also, a defined mode for displaying results will provide a basis for effectively comparing various computation projects. The objective of standardization in the field of numerical welding simulation is to improve its application for calculating welding-specific phenomena and optimizing undesired effects, addressing above all users who do not possess extensive knowledge of simulation methods. In order to meet this objective, the German Institute for Standardization (DIN) has initiated diverse preliminary work that is outlined in the following section.

Preliminary Work

The need for standardization in the welding simulation area was recognized more than two years ago by DIN. As a consequence, two projects were funded as part of the Innovation with Norms and Standards (INS) sponsorship initiative launched in 2006 by the German Federal Ministry of Economics and Technology, which evolved from the German government's high-tech initiative. Both projects were concerned with the "draft guideline for a structured approach for the execution, analysis, and postprocessing of numerical simulation of welding-induced distortion and residual stresses." In addition to a literature review related to welding simulation standardization, these projects also included preparation of a draft guideline proposing a structured approach to a simulation for determining the heat effects of welding by giving a detailed simulation example including ex-

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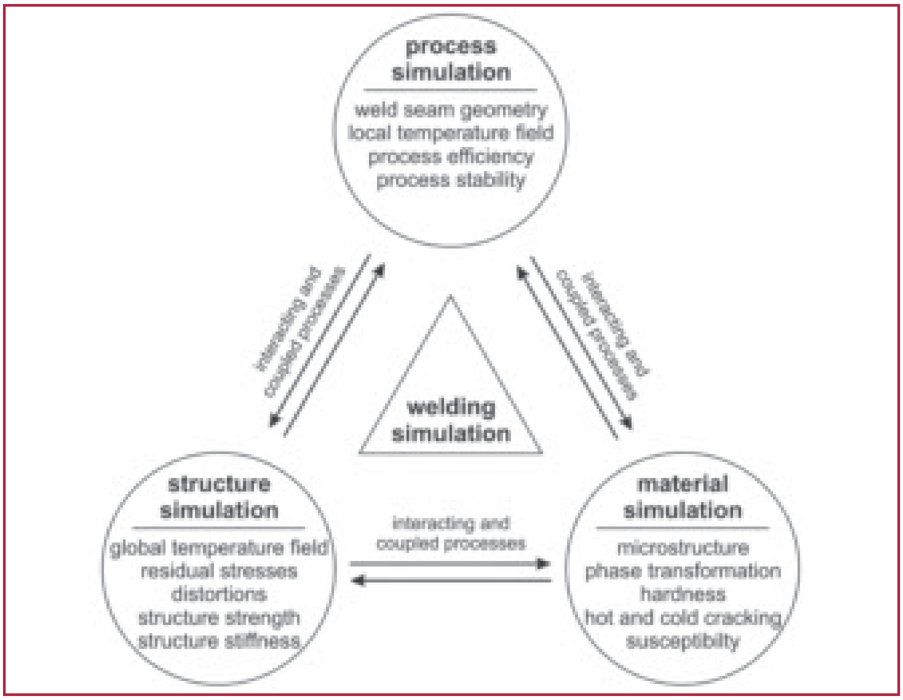

Fig. 1 — Subdomains of welding simulation showing the main target and coupling factors, with reference to Radaj (Ref. 7).

perimental validation (Ref. 3). Based on these results, the influence of material properties on the calculation results was determined for better assessment of the relevance and accuracy of the simulation (Refs. 4, 5).The work was performed at BAM Federal Institute for Materials Research and Testing in Berlin and has laid the foundation for the welding simulation standardization activities currently underway at DIN.

Due to the complexity of the subject matter and demands of the industrial user, the NAS Standards Committee NA 092-00-29 AA, Welding Simulation, was established to further utilize the results achieved in the INS projects and to make them available as a standard. Most notably, the existent simulation methods, the differing calculation results as regard, for example, component distortion, weld pool formation, hardness values, or microstructure (Refs. 6, 7), as well as the necessary verification and validation of the simulation results (Ref. 8), are to be summarized in common collaborative committee work undertaken by research and industry representatives to become an easily understandable document for use in industry. The committee structures as well as the goals of the activities at DIN are explained in the following two sections.

National and International Activities

The Standards Committee NA 092-00-29 AA, Welding Simulation, which was established in 2009, is a subcommittee of the NAS Standards Committee for Welding and Allied Processes. It is conducted jointly with DVS, but the NAS office is in charge overall. For DVS, it represents Subgroup AG I 2.1 of Working Group FA I2, Application-Oriented Welding Simulation, of the AFT Committee for Technology, which acts at the same time within the DVS Research Association in its capacity as a technical committee. The resulting close link with the projects handled by the research association, in addition to the direct cooperation of the industry representatives with the standards committee, ensures a practice-oriented line of research and excellent thematic expertise to create widely accepted and comprehensive guidelines suited to industry's needs.

For the past few years, the American Welding Society has also been doing a lot of work on standards for welding simulation. Its A9, Computational Weld Mechanics, group chaired by Prof. S. S. Babu from The Ohio State University, deals with the same basic themes addressed in Germany, but focuses more on verification and validation of the simulation results. Continual active collaboration of German representatives on this committee aims at bringing both approaches into the best possible harmony. The idea behind such collaboration is to facilitate later harmonization of prepared documents in view of a potential ISO standard for welding simulation. In addition, collaboration between the two committees enables a speedy exchange of information and experience, thus enhancing the quality of the results and avoiding unnecessary parallel work.

Current Aims of the DIN Standards Committee

The German Welding Simulation Committee aims to prepare a guideline summarizing the commonly applied calculation methods for welding simulation and make them available in the form of a basic structure including illustrative examples. This will be accomplished by taking account of all domains in which welding simulation is feasible and also by providing easy-to-implement flexible extension and adjustment options in the document for aspects to be considered later on. This task has the promise for being performed by dividing the domains into various subdomains that give an immediate overview for identifying the items to which new methods and computation aims have to be allocated. A frequently adopted schematic categorizing the various welding simulation subdomains into the three groups of process, structure, and materials simulation was presented by Radaj (Ref. 7), as depicted in Fig. 1.

The target factors addressed in this schematic will be covered by the basic DIN specification structure while ensuring flexible extension of the document with respect to future simulation methods and calculation aspects. The DIN specification will not lay down strict targets but instead provide a general list of data required for a structured approach and for effective simulation traceability. Attention is given to the following subtopics:

- **Simulation object.** Description of the component or structure, respectively, and of all necessary data relating to the applied welding procedures and parameters.
- **Simulation goal.** Details concerning the desired calculation results.
- **Physical model.** Description of the physical processes to be simulated, of the given boundary conditions, as well as indication of the simplifications and assumptions made.
- **Mathematical model and method of solution.** Data relating to the geometric model, dimensionality, and adopted method of solution.
- **Implementation.** Indication of the applied specific software, and details concerning networking, material characteristics, etc.
- **Evaluation and display of results.**
- **Recommended measures to ensure the simulation results.** These include verification, validation, calibration, and checking.
- **Documentation of the approach and results.**

The last aspect includes preparation of a generally valid report template that takes account the mentioned points and, if appropriately applied, improves the comparability of various calculation projects. For completion, this structure will be exemplified by applying it to specific simulation projects for illustration and transparency. This will add to the convenience of application, particularly for users without expert knowledge of welding simulation, and may help them get into this subject matter. Further examples will be collected continually and made available in an identical form giving a clear overview and providing a universally valid structure, supported by examples from practice, in the form of a generally accepted DIN standard as a medium- or long-term perspective.

Summary and Outlook

Simulation of the welding process offers vast potential for analyzing and optimizing the processes and for predicting component properties. Due to the complexity of the welding process and of the manifold simulation approaches, it is still difficult for nonexperts to select the appropriate approach and apply it correctly. This is the reason why a practice-linked guideline for the application of welding simulation in industry is urgently needed in order to exploit the existing potential, especially for users just getting into welding simulation. Additionally, the guideline will provide the basis for effective comparability between various simulation projects that will greatly help to ease application and communication for both customers and engineering service providers.

Such a guideline is currently being prepared at the German Institute for Standardization in direct cooperation with the German Welding Society. Cooperation of representatives of both industry and research contributes to successful and practice-linked standardization work taking into account the current state of the art of research and development. The near-term focus of the activities is to complete an official DIN specification for welding simulation including various examples. (The first part of DIN SPEC 32534, *Numerical Welding Simulation*, became available in March.) Mid-term, this document is supposed to be provided with further examples, and over the long run it is intended to be transformed into a DIN standard. An international introduction at the ISO level is possible in the future in cooperation with the American Welding Society and other groups working on the same topic.♦

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Latest Developments in Welding Skills Training

Virtual welder training offers cost and safety advantages over traditional training methods

BY STEFFEN KEITEL AND CHRISTIAN AHRENS

Education and career are two sides of the same coin. This is not a new idea in the world of technical skills because, from the origin of handicrafts, it has been known that a good apprenticeship is the basis of sound skills and it is the skilled craftsperson who usually obtains economic success. To this end, craftspeople have often traveled around after their apprenticeship in order to learn new methods and working skills.

In industry, too, continuous education is the basis of success. This has been proven by companies that have been successful for many decades.

New Methods: Virtual Welding Trainers

Not only in theoretical education, but also in practical training, the basic structures that have remained unchanged for more than 50 years must be reconsidered. There are many things that influence welders and their handicraft skills; therefore, the following must be considered:

- Developments in welding equipment, and in particular, electric power sources
- Changes in personal protection for workers
- New material properties (base metals, filler metals, gases)
- Increasing productivity within the company
- Specialization of products.

Moreover, the question must be raised for training institutes on how they can reduce the length and cost of educational programs while still improving the quality of the education they provide. Furthermore, educational organizations must ensure that students can commence their training at any time. For teachers, this means they must be nearly 100% flexible when presenting the training course.

In order to meet these demands, we need to take a look at what takes place in other fields. For example, in competitive sports, complex motions are trained separately. In principle, this is also possible in welding.

In the 1990s, Gesellschaft für Schweisstechnik International mbH (GSI), as part of a common research project with the Paton Institute in Kiev, laid the foundation for a device called a "virtual welding trainer" — Fig. 1. With the virtual welding trainer, the basic capabilities of arc welding are taught without the need to strike the high-performance arc. Instead, a pilot arc simulates the actual working conditions of a welder. The three-dimensional guidance of the torch is electronically controlled, and the welders receive instructions through a signal and audio voice unit inside the helmet for carrying out corrections — Figs. 2–4. The pilot arc simulates the actual welding process and trains the welder in how to strike the arc. During welding, the trainee listens to the sounds the welding arc makes, and after the program sees a real weld interface. With each weld, an examination of the parameters is performed. The range of parameters presented after the trainee has finished welding shows the consistency of the movements. Only after the trainee successfully completes the virtual training exercises does the "training in safety" end and the trainee changes to high-performance power sources.

Once the student completes virtual training, he or she can carry out the movements already learned to concentrate on the high-performance arc and formation of the weld pool. One after the other or in different combinations, the trainee can learn to optimize the welding speed, torch angles, contact tube distance, and ignition.

This step-by-step procedure helps the trainee avoid the mistakes that might creep in during the movements, which otherwise could be corrected only at a large expense.

The extent of assistance is also improved when virtual welding trainers are used. Initial mistakes are reduced and the processes can be split into individual components on which the student can better concentrate. For the final handling of the torch, all the components can be brought together again.

With this type of equipment, the training scheme of the vocational training center must be changed in order to make use of all the advantages of the new technology. These advantages include the following:

- Ability to use standard lecture rooms
- The more expensive welding booths can be reserved for training advanced students and not for beginning trainees
- Fewer trainer's hours required (30 to 50% reduction)
- Less material, gas, electrodes ($34/day)
- Less energy (50 to 60% reduction)
- No exhaust or welding curtain needs
- Less smoke means less filtering needed
- Utilizes same power source as for welding
- Improved attraction and motivation for young people
- Less wear and fewer repairs on equipment

STEFFEN KEITEL is managing director and CHRISTIAN AHRENS (ahrens@gsi-slv.de) *is managing director, foreign business, GSI-Gesellschaft für Schweisstechnik International mbH (German Welding Institute), Duisburg, Germany.*

Fig. 1 — Training of manual skills when using the virtual welding trainer.

Fig. 2 — Position-controlled welding torch.

- Continuous observation of correct handling methods (position, speed, workpiece distance).

In the long term, such development offers advantages for everyone: trainee, training center, industry, and last but not least, the developer of the training system.

Virtual systems such as the one described here have been developed worldwide by using modern computer technologies in 3D or 2D versions. At the Essen Welding Show in September 2009, eight companies from all over the world presented their virtual welding equipment at the GSI booth. Following are some virtual weld training products already on the market:

- Welding Trainer, SLV Halle, Germany
- CS Wave, France
- VRTEX®360, The Lincoln Electric Co., Cleveland, Ohio
- Arc+, 123 Certification, Inc., Canada
- Virtual Welding, Fronius, Austria
- Welding Trainer, Apolo Studio, Spain.

Summary

GSI has contributed several newer education competencies such as distance learning courses, blended learning, and the training device "Virtual Welding Trainer."

Because welding is embedded into more and more complex processes, education in welding must also include interdisciplinary subjects. These include material testing and corrosion protection. The training and further education of designers in the field of welding technology also needs to be given special attention.

In addition, modern education presupposes a close relation to the general state of the art of science and technology. To this end, the network of the International Institute of Welding and, in particular, the elevated competences of university research institutes offer the best opportunities.

In September 2010, at the first international conference Welding Trainer 2010 — The Future of Education, the virtual welding training industry met in Duisburg, Germany. The international conference was supported by most of the experienced developers and users of virtual welding trainer systems from the United States, Canada, France, Spain, Austria, and Germany. It offered a large forum with more than 80 participants from 5 continents and 25 countries to discuss new and innovative teaching methods. The final decision of the parties involved was to go ahead with their development of virtual welding systems and to repeat the event on a biannual schedule.♦

Fig. 3 — Welding position control.

Fig. 4 — Interactive welding helmet.

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

AeroDef Manufacturing Expo. April 5–7. Anaheim Convention Center, Anaheim, Calif. Sponsored by Society of Manufacturing Engineers; *http://aerodef.sme.org.*

Nano and Micromanufacturing Confs. & Exhibits. April 5, 6. Drury Lane Convention Center, Oakbrook Terrace, Ill. Society of Manufacturing Engineers; *www.sme.org/nanomanufacturing; www.sme.org/micro.*

Aluminum Assn. Spring Meeting. April 7–9. Sanibel Harbour Marriott Resort & Spa, Fort Myers, Fla.; *www.aluminum.org.*

GAWDA Spring Management Conf. April 11–13. Marriott Tampa Waterside Hotel & Marina, Tampa, Fla. Gases and Welding Distributors Assn., *www.gawda.org.*

Composites Manufacturing. April 12–14. Dayton Convention Center, Dayton, Ohio. Sponsored by Society of Manufacturing Engineers; *www.sme.org/composites.*

IPC APEX Expo™ Electronics Industry Show. April 12–14. Mandalay Bay Resort and Convention Center, Las Vegas, Nev.; *www.ipcapexexpo.org.*

HOUSTEX. April 18–20. George R. Brown Convention Center, Houston, Tex. Sponsored by Society of Manufacturing Engineers; *www.houstexonline.com.*

INTERTECH 2011. May 2–4. Hyatt Regency O'Hare, Chicago, Ill. To share new technology and application developments for all superabrasive materials; *www.intertechconference.com.*

Offshore Technology Conf. May 2–5. Reliant Park, Houston, Tex.; *www.otcnet.org/2011/.*

Int'l Conf. on Soldering and Reliability. May 3–6, Crowne Plaza Toronto Airport Hotel, Toronto, Ont., Canada. Surface Mount Technology Assn. Int'l, *www.smta.org.*

JOM-16, Int'l Conf. on the Joining of Materials and ICEW-7, 7th Int'l Conf. on Education in Welding. May 10–13. Sankt Helene Centre, Tisvildeleje, Denmark. Contact JOM Institute, Gilleleje, Denmark. Phone +45 48 35 54 58; *jom_aws@post10.tele.dk.*

♦AWS WELDMEX. May 11–13, Cintermex, Monterrey, Mexico. Colocated with **FABTECH Mexico** and **MetalForm Mexico.** See the latest welding and cutting products, thermal spray, metal finishing and safety equipment, metalforming products, tool and die, metal stamping, forming and assembly, and a variety of bending and fabrication products, including laser and plasma cutting, coil processing, roll forming, plate and structural fabricating, saws and cut-off machines, tooling, press brakes, shears, punching, and tube and pipe equipment; *www.awsweldmex.com.*

North American Steel Construction Conf. May 11–14. David L. Lawrence Conf. Center, Pittsburgh, Pa.; *www.aisc.org/content.aspx?id=25212.*

Int'l Symposium on Nondestructive Testing of Materials and Structures. May 15–18. Suleyman Demirel Cultural Center, Maslak Campus of Istanbul Technical University, Istanbul, Turkey; *www.ndtms.itu.edu.tr.*

ASQ World Conf. on Quality and Improvement and Quality Institute for Healthcare Conf. May 16–18. David L. Lawrence Convention Center, Pittsburgh, Pa. Sponsored by American Society for Quality, *http://wcqi.asq.org.*

Cold Spray 2011, 1st Australasian Cold Spray Conf. May 16–18. The Langham Melbourne, Melbourne, Southbank, Victoria, Australia; *www.csiro.au/org/ColdSpray-Conference-2011.html.*

EASTEC Eastern States Expo. May 17–19. West Springfield, Mass. Sponsored by the Society of Manufacturing Engineers; *www.easteconline.com.*

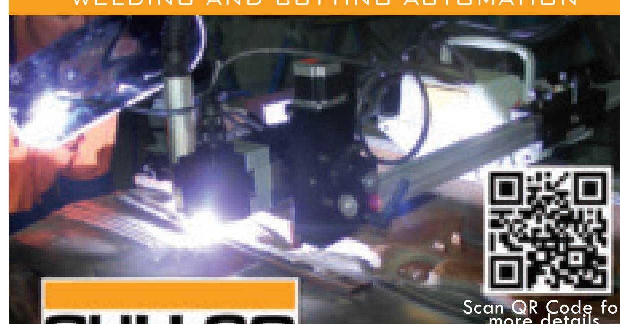
♦**AWS National Robotic Arc Welding Conf. and Expo.** May 23–25. Sponsored by AWS D16 Committee on Robotics and Automatic Welding and AWS Milwaukee Section. Contact Karen Gilgenbach, (262) 613-3790, *Karen.gilgenbach@airgas.com.*

Russia Essen Welding & Cutting. May 23–26. Krasnaya Presnya Expo Center, Moscow, Russia; *www.schweissen-schneiden.com.*

Beijing-Essen Welding & Cutting Fair. June 2–5. New Int'l Expo Center, Shanghai, China; *www.beijing-essen-welding.de/.*

SME Annual Conf. June 5–7. Hyatt Regency Bellevue, Bellevue, Wash. Sponsored by Society of Manufacturing Engineers; *www.sme.org/conference.*

Int'l Chemical and Petroleum Industry Inspection Technology XII Conf. June 8–11. Houston Marriott North at Greenspoint, Houston, Tex.; *www.asnt.org.*



Western Manufacturing Technology Show. June 14–16. Edmonton Expo Centre, Edmonton, Alb., Canada. Sponsored by Society of Manufacturing Engineers; *www.wmts.ca.*

IIW 64th Annual Assembly and Int'l Conf. on Global Trends in Joining, Cutting, and Surfacing Technology. July 17–22. Chennai Trade Center, Chennai, India; *www.iiwindia.com.*

ASNT Digital Imaging XIV. July 18–20. Foxwoods Resort, Mashantucket, Conn.; *www.asnt.org.*

Weld India 2011, Int'l Expo on Joining, Cutting, and Surfacing. July 21–23. Chennai Trade Center, Chennai, India; *www.iiwindia.com.*

imX-Interactive Manufacturing Experience. Sept. 12–14. Las Vegas Convention Center, Las Vegas, Nev. Sponsored by the Society of Manufacturing Engineers; *www.imxevent.com.*

Die Casting Congress & Tabletop. Sept. 19–21. Greater Columbus Convention Center, Columbus, Ohio. Sponsored by North American Die Casting Assn.; *www.diecasting.org/congress.*

DVS Congress and Expo. Sept. 27–29. Congress Center, Hamburg, Germany. Sponsored by Messe Essen and German Welding Society; *www.dvs-expo.de.*

Offshore Technology Conf. and Exhibition (OTC Brasil 2011). Oct. 4–6, Riocentro, Rio de Janeiro, Brazil; *www.otcbrasil.org.*

GAWDA Annual Convention. Oct. 9–12, Times Square Marriott Marquis, New York, N.Y. Gases and Welding Distributors Assoc.; *www.gawda.org.*

SOUTH-TEC. Oct. 11–13. Charlotte Convention Center, Charlotte, N.C. Sponsored by Society of Manufacturing Engineers; *www.southteconline.com.*

SMTA Int'l Conf. and Expo. Oct. 16–20, Fort Worth Convention Center, Fort Worth, Tex. Surface Mount Technology Assn. Int'l, *www.smta.org.*

Educational Opportunities

ASME Section IX Seminars. June 6–8 and Oct. 24–26, Houston, Tex.; Dec. 5–7, Atlanta, Ga. Call Marian Hess, (212) 591-7161; *www.asme.org/Education/Courses/Public/.*

Brazing Seminars. Three-day programs beginning April 19, Los Angeles, Calif.; May 17, Hartford, Conn.; Oct. 11, Greenville, S.C.; Nov. 15, Hartford, Conn. Contact: Kay & Associates, (860) 651-5595; *dan@kaybrazing.com; www.kaybrazing.com.*

CWI/CWE Preparation with Exam. AWS Certified Welding Inspector and AWS Certified Welding Educator, two-week-long classes beginning April 4, May 9, June 13, July 25, Oct. 3, Oct. 31, Dec. 5. Hobart Institute of Welding Technology, Troy, Ohio; *www.welding.org; hiwt@welding.org;* (800) 332-9448.

Certified Welding Supervisor Preparation with Exam. Two-week-long class beginning Sept. 1. Hobart Institute of Welding Technology, Troy, Ohio; *www.welding.org; hiwt@welding.org;* (800) 332-9448.

Fundamentals of Brazing Seminar. April 12–14, Doubletree Hotel Charlotte Airport, Charlotte, N.C. Contact Lucas-Milhaupt, (800) 558-3856; *www.lucasmilhaupt.com.*

Laser Safety Officer Course. April 5–7, San Francisco, Calif.; June 7–9, St. Paul, Minn. Contact Laservision Academy, (800) 393-5565; *http://academy.lasersafety.com.*

Robotic Arc Welding Training and Certification. Week of May 23, Davenport, Iowa. Preparation and testing for AWS CRAW-T and CRAW-O certifications. Genesis-Systems Group. Call Jane Eagle, (563) 445-5688.

Canadian Manufacturing Technology Show. Oct. 17–20. Direct Energy Centre, Toronto, Ont., Canada. Sponsored by Society of Manufacturing Engineers; *www.cmts.ca.*

Seminars, Code Clinics, and Examinations

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

Certified Welding Inspector (CWI)

Location	Seminar Dates	Exam Date
Corpus Christi, TX	Exam only	April 23
St. Louis, MO	Exam only	April 23
Baton Rouge, LA	May 1–6	May 7
San Francisco, CA	May 1–6	May 7
Waco, TX	Exam only	May 7
Nashville, TN	May 8–13	May 14
Jacksonville, FL	May 8–13	May 14
Baltimore, MD	May 8–13	May 14
Detroit, MI	May 15–20	May 21
Miami, FL	May 15–20	May 21
Albuquerque, NM	May 15–20	May 21
Long Beach, CA	Exam only	May 28
Spokane, WA	June 5–10	June 11
Oklahoma City, OK	June 5–10	June 11
Birmingham, AL	June 5–10	June 11
Hartford, CT	June 12–17	June 18
Pittsburgh, PA	June 12–17	June 18
Beaumont, TX	June 12–17	June 18
Miami, FL	June 12–17	June 18
Corpus Christi, TX	Exam only	June 25
New Orleans, LA	July 10	July 16
Phoenix, AZ	July 10	July 16
Memphis, TN	July 10	July 16
Miami, FL	July 10	July 16
Orlando, FL	July 17–22	July 23
Milwaukee, WI	July 17–22	July 23
Los Angeles, CA	July 17–22	July 23
Sacramento, CA	July 17–22	July 23
Kansas City, MO	July 24–29	July 30
Cleveland, OH	July 24–29	July 30
Louisville, KY	July 24–29	July 30
Denver, CO	July 31–Aug. 5	Aug. 6
Philadelphia, PA	July 31–Aug. 5	Aug. 6
San Diego, CA	Aug. 7–12	Aug. 13
Chicago, IL	Aug. 7–12	Aug. 13
Miami, FL	Aug. 7–12	Aug. 13
Charlotte, NC	Aug. 14–19	Aug. 20
San Antonio, TX	Aug. 14–19	Aug. 20
Bakersfield, CA	Aug. 14–19	Aug. 20
Portland, ME	Aug. 21–26	Aug. 27
Salt Lake City, UT	Aug. 21–26	Aug. 27
Pittsburgh, PA	Aug. 21–26	Aug. 27
Seattle, WA	Aug. 21–26	Aug. 27
Houston, TX	Sept. 11–16	Sept. 17
Minneapolis, MN	Sept. 11–16	Sept. 17
St. Louis, MO	Sept. 18–23	Sept. 24
Miami, FL	Sept. 18–23	Sept. 24
New Orleans, LA	Sept. 18–23	Sept. 24
Tulsa, OK	Oct. 16–21	Oct. 22
Long Beach, CA	Oct. 16–21	Oct. 22
Newark, NJ	Oct. 16–21	Oct. 22
Nashville, TN	Oct. 16–21	Oct. 22
Portland, OR	Oct. 23–28	Oct. 29
Roanoke, VA	Oct. 23–28	Oct. 29
Cleveland, OH	Oct. 23–28	Oct. 29
Detroit, MI	Oct. 23–28	Oct. 29
Miami, FL	Oct. 23–28	Oct. 29

9–Year Recertification Seminar for CWI/SCWI

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

Location	Seminar Dates	Exam Date
Sacramento, CA	May 9–14	No exam
Pittsburgh, PA	June 6–10	No exam
San Diego, CA	July 11–16	No exam
Miami, FL	July 17–23	No exam
Orlando, FL	Aug. 22–27	No exam
Denver, CO	Sept. 19–24	No exam
Dallas, TX	Oct. 17–22	No exam

Certified Welding Supervisor (CWS)

Location	Seminar Dates	Exam Date
Minneapolis, MN	July 18–22	July 23
Miami, FL	Sept. 12–16	Sept. 17
Norfolk, VA	Oct. 17–21	Oct. 22

CWS exams are also given at all CWI exam sites.

Certified Radiographic Interpreter (CRI)

Location	Seminar Dates	Exam Date
Las Vegas, NV	May 16–20	May 21
Miami, FL	June 6–10	June 11
Dallas, TX	July 18–22	July 23
Chicago, IL	Sept. 12–16	Sept. 17
Pittsburgh, PA	Oct. 17–21	Oct. 22

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

Certified Welding Sales Representative (CWSR)

Location	Seminar Dates	Exam Date
Miami, FL	May 4–6	May 6
Atlanta, GA	June 8–10	June 10
Miami, FL	Aug. 24–26	Aug. 26
Indianapolis, IN	Sept. 21–23	Sept. 23

CWSR exams will also be given at CWI exam sites.

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

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

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

Certified Robotic Arc Welding (CRAW)

Week of	Location	Contact
April 25	Wolf Robotics, Ft. Collins, CO	(970) 225-7736
May 2	ABB, Inc., Auburn Hills, MI	(248) 391-8421
May 23	Genesis–Systems , Davenport, IA	(563) 445-5688
Aug. 1	Wolf Robotics, Ft. Collins, CO	(970) 225-7736
Aug. 1	ABB, Inc., Auburn Hills, MI	(248) 391-8421

International CWI Courses and Exams

Please visit *www.aws.org/certification/inter_contact.html*

***Important:** This schedule is subject to change without notice. Please verify your event dates with the Certification Dept. and confirm your course status before making your travel plans. For information, visit* www.aws.org/certification, *or call (800/305) 443–9353, ext. 273, for Certification; or ext. 455 for Seminars. Apply early to avoid paying the $250 Fast Track fee.*

Melt-Through and Root Surface Profiles

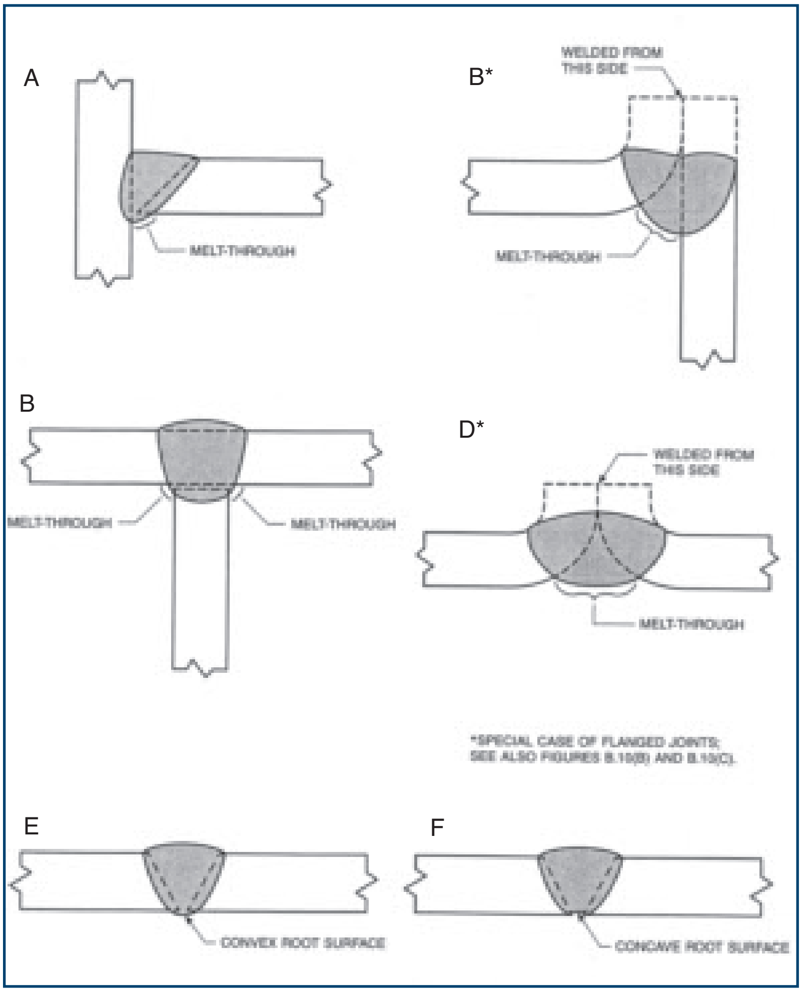


Fig. 1 — Melt-through and root surface profile.

Melt-through is a procedure-related discontinuity that results from improper welding procedures — Fig. 1A–D. It is weld metal that appears outside of the weld joint. An extreme case of this discontinuity is termed **excessive melt-through**. Melt-through is characterized by visible root reinforcement in a joint welded from one side or a hole in the weld bead. You can avoid melt-through by strictly adhering to the specified procedure and adjusting the welding current and voltage.

In electrogas welding, because melt-through in the starting weld tab occurs outside of the production weld, it is not a weld discontinuity. However, it prevents satisfactory welding of the workpiece due to the loss of the weld pool. You can easily prevent melt-through in this case by using an adequate thickness of material on the bottom of the starting weld tab or by attaching a backup plate to the starting weld tab. Poorly fitted backing shoes can also result in melt-through.

Figure 1E and F depict convex and concave root surface profiles, respectively. The root surface is the exposed surface of a weld opposite the side from which welding was done. Figure 2 offers other views of the root surface.◆

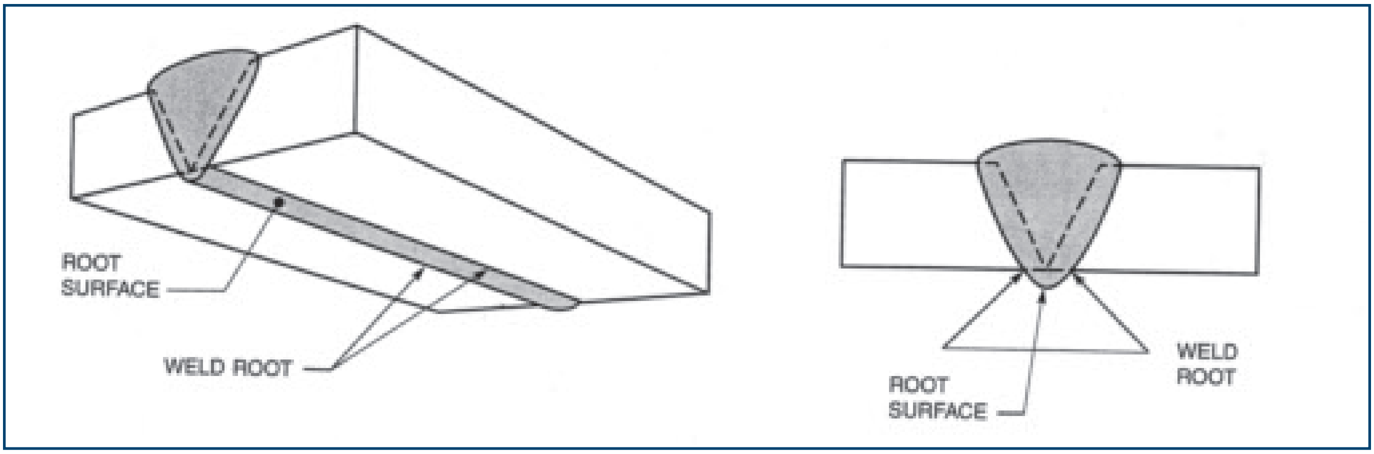


Fig. 2 — Root surface.

Excerpted from the *Welding Handbook,* Volumes 1 and 2, ninth edition, and AWS A3.0, *Standard Welding Terms and Definitions*.

BY HOWARD M. WOODWARD
woodward@aws.org

National Officers Transition in Miami

BY KRISTIN CAMPBELL

During the officers' transition ceremony held Feb. 4 at AWS headquarters in Miami, Fla., **John Mendoza** stated he will focus on AWS certification during his term as 2011 president of the Society.

"The work that this organization does is relevant to people's lives, their careers, and their standard of living. I hope we never take that for granted," Mendoza said. He recalled seeing cutting-edge technology and research at the Los Alamos and Sandia National Laboratories. "The way that we were treated there really brought home the impact of what this office (AWS president) means to so many people."

Mendoza acknowledged the AWS volunteers and staff members. "The two together just work," he said. This can been seen through many accomplishments, including the future AWS headquarters expansion move to Doral, Fla.

John Bruskotter, outgoing president, spoke about his travels worldwide. He cited a meeting with the German Welding Society officials who marveled at AWS's growth in achieving nearly 67,000 members in these tough economic times. He also expressed appreciation for the Society's hard-working volunteers and staff members. "I'm pleased to have represented you this year, and I thank you for having me as your president."

Miami Mayor **Tomas Regalado** proclaimed Feb. 4 as American Welding Society Day in the city. The mayor of Miami-Dade County also sent a proclamation declaring Feb. 4 as AWS Day in the county.

The following officers and spouses attended the event: AWS Foundation Chair **Gerald Uttrachi** and **Christine**, past President **Ronald Pierce** and **Joyce**, District 18 Director **John Bray** and **Luanne**, District 20 Director **William Komlos** and **Carol,** past AWS President **Victor Matthews** and **Sally**, Treasurer **Robert Pali** and **Annette**, District 16 Director **David Landon** and **Kay**, Vice President **Nancy Cole** and **Leon,** and Vice President **William Rice Jr.** and **Cherry**. Also attending were Vice President **Dean Wilson**, Director-at-Large **Thomas Lienert**, Executive Director **Ray Shook**, and the AWS headquarters staff members.

Employee of the Year

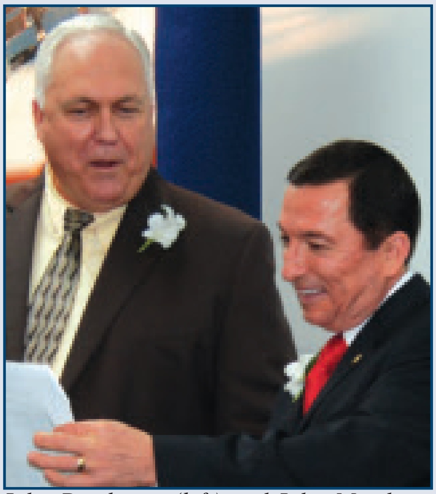
Willie Chinn, the graphic artist in the Marketing Department, received the 2010 Michael A. Rowland Employee of the Year Award. This peer-nominated honor recognizes an employee who has provided exemplary service and made notable contributions above the scope of normal duties, plus possesses an attitude and behavior contributing to teamwork and positive treatment of others in ways that exceeded job expectations.

Chinn's citation read, in part, "His artistry has elevated the public image of many of AWS's programs. He uses his creative gifts and technical skills to add perceived value to our products. He is not only an excellent graphic designer, he also uses unique 3D modeling technology to create realistic illustrations to meet our marketing needs. This has saved AWS tens of thousands of dollars in photography costs."

Chinn has created logos and graphic identities for new programs — including the AWS Certified Welding Fabricator, Accredited Test Facility, and American Welding University, and also completely redesigned *Inspection Trends* magazine.

Ray Shook noted, "Millions of people around the world are exposed to Willie's work who may never attend our show or even talk with an AWS employee, but who acquire a positive image of AWS through his creations on the web and in print." With employee **Cecilia Barbier**, Chinn took the initiative to create the professional Image of Welding trophy, designing a prototype, and getting funding for this project.

Chinn's recognition included an engraved mantel clock, $1000, dinner for two at a local restaurant, and a reserved parking space for one year.♦



John Bruskotter (left) and John Mendoza, the 2010 and 2011 AWS presidents, respectively, chat at the transition program.

Willie Chinn earned the 2010 Michael A. Rowland Employee of the Year Award.

Miami Mayor Tomas Regalado (left), with President Mendoza, proclaimed Feb. 4 as American Welding Society Day in the city.

KRISTIN CAMPBELL (kcampbell@aws.org) *is associate editor of the* Welding Journal.

Errata AWS D3.6M:2010 *Underwater Welding Code*

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

Page 72. Table 8.1, note a — Correct "First position only. Qualification for additional positions will omit groove weld tension, macroetch, and fillet weld shear strength tests." to "First position only. Qualification for additional positions will omit groove weld tension, macroetch, Charpy tests, and fillet weld shear strength tests."

Page 72. Table 8.1, note 1 — Correct "WM — Weld Metal; HAZ = Heat-Affected Zone." to "HAZ Charpy Impact Testing is not required for qualification of wet welding procedures. WM = Weld Metal; HAZ = Heat-Affected Zone."

Page 75. Table 8.2, footnote b — Correct "See 5.11.5 and Table 8.1, Note 5." to "HAZ Charpy Impact Testing is not required for qualification of wet welding procedures. See 5.11.5 and Table 8.1, footnote d."

Page 79. Table 8.3, Column heading — Correct "Fillet Weld Break (See Figure 5.9)" to "Fillet Weld Break (See Figure 5.8)".

New Standards Projects

Development work has begun on the following standards. Affected individuals are invited to contribute to their development. To participate, call R. Gupta (305) 443-9353, ext. 301, except as shown. Participation on AWS technical committees is open to all persons.

A5.4/A5.4M:20XX, *Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding.* Composition and other requirements are specified for more than 40 classifications of covered stainless steel welding electrodes. The requirements include general requirements, testing, and packaging. Annex A provides application guidelines and other useful information about the electrodes. This specification makes use of both U.S. Customary Units and the International System of Units [SI]. Stakeholder: Welding Industry.

A5.14/A5.14M:20XX (ISO 18274:2010 MOD), *Specification for Nickel and Nickel-Alloy Bare Welding Electrodes and Rods.* The chemical compositions of 51 nickel and nickel-alloy welding electrodes and rods are specified, including one composition not previously classified. Major topics include general requirements, testing, packaging, and application guidelines. This specification makes use of both U.S. Customary Units and the International System of Units (SI). Stakeholder: Welding industry.

A5.18/A5.18M:20XX, *Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding.* This specification prescribes the requirements for classification of solid carbon steel electrodes and rods, composite stranded carbon steel electrodes, and composite metal cored carbon steel electrodes for gas shielded arc welding. Classification is based on chemical composition of the electrode for solid electrodes and rods, chemical composition of weld metal for composite stranded and composite metal cored electrodes, and the as-welded mechanical properties of the weld metal for each. Stakeholder: Welding industry.

A5.20/A5.20M:20XX, *Specification for Carbon Steel Electrodes for Flux Cored Arc Welding.* This specification prescribes the requirements for classification of carbon steel electrodes for flux cored arc welding. Stakeholder: Welding industry.

A5.22/A5.22M:20XX, *Specification for Stainless Steel Flux Cored and Metal Cored Welding Electrodes.* Classification and other requirements are specified for numerous grades of flux cored and metal cored stainless steel electrodes and rods. New classifications include a duplex alloy and three high-carbon classifications not previously classified. New classifications also include all of the metal cored electrodes that are currently in A5.9/A5.9M. In the next revision of A5.9/A5.9M, these metal cored electrodes will be deleted from that specification. Stakeholder: Welding industry.

A5.23/A5.23M:20XX, *Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding.* This specification provides requirements for the classification of solid and composite carbon steel and low-alloy steel electrodes and fluxes for submerged arc welding. Stakeholder: Welding industry.

A5.28/A5.28M:20XX, *Specification for Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding.* This specification prescribes the requirements for classification of solid low-alloy steel electrodes and rods, composite stranded low-alloy steel electrodes, and composite metal cored low-alloy steel electrodes for gas shielded arc welding. Classification is based on chemical composition of the electrode for solid electrodes and rods, chemical composition of weld metal for composite stranded and composite metal cored electrodes and the as-welded or postweld heat treated mechanical properties of the weld metal for each. Stakeholder: Welding industry.

A5.29/A5.29M:20XX, *Specification for Low-Alloy Steel Electrodes for Flux Cored Arc Welding.* Classification and other requirements are specified for numerous grades of flux cored and metal cored stainless steel electrodes and rods. Stakeholder: Welding industry.

C2.18:20XX, *Guide for the Protection of Steel with Thermal Sprayed Coatings of Aluminum and Zinc and their Alloys and Composites.* This guide presents an industrial process for the application of thermal spray coatings (TSC) on steel. It covers safety, job/contract description, background and requirements, selection of TSCs, TSC operator qualification, materials and equipment, application-process method with quality control check points, Job Control Record, maintenance and repair of TSCs, records, debris containment and control, and warranty. Stakeholders: Users of AWS C2.23, thermal spray facility owners, coating applicators, and inspection and training. J. Gayler, ext. 472.

Standards Approved by ANSI

D1.4/D1.4M:2011, *Structural Welding Code — Reinforcing Steel.* Revision approved 1/31/11.

C5.3:2000 (R2011), *Recommended Practices for Air Carbon Arc Gouging and Cutting.* Reaffirmed 1/26/11.

Standards for Public Review

A5.8M/A5.8:20XX, *Specification for Filler Metals for Brazing and Braze Welding.* Revised. $36. Review expired 3/21/11.

A5.23/A5.23M:20XX, *Specification for Low-Alloy Electrodes and Fluxes for Submerged Arc Welding.* Revised. $46.50. Review expires 4/18/11.

C2.19/C2.19M:20XX, *Specification for the Application of Thermal Spray Coatings to Machine Elements for OEM and Repair.* New standard. $32.50. Review expires 4/4/11.

C6.2/C6.2M:2006 (R20XX), *Specification for Friction Welding of Metals.* Reaffirmed standard. $25. Review expires 4/4/11.

AWS was approved as an accredited standards-preparing organization by the American National Standards Institute (ANSI) in 1979. AWS rules, as approved by ANSI, require that all standards be open to public review for comment during the approval process. The above standards were submitted for public review. To order draft copies, contact R. O'Neill, *roneill@aws.org,* (305) 443-9353, ext. 451.

Technical Committee Meetings

All AWS technical committee meetings are open to the public. To attend a meeting, call the committee secretary, (305) 443-9353, at the extension listed.

April 5, 6. D15 Committee on Railroad Welding. Chicago, Ill. S. Borrero, ext. 334.

April 5, 6. D15A Subcommittee on Freight Cars and Their Materials. Chicago, Ill. S. Borrero, ext. 334.

April 26–28. B2 Committee on Procedure and Performance Qualifications. Salt Lake City, Utah. J. Gayler, ext. 472.

May 4–6. A2 Committee on Definitions and Symbols. Virginia Beach, Va. S. Borrero, ext. 334.

May 10–12. D14 Committee on Machinery and Equipment. Milwaukee, Wis. M. Rubin, ext. 215.

May 17–19. D17 Committee on Welding in the Aircraft and Aerospace Industries. Seattle, Wash. A. Diaz, ext. 304.

Contribute Your Knowledge to These Technical Committees

It is the volunteers on AWS Technical Committees who provide the expertise to develop the standards, codes, and other technical publications to serve industry's ever-changing needs for welding and allied processes. Currently, more than 1800 volunteers serve on the 160 American Welding Society technical committees and subcommittees.

Membership on AWS technical committees is open to everyone. Review the committee volunteer openings outlined here, then contact the committee secretary listed to learn more about the advantages and requirements for contributing to this work.

Joining Wrought Nickel Alloys

The G2C Subcommittee on Nickel Alloys seeks volunteers to review G2.1M/G2.1, *Guide for the Joining of Wrought Nickel-Based Alloys,* and participate in the regular meetings and teleconferences. Contact Stephen Borrero, *sborrero@aws.org,* ext. 334.

Marine Construction

The D3 Committee for Welding in Marine Construction to contribute to the development of **D3.5,** *Guide for Steel Hull Welding;* **D3.6,** *Specification for Underwater Welding;* **D3.7,** *Guide for Aluminum Hull Welding;* and **D3.9,** *Specification for Classification of Weld-Through Paint Primers.* Contact B. McGrath, *bmcgrath@aws.org,* ext. 311.

Mechanical Testing of Welds

The B4 Committee for Mechanical Testing of Welds to contribute to **B4.0,** *Standard Methods for Mechanical Testing of Welds.* Contact B. McGrath, *bmcgrath@aws.org,* ext. 311.

Surfacing Industrial Mill Rolls

D14H Subcommittee on Surfacing and Reconditioning of Industrial Mill Rolls to revise **AWS D14.7,** *Recommended Practices for Surfacing and Reconditioning of Industrial Mill Rolls.* Contact M. Rubin, *mrubin@aws.org*, ext. 215.

Magnesium Alloy Filler Metals

A5L Subcommittee on Magnesium Alloy Filler Metals to assist in the updating of **AWS A5.19-92 (R2006),** *Specification for Magnesium Alloy Welding Electrodes and Rods.* Contact R. Gupta, *gupta@aws.org,* ext. 301.

Robotic and Automatic Welding

D16 Committee on Robotic and Automatic Welding to update **D16.1,** *Specification for Robotic Arc Welding Safety;* **D16.2,** *Guide for Components of Robotic and Automatic Arc Welding Installations;* **D16.3,** *Risk Assessment Guide for Robotic Arc Welding;* **D16.4,** *Specification for Qualification of Robotic Arc Welding Personnel.* Contact M. Rubin, *mrubin@aws.org*, ext. 215.

Thermal Spraying

C2 Committee on Thermal Spraying to update **C2.16,** *Guide for Thermal Spray Operator Qualification*; **C2.18,** *Guide for the Protection of Steel with Thermal Sprayed Coatings of Aluminum and Zinc and Their Alloys and Composites;* **C2.19,** *Machine Element Repair*; **C2.23,** *Specification for the Application of Thermal Spray Coatings (Metallizing) of Aluminum, Zinc, and Their Alloys and Composites for the Corrosion Protection of Steel.* Contact J. Gayler, *gayler@aws.org*, ext. 472.

Labeling and Safe Practices

SH4 Subcommittee on Labeling and Safe Practices to update **AWS F2.2,** *Lens Shade Selector;* **AWS F4.1,** *Safe Practices for the Preparation of Containers and Piping for Welding and Cutting;* and the AWS *Safety and Health Fact Sheets.* S. Hedrick, *steveh@aws.org*, ext. 305.

How to Order *Journal* Article Reprints and AWS Publications

To order custom reprints of *Welding Journal* articles in quantities of 100 or more, or electronic posting of articles, contact Rhonda Brown, Foster Printing Services, *rhondab@foster-printing.com;* (866) 879-9144, ext. 194; *www.marketingreprints.com.*

To order individual copies of *Welding Journal* articles, contact Edalia Suarez, *suarez@aws.org,* or Ruben Lara, *rlara@aws.org.*

To order AWS standards, books, and other publications, contact WEX (World Engineering Xchange), *www.awspubs.com*; call toll-free in the United States (888) 935-3464; elsewhere call (305) 826-6192; or FAX (305) 826-6195.

Member-Get-A-Member Campaign

Listed below are the February 17, 2011, standings of the members participating in the 2010–2011 Member-Get-A-Member Campaign. For complete campaign rules and prize list, see page 69 of this *Welding Journal,* or visit *www.aws.org/mgm.* Call the Membership Department, (800) 443-9353, ext. 480, for questions concerning your member-proposer status.

Winner's Circle

AWS Members who have sponsored 20 or more new Individual Members, per year, since June 1, 1999. The superscript denotes the number of years the member earned Winner's Circle status, if more than once.

J. Compton, San Fernando Valley[7]
E. Ezell, Mobile[7]
J. Merzthal, Peru[2]
G. Taylor, Pascagoula[2]
L. Taylor, Pascagoula[2]
B. Chin, Auburn
S. Esders, Detroit
M. Haggard, Inland Empire
M. Karagoulis, Detroit
S. McGill, NE Tennessee
B. Mikeska, Houston
W. Shreve, Fox Valley
T. Weaver, Johnstown/Altoona
G. Woomer, Johnstown/Altoona
R. Wray, Nebraska

President's Roundtable

Sponsored 9–19 new members

E. Ezell, Mobile — 23
G. Kirk, Pittsburgh — 17
M. Pelegrino, Chicago — 9

President's Club

Sponsored 3–8 new members

M. Tryon, Utah — 8
T. Crate, Drake Well — 7
J. Daubert, Northern New York — 6
R. Dawson, Western Carolina — 4
J. Dolan, New Jersey — 4
J. Hope, Puget Sound — 4
J. Hopwood, Iowa — 4
D. Steyer, Niagara Frontier — 4
D. Wright, Kansas City — 4
G. Bish, Atlanta — 3
H. Cable, Pittsburgh — 3
C. Crumpton, Florida W. Coast — 3
R. Ellenbecker, Fox Valley — 3
M. Haggard, Inland Empire — 3
D. McQuaid, Pittsburgh — 3
F. Oravets, Inland Empire — 3
W. Sartin, Long Bch./Or. Cty. — 3
G. Seese, Johnstown-Altoona — 3
W. Sturge, New York — 3

President's Honor Roll

Sponsored 2 new members

M. Allen, Charlotte
D. Berger, New Orleans
J. Carney, West Michigan
R. Fuller, Florida W. Coast
G. Hamilton, Houston
J. Hill, Nebraska
A. Holt, St. Louis
J. Kline, Northern New York
A. Laabs, Lakeshore
F. Nguni, New Jersey
T. Palmer, Columbia
W. Wall, Auburn
D. Wantz, York-Central Pa.
G. Watry, Houston
S. Witkowski, Madison-Beloit

Student Sponsors

Sponsored 3+ Student Members

M. Pelegrino, Chicago — 69
G. Bish, Atlanta — 50
G. Seese, Johnstown-Altoona — 36
D. Saunders, Lakeshore — 31
R. Culbert, Inland Empire — 28
M. Anderson, Indiana — 27
D. Berger, New Orleans — 27
J. Carney, West Michigan — 27
M. Boggs, Stark Central — 25
G. Gammill, NE Mississippi — 25
G. Kirk, Pittsburgh — 24
H. Browne, New Jersey — 24
S. Siviski, Maine — 22
A. Reis, Pittsburgh — 21
V. Facchiano, Lehigh Valley — 20
M. Haggard, Spokane — 20
B. Scherer, Cincinnati — 20
A. Baughman, Stark Central — 19
G. Smith, Lehigh Valley — 19
E. Norman, Ozark — 18
A. Syder, Spokane — 18
J. Bruskotter, New Orleans — 17
T. Buchanan, Mid-Ohio Valley — 17
K. Cox, Palm Beach — 17
S. Robeson, Cumberland Valley — 17
D. Schnalzer, Lehigh Valley — 17
H. Hughes, Mahoning Valley — 16
F. Oravets, Pittsburgh — 16
T. Crate, Drake Well — 15
C. Hobson, Olympic Section — 15
T. Shirk, Tidewater — 15
R. Evans, Siouxland — 14
K. Karwoski, Racine-Kenosha — 14
C. Schiner, Wyoming Section — 14
M. Arand, Louisville — 13
W. Davis, Syracuse — 13
C. Donnell, Northwest Ohio — 13
G. Watry, Houston — 13
R. Boyer, Nevada — 12
J. Daughtery, Louisville — 12
J. Goodson, New Orleans — 12
R. Wahrman, Triangle — 12
D. Zabel, Southeast Nebraska — 12
J. Boyer, Lancaster — 11
D. Porter, Nashville — 11
D. Wright, Kansas City — 10
R. Young, Iowa — 10
A. Badeaux, Washington, D.C. — 9
J. Ciaramitaro, N. Central Florida — 9
C. Renfro, Chattanooga — 9
S. Ulrich, St. Louis — 9
C. Kipp, Lehigh Valley — 8
T. Moore, New Orleans — 8
W. Wilson, New Orleans — 8
R. Belluzzi, New York — 7
R. Hutchinson, Long Bch./Or. Cty. — 7
D. Ketler, Willamette Valley — 7
J. Kline, Northern New York — 7
T. Palmer, Columbia — 7
G. Siepert, Kansas — 7
A. Duron, New Orleans — 6
J. Johnson, Madison-Beloit — 6
J. Gerdin, Northwest — 5
T. Green, Central Arkansas — 5
D. Kowalski, Pittsburgh — 5
J. Meyer, San Francisco — 5
T. Smeltzer, San Francisco — 5
B. Suckow, Northern Plains — 5
B. Benyon, Drake Well — 4
S. Colton, Arizona — 4
W. Galvery, Long Bch./Or. Cty. — 4
A. Holt, St. Louis — 4
S. Mackenzie, Northern Michigan — 4
C. Warren, N. Central Florida — 4
D. Aragon, Puget Sound — 3
R. Bass, Tulsa — 3
R. Chase, L.A./Inland Empire — 3
B. Clark, Iowa — 3
R. Harris, Spokane — 3
R. Hilty, Pittsburgh — 3
C. Lindquist, Central Michigan — 3
S. Miner, San Francisco — 3
J. Morash, Boston — 3
F. Pruitt, Greater Hunts — 3
G. Rolla, L.A./Inland Empire — 3
J. Seitzer, York-Central Pa. — 3
J. Sullivan, Mobile — 3
B. Wenzel, Sacramento — 3

Nominations Sought for the M.I.T. Prof. Masubuchi Award

The deadline for submitting nominations for the 2012 Prof. Koichi Masubuchi Award is Nov. 2, 2011. Sponsored by the Dept. of Ocean Engineering at Massachusetts Institute of Technology (M.I.T.), this award includes a $5000 honorarium. It is presented each year to one person, 40 years old or younger, who has made significant contributions to the advancement of materials joining through research and development.

Nominations should include the candidate's experience, publications, honors, and awards, and at least three letters of recommendation from fellow researchers. E-mail your nomination package to Todd A. Palmer, assistant professor, The Pennsylvania State University, *tap103@psu.edu.*

First AWS ATF Certified Welder Program Established in Taiwan

The first Taiwan AWS Authorized Testing Facility (ATF) was audited and officially accredited in January. The achievement was a collaborative effort between the International Welding Technology Research Laboratory (IWTRL), the AWS International Agent for Taiwan (Taipei), led by Dr. Chon L. Tsai, with Lockheed Martin Missile and Fire Controls USA, and Chenfull International, Inc., Taichung, Taiwan. The project was initiated in October 2010 to establish and implement the AWS ATF Certified Welder (CW) program, the first of its kind to be conducted in Taiwan. The plan was to have all welding by Chenfull be performed only by AWS CWs and the facility accredited as an AWS ATF in the December 2010 to January 2011 timeframe. IWTRL, along with Construction Technical Services, Inc. (CTSI), Houston, Tex., worked closely with Chenfull and IWTRL during this period to meet this schedule.

"The facility performed equal to and in some cases exceptionally better than many companies I have consulted with over the years," said Steven Snyder, CTSI consultant, and an AWS Senior Certified Welding Inspector and Certified Welding Educator, and an ASQ Certified Quality Auditor. "Their ability to understand and follow detailed procedures and work instructions was remarkable during all phases of the consulting." The AWS ATF CW Program will set the standard for welder qualification for the Lockheed Martin project work with the use of AWS D17.1 and will be key for Chenfull International to expand and advance its component fabrication and processing capabilities.

David Diaz, AWS lead auditor, speaks to the test supervisor, quality engineer, and a welder at Chenfull International, Inc., during the AWS Accredited Test Facility audit.

The new ATF is especially valuable because the aerospace manufacturing and fabrication industry has many challenging and demanding welding applications and requirements for various aircraft, ground support, and related components. The welding must be performed by qualified welders and operators. Having assurance that the welding personnel are appropriately qualified and that the welding qualification process itself is stringently conducted from initiation to completion is of key importance to the manufacturers and prime suppliers of these components. Knowing that a qualified welding test supervisor with AWS Certified Welding Inspector credentials administered, controlled, and documented the entire process, provides that assurance. The AWS Authorized Testing Facility (ATF) program offers significant recognition to facilities that can meet the AWS QC4-89 and QC7-93 standards and supplemental requirements, as it has done for more than 22 years.

Sperko Details ASME Section IX during India Lecture Tour

Walter J. Sperko, chairman, ASME Section IX Committee, and president of Sperko Engineering Services, Inc., Greensboro, N.C., was the featured speaker for the AWS Lecture Series V. The tour, held Sept. 3–11 under the aegis of IIW-India, included seven cities across the country.

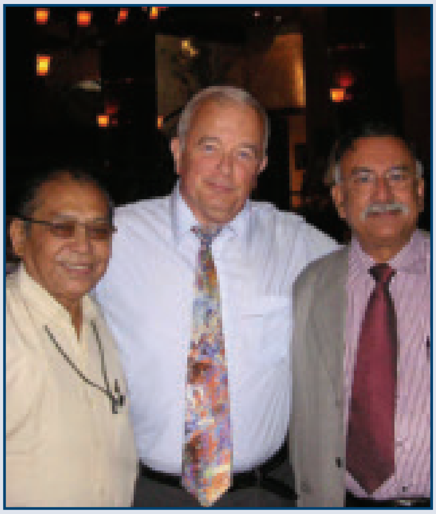
Sperko presented his lecture, *The Secrets to Using ASME Section IX*, in New Delhi, Calcutta, Chennai, Pune, Mumbai, Surat, and Baroda to a total audience of about 650 welding engineers and manufacturing specialists.

Understanding the ASME code is one of the most important subjects to the Indian fabrication and construction industries to enable them to compete in the world marketplace. Through this ongoing series of lectures, The Indian Institute of Welding and the American Welding Society promote and exchange technology and know-how related to welding and joining of metals.

Sperko's information was found to be extremely useful by the audience who asked numerous questions to clarify details about the code. Following the presentation, each attendee received a CD and hard copy of the lecture materials.

Sperko concluded the lecture tour was rewarding to him, and "I'm sure it spread goodwill among the welding community in India." The schedule was "a forced march," leaving little free time, but while in Pune, Sperko toured Larsen and Toubro, an ASME Section VIII Div. 1, Div. 2, and N-stamp shop in the process of building 16-ft-diameter, 8-in.-thick Cr-Mo-V vessels for Exxon and nuclear vessels for installation in India.

Sperko is indebted to **Narmail K. Sarkar** of IIW-India, a retired chief metallurgist with the Indian Railway, who coordinated his travel arrangements and accompanied him as a personal guide for his entire stay in India.



Walter Sperko (center) chats with his guide, Narmail Sarkar (left), and N. Kalyan, director of ELCA Laboratories, during his India tour. Photo taken by Chander Girotra.

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Newport News, VA 23612

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Kuo Chung 1st Rd.
Dali, Taichung 412, Taiwan

Worton Mfg. Co., Ltd.
355 Signet Dr.
Toronto, ON M9L 1V3, Canada

Educational Institutions

Adult Evening Technical Center
2020 Westwood Ave.
Richmond, VA 23230

Bradley Central High School
1000 S. Lee Hwy., Cleveland, TN 37311

Floyd County Area Technology Center
1024 KY Rte. 122, Martin, KY 41649

GLOMACS
Office No. 108, Bk. No. 02-B, 1st Fl.
Dubai Knowledge Village
Dubai 87079, UAE

Kentucky Tech Clay Co. ATC
1097 N. Hwy. 11
Manchester, KY 40962

Merrill Institute of Welding
520 Republic Ave.
Alma, MI 48801

Montgomery County ATC
682 Woodford Dr.
Mt. Sterling, KY 40353

Muskegon Area Career Tech Center
200 Harvey St.
Muskegon, MI 49442

Needville High School
16319 Hwy. 36, PO Box 412
Needville, TX 77461

Universidad Tecnológica de Pereira
Vereda La Julita, Pereira
Risaralda, Colombia

AWS Member Counts

March 1, 2011

Grades

Sustaining	509
Supporting	303
Educational	561
Affiliate	463
Welding Distributor	46
Total Corporate	**1,882**
Individual	56,205
Student + Transitional	10,589
Total Members	**66,794**

Honorary Meritorious Awards

The deadline for submitting candidates for these awards is December 31 prior to the year of the awards presentations. Send candidate materials to Wendy Sue Reeve, *wreeve@aws.org;* 550 NW LeJeune Rd., Miami, FL 33126.

William Irrgang Memorial Award

This award is given to the individual who has done the most over the past five years to enhance the Society's goal of advancing the science and technology of welding. It includes a $2500 honorarium and a certificate.

National Meritorious Certificate Award

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

George E. Willis Award

This award is given an individual who promoted the advancement of welding internationally by fostering cooperative participation in technology transfer, standards rationalization, and promotion of industrial goodwill. It includes a $2500 honorarium.

Honorary Membership Award

This award acknowledges eminence in the welding profession, or one who is credited with exceptional accomplishments in the development of the welding art. Honorary Members have full rights of membership.

International Meritorious Certificate Award

This honor recognizes recipients' significant contributions to the welding industry for service to the international welding community in the broadest terms. The award consists of a certificate and a one-year AWS membership.

SECTION NEWS

Southern Maine C.C. students and Maine Section members are shown at the vendors' night program.

District 1

Thomas Ferri, director
(508) 527-1884
thomas_ferri@thermadyne.com

BOSTON-CENTRAL MASS.-RHODE ISLAND

FEBRUARY 10

Activity: Members of the three Sections met in New Bedford, Mass., for a vendors' night and equipment expo held at New Bedford Regional Vocational School. The vendors included Thermadyne, Lincoln, Mekrut Sales, Weld Tooling, Bullard Abrasives, New Bedford Welding Supply, Mid City Steel, Camel Grinding Wheels, BFD Co., Hougen Drill, Kalamazoo Saws, Pferd Abrasives, and Total Welding Supply. Students from the Greater New Bedford and Rochester Technical Schools brought the total attendance to more than 100. The Greater New Bedford culinary arts department provided the refreshments.

A few of the attendees are shown at the vendors' night program held by the Boston, Central Massachusetts, and Rhode Island Sections.

MAINE

JANUARY 27

Activity: **Mark Legel,** a CWI and head instructor at Southern Maine Community College, coordinated the 6th annual vendors' night at the college to expose his students and Section members to the latest welding-related technology. Participating this year were Advantage Gases, Airgas, ESAB, Hypertherm, Lincoln Electric, Miller Electric, and Thermadyne. **Russ Norris** was presented the District 1 Director's Award for his tireless services over the years.

Mark Legel (left) is congratulated for a job well done by Tom Ferri, District 1 director, at the Maine Section vendors' night.

Russ Norris (left) is shown with Tom Ferri, District 1 director, at the Maine Section event.

District 2

Harland W. Thompson, director
(631) 546-2903
harland.w.thompson@us.ul.com

Shown at the York-Central Pa. Section program are (from left) Vice Chair Mike Fink, speaker Randall Leaman, and Chair Jim Henry.

Shown at the Southwest Virginia Section program are Treasurer David Cash (center) with speakers Paul Cseko (left) and Jim Wynegar.

Speaker Brad Bornstein (left) is shown with Ken Temme, Philadelphia Section vice chair.

Shown are speaker Thomas Burns (left) and Paul Hebert, Tidewater Section chair.

PHILADELPHIA

February 9
Speaker: **Brad Bornstein,** technical sales representative
Affiliation: Olympus NDT
Topic: Ultrasound and phased array theory and equipment for nondestructive testing
Activity: The program was held at Villari's Restaurant in Sicklerville, N.J.

District 3

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

YORK-CENTRAL PA.

February 3
Speaker: **Randall Leaman,** secretary and treasurer
Affiliation: Airborne Contamination Identification Associates
Topic: How to comply with OSHA's regulations on chemical and welding fumes
Activity: The program was held at Heritage Hills Conference Center in York, Pa.

District 4

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

SOUTHWEST VIRGINIA

February 17
Speakers: **Jim Wynegar** and **Paul Cseko,** regional account manager and district manager, respectively
Affiliation: Miller Electric Co.
Topic: Advanced manufacturing systems
Activity: The program was held in Salem, Va.

TIDEWATER

February 10
Speaker: **Thomas Burns,** director of technical services
Affiliation: Alcotec Wire Corp.
Topic: Welding aluminum
Activity: District 4 Director **Roy Lanier** attended the program, held at Peking International Buffet in Hampton, Va.

District 5

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

ATLANTA

January 26
Activity: The Section members met at Applied Technical Services in Marietta, Ga., to tour the facilities and study its failure analysis and weld-testing methods. Conducting the tour were **Jason Loy,** senior material testing engineer; and **Burak Akyuz,** a metallurgist. Loy spoke about welding testing procedures equipment. Akyuz discussed metallurgy and failure analysis techniques.

February 8
Activity: The Atlanta Section members met at the Lincoln Electric training facility in Lithia Springs, Ga., for a tour and demonstration of the VRTEX® 360 virtual reality arc welding trainer. **Russell Farrar** conducted the program and instructed the Section members on using VR equipment.

FLORIDA WEST COAST

February 9
Activity: The Section members toured Tampa Tank, Inc., Florida Structural Steel Fabrication Facility in Tampa, Fla. Leading the activity were **David Hale,** fabrication/erection president of Tampa Tank, and **Dale Inson,** manufacturing/QA manager. More than 50 members and students participated in the event that concluded with a barbecue dinner.

NORTH CENTRAL FLORIDA

February 8

Florida West Coast Section members are shown during their tour of Tampa Tank, Inc.

Rick Montana (left) and William Seyfarth display their awards at the North Central Florida Section program.

Speaker: **Michael Bannester** (ret.)
Affiliation: Central Florida College, welding instructor
Topic: How to obtain welding scholarships
Activity: District 5 Director **Steve Mattson** presented the District Educator of the Year Award to **Rick Montana,** a welding instructor at Mid-Florida Tech in Orlando. The District Meritorious Award was presented to **William Seyfarth,** owner of Weldtest Services and long-time Section treasurer.

SOUTH CAROLINA

JANUARY 20
Speaker: **Danny Sechler,** power generation weld specialist
Affiliation: The Lincoln Electric Co.
Topic: Welder training for the nuclear power industry
Activity: This program was held at B&D Boilers in North Charleston, S.C. Following the talk, the attendees toured the facility to study its operations.

Shown at the January Atlanta Section program are (from left) presenters Burak Akyuz and Jason Loy with Chair David Ennis and Carl Matricardi, deputy District 5 director.

Presenter Russell Farrar (left) is shown with Atlanta Section Chair David Ennis (center) and Carl Matricardi, deputy District 5 director, at the February program.

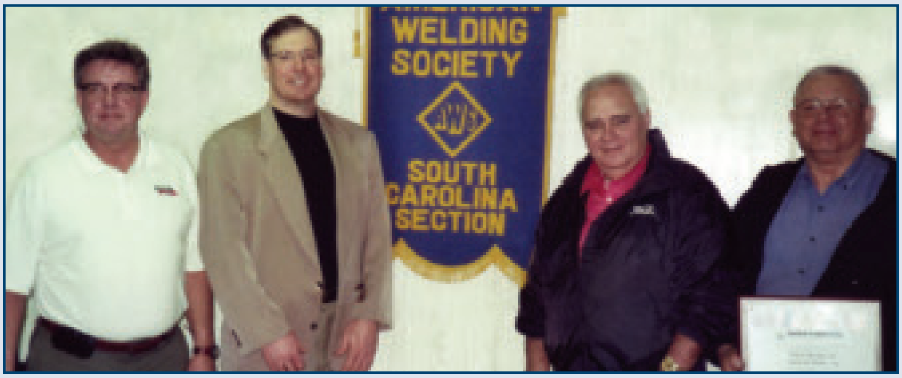
Shown at the Florida West Coast Section tour are (from left) David Hale, Vice Chair Damen Johnson, and Dale Inson.

District 6

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

Niagara Frontier Section members are shown at the October program.

Gale Mole (front, far right), South Carolina Section chair, is shown with B&D Boilers employees in January.



Shown at the South Carolina section program are (from left) speaker Danny Sechler, Toby Kearney, Chair Gale Mole, and Charles Dunning.

Niagara Frontier Section Chair Paul Swatland (left) is shown with speaker Ron Stahura.

Bill Davis (right) received the District and Section CWI of the Year Awards from Ken Phy, District 6 director, at the Syracuse event.

Paul Shields discussed oxyfuel safety at the Pittsburgh Section program.

NIAGARA FRONTIER

OCTOBER 28
Speaker: **Ron Stahura**
Affiliation: Quality Technical Training Institute
Topic: What you need to know about welding stainless steel

NORTHERN NEW YORK

FEBRUARY 8
Speaker: **Ronald J. Parrington,** president
Affiliation: IMR Test Labs
Topic: Failure analysis of welds
Activity: The meeting included members of the Eastern New York Chapter of ASM International. The event was held at Mill Road Restaurant in Latham, N.Y.

SYRACUSE

FEBRUARY 9
Speaker: **Burrell Fisher,** PE
Topic: Welding, its use and control
Activity: District 6 Director **Ken Phy** presented the District Dalton E. Hamilton CWI of the Year Award to **Bill Davis,** and the Section CWI of the Year Award to **Bill Davis, Bob Davis,** and **Vince Carnifax. Tom Bryant** and **Tim Howell** received the Section Educator Award. **Neal Chapman** received the District Meritorious Award.

The Pittsburgh Section members are shown at the January 15 program.

The Northeast Mississippi Section members toured Sly, Inc., in January.

District 7

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

PITTSBURGH

JANUARY 15
Activity: The members met at Steamfitters Local 449 class room facilties for a presentation by **Paul Shields,** regional manager, The Harris Products Group. He displayed samples of cylinders and cutting torch heads damaged by improper use. He then gave a hands-on demonstration of the proper use and care of oxyfuel and gas cutting equipment. The dinner was held at La Mont Restaurant in Pittsburgh, Pa.

JANUARY 20
Activity: The Pittsburgh Section Technical Advisory Committee members met to prepare for attending the AWS Technical Activities Meeting held at NASA's Kennedy Space Center in Cape Canaveral, Fla. The representatives included **Ed Yevick, Jim Sekely,** and **Larry Schweinegruber.**

District 8

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

NORTHEAST MISSISSIPPI

JANUARY 20
Activity: The Section members toured Sly, Inc., in Mathiston, Miss., to study the manufacture of dust collectors and other air-pollution-control equipment. **Kevin Reed,** plant manager, conducted the program.

Michael Callahan (right) is shown with Davis Rayburn, Baton Rouge Section chair.

District 9

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

BATON ROUGE

JANUARY 20
Speakers: **Jason Lange, Michael Callahan**
Affiliation: The Lincoln Electric Co.
Topic: Welding fume regulations
Activity: The program was hosted by Lincoln Electric at Mestizo Louisiana Mexican Restaurant in Baton Rouge, La.

NEW ORLEANS

JANUARY 25
Speaker: **Jimmy Cochran**
Affiliation: Kiewit Industries
Topic: The Huey P. Long Bridge expansion
Activity: The program was sponsored by Inspection Specialists, Inc., represented by **Travis Moore** and **Melissa Wainwright.** Attending were 65 members and guests, including 35 students. District 9 Director **George Fairbanks** attended the program, held at Cafe Hope in Marrero, La.

Shown at the Pittsburgh Section technical committee meeting are (from left) Ed Yevick, Jim Sekely, and Larry Schweinegruber.

Baton Rouge Section Chair Davis Rayburn (left) presents a speaker gift to Jason Lange.

Shown (from right) are New Orleans Section Chair D. J. Berger and District 9 Director George Fairbanks presenting a sponsor-appreciation plaque to Melissa Wainwright and Travis Moore.

Drake Well Section Chair Mike Owens (left) is shown with District 10 Director Richard Harris (center) and Secretary Travis Crate.

District 9 Director George Fairbanks (left) and speaker Jimmy Cochran are shown at the New Orleans Section event.

Life Member Patsy Pilorusso (right) is shown with Kenny Jones, Mahoning Valley Section chair.

Shown at the Mahoning Valley Section program are (from left) speaker Steve Kusik, Ironworker Mike Sampson, District 10 Director Rich Harris, and Chair Kenny Jones.

District 10

Richard A. Harris, director
(440) 338-5921
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DRAKE WELL

February 8
Speaker: **Richard Harris,** District 10 director
Topic: Update on national AWS activities
Activity: Harris presented Secretary **Travis Crate** the District Private Sector Instructor Award and Chair **Mike Owens** the District Director Award. The program was held at The Commons in Franklin, Pa. Attending were **Don Rog, Dan Bubenheime, Rolf Laemmer, Tyler Bubenheim, Jacob Roxberry, Adam Baughman, Bill Henderson, Issac Seniour, Jason Cacherl, Don Adams, Jason Adams, Travis Corbett,** and **Gary Riddle.**

MAHONING VALLEY

February 17
Speaker: **Steve Kusik**
Affiliation: Stud Welding Associates
Topic: Short cycle gas arc stud welding
Activity: District 10 Director **Rich Harris** presented Chairman **Kenny Jones** and **Chuck Moore** the District Director Certificate Award, **Michael Sampson** the Dalton E. Hamilton Memorial CWI of the Year Award, and **Dave Hughes** the Section Meritorious Award. **Patsy Pilorusso** received his Life Membership Certificate for 35 years of service to the Society. The event was hosted by Ironworkers Local #207 in Boardman, Ohio.

District 11

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DETROIT

February 10
Speaker: **Reno Boilard,** director of marketing
Affiliation: Welding Technology Corp.
Topic: Welding automation
Activity: The annual patron's night program was held at Welding Technology Corp. in Farmington Hills, Mich. Twenty-five companies and individuals were presented certificates in recognition of their support for the Section's activities.

NORTHWEST OHIO

January 26
Activity: The Section members met at ARC Services, Inc., in Toledo, Ohio, for a tour of the facilities. Company owners **Christian** and **Kevin Baumberger** conducted the program. The company performs repairs on welding and cutting

Detroit Section patrons display their certificates at the February program.

equipment manufactured by various companies, and offers training and certifications for many welding procedures.

District 12

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MILWAUKEE

JANUARY 20
Speaker: **Randall Counselman,** CWE
Affiliation: Oldenburg Group, Inc.
Topic: Weld procedure and welder performance qualifications, AWS D1.1 code changes, and differences among the various AWS, ISO, API, and ASME Section IX codes
Activity: The program was held in Milwaukee, Wis., for 70 attendees

District 13

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CHICAGO

JANUARY 26
Activity: The board members met at Papa Passero's Restaurant in Chicago, Ill. **Eric Purkey** was named to update the Section's Web site. **Pete Host** and **Craig Tichelar** were nominated for the National Educator of the Year Award. Others attending the program were Chair **Chuck Hubbard, Bob Zimny, Jeff Stanczak, Marty Vondra, Eric Krauss,** and **Cliff Iftimie.**

District 14

Robert L. Richwine, director
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bobrichwine@aol.com

INDIANA

JANUARY 26
Speaker: **Tom MacCormick,** regional sales manager
Affiliation: SAIT, United Abrasives, Inc.
Topic: Manufacturing and safety of SAIT grinding wheels
Activity: Following the talk, the attendees tried their hand at using various types of grinding wheels on different metals. The program was held at Indiana Oxygen in Indianapolis, Ind.

Tom MacCormick demonstrates grinding techniques for Indiana Section members.

Mike Palko (left), Detroit Section program chair, chats with speaker Reno Boilard.

Shown at the Milwaukee Section program are (from left) Bob Bruss, Chair Karen Gilgenbach, speaker Randall Counselman, Bob Dricken, Sue Silverstien, Nate Leszewski, and Anni VanDyke.

The Chicago Section members are (from left) Eric Purkey, Bob Zimny, Craig Tichelar, Jeff Stanczak, Marty Vondra, Pete Host, Chair Chuck Hubbard, Eric Krauss, and Cliff Iftimie.

St. Louis Section members pose at the February tour of Ameren Missouri.

Kansas Section bowlers take a break during the January fund-raising event.

St. Louis Section Chair Victor Shorkey (center) is shown with presenters Steve Zaitz (left) and Laurie Kutz.

Butch Wagner discussed metal cored wires at the Indiana Section February event.

FEBRUARY 9
Speaker: **Butch Wagner**
Affiliation: Hobart Brothers
Topic: Metal cored gas shielded wires
Activity: This Indiana Section program was held at J. Everett Light Career Center in Indianapolis, Ind.

ST. LOUIS

FEBRUARY 17
Activity: The members toured the Ameren Missouri power operations services training center in St. Louis, Mo. **Laurie Kutz,** senior training supervisor, and **Steve Zaitz,** training supervisor, led the tour.

District 15

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District 16

David Landon, director
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KANSAS

JANUARY 22
Activity: The Section held its second annual bowling tournament fund-raiser to benefit its scholarship program. Fourteen teams participated in the Scotch doubles, 9-pin No-Tap event. The door prizes were donated by Thermadyne Industries, Airgas Mid South, Matheson Tri-Gas, Lampton Welding, and Rubbermaid, Inc.

FEBRUARY 10
Activity: The Section members toured Globe Engineering Co. in Wichita, Kan., to study its methods for fabricating precision sheet metal parts and assemblies for the aerospace industry.

KANSAS CITY

FEBRUARY 10

Kansas Section members are shown during their tour of Globe Engineering in February.

Speaker Michael Turner (white shirt) is shown with members of the Kansas City Section.

Speaker: **Michael Turner,** PE
Affiliation: Olympus NDT
Topic: Ultrasonic testing and demonstration
Activity: The program was held at Johnny C's Restaurant in Kansas City, Mo.

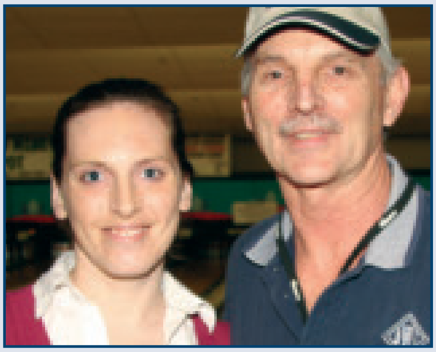

The Nebraska Section members are shown at their bowling and fund-raising event.

NEBRASKA

JANUARY 22
Activity: The held its 5th annual bowling outing and silent auction fund-raising event to benefit the Section's scholarship fund. **Melissa Wager** received a scholarship to continue her studies at Metropolitan C.C. The top bowlers included Praxair's **Joe Pensick** and **Gary Barnes,** and Ironworkers Local #1 workers **Jim Huettner, Bob Peck, Mike Lincoln,** and **Ryan Mehser.**

FEBRUARY 17
Speaker: **Scott Blankman**
Affiliation: Praxair Distribution
Topic: The effects of overwelding
Activity: This Nebraska Section program was held in Omaha, Neb.


Speaker Scott Blankman (left) is shown with Jason Hill, Nebraska Section vice chair.


Scholarship winner Melissa Wager is shown with Monty Rodgers, Nebraska Section chair.

The Nebraska Section members are shown at the February meeting.

Corpus Christi Section Chair Misty Ralls receives an award from John Bray, District 18 director.

Welding instructor Dan Jones (left) is shown with John Bray, District 18 director, at the Houston Section program.

CWI Awardee Richard Marslender (left) is shown with John Bray, District 18 director, at the Corpus Christi event.

Speaker Bryan Willingham (right) chats with John Husfeld, Houston Section chair.

Anne Matula receives her award from John Bray, District 18 director, at the Corpus Christi program.

Sculptor Rick Davis (right) chats with Art Sabiston at the Spokane Section event.

District 17

J. Jones, director
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jjones@thermadyne.com

EAST TEXAS

FEBRUARY 3
Speaker: **J. Jones,** District 17 director
Affiliation: Thermal Dynamics
Topic: Automated plasma arc cutting with demonstration
Activity: The program was held at Tyler Jr. College in Tyler, Tex.

District 18

John Bray, director
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CORPUS CHRISTI

DECEMBER 9
Activity: The Section held its Christmas party and awards-presentation meeting at Radisson Beach Hotel in Corpus Christi, Tex. **Misty Ralls** received the District Meritorious Award. **James Bryant** and **Jim Miller** received Section Meritorious Awards, **Rick Ford** and **Anne Matula** received Instructor of the Year awards, **Ellery Francisco** and **Richard Marslender** received CWI of the Year Awards, and **J. W. Ralls** received the District Director Award.

HOUSTON

DECEMBER 7
Activity: The Section members participated in an open house at the Technical Educational Center in Sugar Land, Tex., coordinated by **Dan Jones,** a welding instructor at Fort Bend ISD Technical Education Center. The students demonstrated their welding and cutting skills for the attendees. District 18 Director **John Bray** made a presentation on the advantages of membership in the American Welding Society.

Shown at the Albuquerque Section program are (from left) Director-at-Large Thomas Lienert, awardees Robert Ulibarri, Richard Moku, Kelly Bingham, and John Mendoza, AWS president.

FEBRUARY 16
Speaker: **Bryan Willingham,** consultant
Topic: Oxyfuel gases and safety
Activity: The Houston Section hosted its annual students' night program at Brady's Landing in Houston, Tex., for 152 attendees, including 75 students. District 18 director **John Bray** presented awards to the winners of the District Skills Contest. The Level 1 award was presented to **Ryan Plaisance,** and **Erick Mata** received the Level 2 award. Both students attend L. P. Card Skill Center.

District 19

Neil Shannon, director
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neilshnn@msn.com

SPOKANE

FEBRUARY 16
Speaker: **Rick Davis,** sculptor
Topic: Art work presentation
Activity: This ladies' night event was held at Luigi's Italian Restaurant in Spokane, Wash. Davis, who first learned to weld at age 12, entertained with a presentation detailing some of his metal sculptures.

District 20

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bkoz@arctechllc.com

ALBUQUERQUE

JANUARY 26
Speaker: **John Mendoza,** AWS president
Affiliation: Lone Star Welding
Topic: The value of AWS certifications
Activity: The event was held at Central New Mexico Community College in Albuquerque, N.Mex., for the students and Section members. **Thomas Lienert,** an AWS director-at-large, spoke to the student on AWS scholarships and how to complete the application process. **Robert Ulibarri** received the Section Educator of the Year Award, **Richard Moku** was presented the District 20 Meritorious Certificate Award, and **Kelly Bingham** received his Silver Member Certificate for 25 years of service to the Society.

COLORADO

JANUARY 13
Activity: The Section members met at Warren Tech Center in Lakewood, Colo., for a presentation and demonstration of root pass welding on pipe by **Mark Trevithick,** a welding inspector and instructor at the facility. His topics included pipe joint design, preparation, fitup, and welding procedure and inspection of the root pass.

Shown at the Colorado Section program are presenter Mark Trevithick (left) and Treasurer Tom Kienbaum.

District 21

Nanette Samanich, director
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AWCIWT Student Chapter

NOVEMBER 18
Activity: The Student Chapter members participated in their Arizona Western College Institute of Welding Technology's (AWCIWT) annual family night program. They manned a booth, distributed welding information booklets, set up several pieces of welding equipment, and answered questions from attendees about choosing welding for a career. Supporting the students were **Chuck Taber** from Miller Electric and **David Sanchez,** an AWS CWI and CWE, and president of Arc Dynamics based in Yuma, Ariz.

Shown at the Southern Nevada SkillsUSA competition are from left (standing) Jason Perez, Dale Stubblefield, District 21 Director Nanette Samanich, John Webb, Bob Nard, Al Fernandez, Jim Alsup, and Noah McKnight; (front) Jose Velasquez and Michael Rumble.

Shown at the Sierra Nevada Section meeting are (from left) Nick Howden-Dougherty, Mike Damon, presenter Jason Grove, Scott Hanson, Korey Rich, Gaylord Rodeman, Eric McAuliffe, Scott Walsh, James Cooney, Robert Nicholls, and Dale Flood, District 22 director.

Shown at the San Francisco Section program are (from left) Vice Chair Elizabeth Moore, Chair Liisa Pine, and speaker David Bosko.

John Hurd (left) and Scott Swafford described the WyoTech auto technology programs for the Sacramento Section members.

The AWS Israel Section and The Israeli National Welding Committee members are shown at their annual welding conference.

NOVEMBER 18
Activity: The AWCIWT Student Chapter members participated in a hands-on seminar on using advanced pulsed gas metal arc technology for welding steel pipe. Leading the demonstrations was **Chuck Taber,** district manager, Miller Electric Co.

DECEMBER 3
Activity: The AWCIWT Student Chapter members met at Grand China Buffet in Yuma, Ariz., for the annual end-of-year social. Owner **Kevin Lee** is a Chapter supporter. **Samuel Colton,** Chapter advisor, addressed the students. He shared his experiences as a welding professional and founder of Welders without Borders, to encourage them to pursue careers in welding.

NEVADA

FEBRUARY 5
Activity: The Section members participated in the SkillsUSA Regional Southern Nevada welding competition. The event was held at Plumbers & Pipefitters UA Local 525 Welding Training Center in Las Vegas, Nev. The judges were provided by the training center. Participating was **Nanette Samanich,** District 21 director and a welding instructor at Desert Rose High School. **Jose Velasquez** won second place in the postsecondary class, and **Michael Rumble** took third place in the secondary class.

District 22

Dale Flood, director
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SACRAMENTO

NOVEMBER 18
Activity: The Section members met at WyoTech Sacramento Auto Technology Department to learn about its facilities and programs. Conducting the event were **John Hurd,** president, and **Scott Swafford,** coordinator for chassis fab and street rods.

SAN FRANCISCO

FEBRUARY 2
Speaker: **David Bosko,** project engineer
Affiliation: Intertech-APTECH
Topic: Pulsed eddy current inspection
Activity: The program was held at Spenger's Restaurant in Berkeley, Calif.

SIERRA NEVADA

DECEMBER 15
Activity: The Section members met at Jensen Precast in Sparks, Nev., for a plant tour. **Jason Grove,** production manager, discussed precast products and how welding and fabrication are applied. The tour included a demonstration of robotic welding of aluminum using a pulse on pulse process. **Dale Flood,** District 22 director, attended the program.

International Section

ISRAEL

JANUARY 26
Activity: The Israel Section and The Israeli National Welding Committee (INWC) held their annual welding conference for 250 attendees. Section Secretary **Chaim Daon** presented a report on the recent INWC annual conference. The subjects discussed at the joint conference were the globalization of welding standards and the differences between the American and European welding standards, welding aluminum, and nonwelding joining processes. Ten new Israeli Certified Welding Inspectors (ICWI) were presented their certificates, bringing to 70 the number of CWIs in the country. The ICWI program has a reciprocity agreement with AWS. The meeting was held in Herzliya, a city in the central coast of Israel, in the western part of the Tel Aviv district.

Guide to AWS Services

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Note: Official interpretations of AWS standards may be obtained only by sending a request in writing to Andrew R. Davis, managing director, Technical Services, adavis@aws.org. *Oral opinions on AWS standards may be rendered, however, oral opinions do not 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.*

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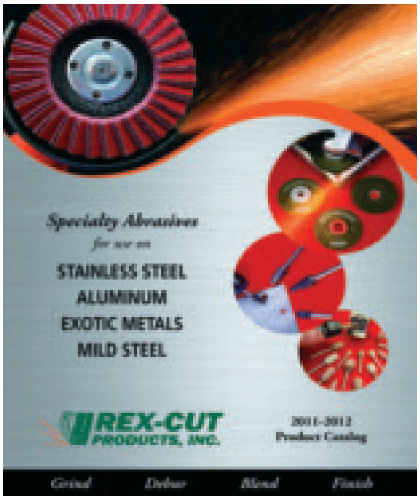
Specialty Abrasives Displayed in Catalog



The 2011–2012 *Specialty Abrasive Products Catalog* features a wide range of products including cotton fiber mounted points and wheels, Type 1 cotton fiber deburring and bench wheels, Type 1 unitized-, convolute-, and fiberglass-backed unitized wheels, interleaf flap discs, T27 cotton fiber grinding wheels, grinding wheels for stainless steel and aluminum, carbide burrs, quick-change discs, cut-off wheels, finishing sticks, and the new Smooth Touch™ blending and polishing wheels for stainless steel, aluminum, and exotic metals. Presented are complete specifications and recommended uses for each product and a guide for when to use specific types of products for heavy stock removal, light grinding, blending, finishing, and polishing. The catalog can be ordered by phone or downloaded from the Web site shown.

Rex-Cut Products, Inc.
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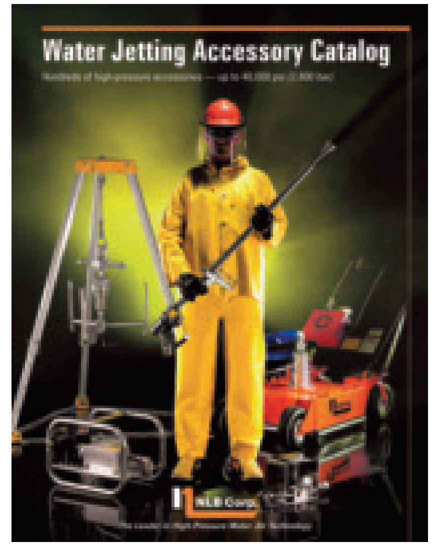
Water Jet Accessories Illustrated in Literature



A new 106-page *Water Jetting Accessory Catalog* illustrates and describes hundreds of high-pressure accessories in the company's complete line of water jet products that are rated to 40,000 lb/in.^{2}. Introduced are numerous products developed during the past two years, including the Typhoon™ self-rotating nozzles for tube cleaning, rotating line moles for pipe cleaning, a new automated system for heat-exchanger tube lancing, and 3-D tank cleaning heads and ultrahigh-pressure rotating heads. The accessories are specified for use in surface preparation, product removal, tank and tube bundle cleaning, pavement stripe and rubber removal, concrete hydrodemolition, and concrete and pipe cutting. The catalog can be ordered by phone or downloaded from the Web site shown.

NLB Corp.
www.nlbcorp.com
(248) 624-5555

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Instron®
www.instron.com
(800) 564-8378

Aluminum Statistical Review Issued

The company has released its annual key statistical publication, *2009 Aluminum Statistical Review.* It covers all statistical data available on the North American aluminum industry, including information on every cycle of the aluminum production process from primary aluminum to markets for finished goods to the recovery of aluminum scrap. This review is intended as an educational tool to support members of the industry, financial analysts, government agencies, students, and the general public. The document, in CD format, is divided into five sections: supply, shipments, markets, foreign trade, and world statistics. It includes text, tables, and charts to provide year-end figures and other historic data on United States and Canadian shipments, markets, supply, and foreign trade. It includes a ten-year summary (1999–2009) as well as historical statistics on the aluminum industry. The CD may be purchased from the Web site shown. Click on "Bookstore" then click on "What's New" on the left side of the screen. The review is $190 list, $95 to members of the association.

The Aluminum Association
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POSTER ABSTRACT SUBMITTAL
Annual FABTECH International & AWS Welding Show
Chicago, IL – November 13-16, 2011

Submission Deadline: April 22, 2011
(Complete a separate submittal for each poster.)

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Poster Subtitle (max. 50 characters):

Co-Author(s):

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- Any technical topic relevant to the welding industry is acceptable (e.g. welding processes & controls, welding procedures, welding design, structural integrity related to welding, weld inspection, welding metallurgy, etc.).
- Submittals that are incomplete and that do not satisfy these basic guidelines will not be considered for competition.

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

Criteria by category as follows:

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

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

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

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

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

Check the category that applies:

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

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

Abstract:

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

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

.

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

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

MUST BE RECEIVED NO LATER THAN April 22, 2011

Member Milestone

Ravi Menon

Ravi Menon

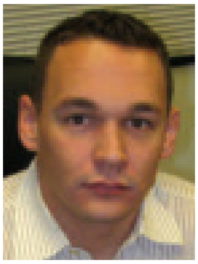
Thermadyne® Industries, Inc., St. Louis, Mo., has appointed **Ravi Menon** general manager of Stoody®, with operations based in Bowling Green, Ky. Menon, an AWS member since 1985, is affiliated with the Nashville Section. He is chairman of the AWS A5G Subcommittee on Hardfacing Filler Metals, and serves on the A5 Committee on Filler Metals and Allied Materials, A5 Executive Committee, A5E Subcommittee on Nickel and Nickel Alloy Filler Metals, A5M Subcommittee on Carbon and Low-Alloy Steel Electrodes, and D14H Subcommittee on the Surfacing of Industrial Rolls. With Stoody for 17 years in a variety of roles, Menon holds a PhD in metallurgical engineering from the University of Tennessee. Terry Downes, Thermadyne executive VP and COO, said, "Ravi has done an excellent job in developing innovative products for growth markets which has driven Stoody's recent success. He has solid global experience and a deep knowledge of Stoody's products and applications. He is, therefore, perfectly positioned to lead the Stoody business plan and achieve its growth potential."

Aerobraze Appoints General Manager

Joe Hetzer

Aerobraze Engineered Technologies, Cincinnati, Ohio, a division of Wall Colmonoy, has promoted **Joe Hetzer** to general manager for the Cincinnati facility. Hetzer previously served as director of manufacturing.

Fronius Appoints Two Robotics Managers



Stefan Mayr

Josh Williamson

Fronius USA, LLC, Brighton, Mich., has promoted **Stefan Mayr** to segment manager resistance welding/DeltaSpot, and named **Josh Williamson** segment manager of robotics. With the company for 13 years, Mayr formerly served as key account manager for robotics and integration. Williamson joined the company with 13 years of experience in robotic welding, most recently as a welding segment manager for ABB Robotics. He also serves on the AWS D16 Committee on Robotic and Automatic Welding.

Maysteel Fills Key Posts

Maysteel LLC, Menomonee Falls, Wis., a manufacturer of precision sheet metal enclosures, has named **J. Monte Roach** president and CEO, **Kevin Matkin** vice president of operations, and **Elizabeth Feldman** CFO. Prior to joining the company, Roach served Actuant as president of its Americas Electrical Group. Matkin previously was president of PreMier Precision Group, LLC, in Minneapolis. Feldman formerly served as group controller for the Energy Automated Solutions group and division at Cooper Power Systems.

Electron Beam Names VPs

Steven Roe

Valgene Raloff

Electron Beam Technologies, Inc., Kankakee, Ill., has promoted **Steven Roe** to vice president of engineering and **Valgene E. Raloff** to vice president of marketing and product development. Roe, with the company since 1990, previously served as chief engineer. Raloff, with the company since 1996, served as product manager with design responsibilities for original equipment manufacturer composite cables and the Fast 'N Easy bulk electrode accessories product lines.

Obituaries

Charles 'Chuck' Hubbard

Charles "Chuck" Hubbard

Charles (Chuck) Hubbard, 69, died Feb. 2, of a heart attack while shoveling snow at his home in Downers Grove, Ill. An AWS member since 1979, he was serving as chairman of the AWS Chicago Section. Following a tour of duty in the U.S. Marine Corps, he attended Cleveland State University where he received his engineering degree. In 1973, Hubbard started his career in welding as a sales trainee with The Lincoln Electric Co. He transferred to the company's Chicago office for field training then worked there as a salesman and technical sales representative until he retired in 2009. Hubbard was recognized by his peers as a walking encyclopedia on the technical aspects of precision welding. In the Section, he served several terms as chairman and as secretary, and also served the role of 'elder statesman.' He was known as a mellow guy who had a knack for easing tension and helping others in need. He's remembered for generously providing a missionary group with a diesel-powered generator to help build homes in an African village, and giving a Section member the tools he needed to do his work. He is survived by his wife, Ida, two children, and five grandchildren.

— continued on page 90

— continued from page 88

Tony Rohrs

Tony Rohrs died suddenly Feb. 1 in Sacramento, Calif. An AWS member since 1965, he served as Blackhawk Section chair (1977–78) and two terms as District 13 director (1979–1985). He graduated from Greer Technical Institute, Chicago, Ill., in 1965, where he learned numerous welding processes, oxygen cutting, and blueprint reading. He then worked as a layout man, welder and fitter in the aerospace and industrial blower industries, and in an ornamental and structural steel job shop through 1969 before becoming a store dock manager for a welding supply distributor. In 1970, Rohrs joined Rockford Cylinder Gas Co. as a sales engineer and later became vice president and sales manager. While at Rockford, he taught industrial welding courses for the Rockford Board of Education in its adult continuing education program, and for the adult education program of Rockford Valley College where he served on the college's advisory board. He also taught basic welding to carpenters, millwrights, and electricians for the Rockford Joint Apprenticeship Trades Committee. He is survived by his wife, Barbara, a son, two daughters, brother, and five grandchildren.

Tony Rohrs

William R. McCourt

William (Bill) R. McCourt, 69, an AWS Life Member, died Feb. 3 in Branford, Conn. Following graduation from St. John's Preparatory in Danvers, Mass., he attended Villanova University. McCourt was co-owner of ABCO Welding & Industrial Supply in Waterford, Conn., the company his father founded in 1921. He started as a truck driver then progressed to a career in sales. He contributed his expertise to other organizations, including the Independent Welders Supply Cooperative, and Gases and Welding Distributor Association (GAWDA). He was a lifelong member of Red Sox Nation who enjoyed outdoor activities of snowmobiling, hunting, and fishing. A dog fancier, he served as an AKC field trial judge and an officer of the Shoreline Retriever Club. He was a member of Snake Meadow Rod & Gun Club in Killingly, Conn. He is survived by his wife, Sandi, three sons, a brother and sister, nine grandchildren, and one great-grandchild.

William McCourt

Roy R. Petty

Roy R. Petty, 63, died Feb. 9 in Old Hickory, Tenn. An AWS member since 1981, he was a longtime member of the Nashville Section where he served as chairman for four terms. A Certified Welding Inspector since 1979, he received the Section CWI of the Year Awards on four occasions, and the District CWI of the Year Award in 1993. For the past 15 years, he worked for World Testing, Inc., in Mount Juliet, Tenn. He was active as a tournament fisherman. Petty is survived by his wife, Judy, a son and daughter, and three grandchildren.

Roy R. Petty

SCHOOL PROFILES APRIL 2011

Employers
Are you in need of good welders?

Students
Are you searching for a way to hone your skills?

Welders
Is it time to expand your talents and knowledge?

Below are welding schools across the country that have taken this advertising opportunity to promote their resources both to industry in need of welders and to those searching for a solid career path to employment. Contact them and take advantage of the services they can provide.

We appreciate any ideas you might have for making this welding school guide more useful to you. Please send comments or requests to be on our mailing list to Rob Saltzstein at salty@aws.org. or Lea Garrigan at garrigan@aws.org. We will be sure your school is on our mailing list and e-mail list to receive advance information on future Welding School Profile edition of *Welding Journal*. Thank you.

Advanced Technology Institute

ATI provides diploma and AOS degree offering training in the practical aspects of construction, repair of equipment and structures built with steel. In addition, students will learn to weld pipe in multiple positions, including training in SMAW, GMAW, GTAW and SMAWA. Instruction is presented in classroom and laboratory using modern welding equipment and tools. ATI provides students with the knowledge and skills necessary for entry-level employment as a combination structural and pipe welder. ATI offers financial assistance for those who qualify and graduate placement assistance. Certified by SCHEV to operate in Virginia.

Advanced Technology Institute (ATI)
5700 Southern Blvd.
Va. Beach, VA 23462
(757) 490-1241
www.auto.edu

Advance Institute Of Welding Technology

Founded 1999

The Advance Institute of Welding Technology was established in 1999 by C Sridhar, Director-Technical. AIWT offers excellent International Level short term skill development and certified basic (SMAW, OFW on plate) and advanced courses on Plate/Pipe - 6G. (SMAW, GTAW, GMAW, FCAW, SAW, RSW etc.) Special courses for marine fitter/welder (through DNV) and welding technology, QA/QC, WPS/ PQR /WPQ, Welding Inspection, NDT Level-II and certificate training programs at Engineer Level in India and abroad. AIWT is ISO 9001-2008 certified and IIW (India) Approved Training Institute. AIWT has trained more than 7500 personnel in their 25 years experience. We conduct In-house programs globally and have received a Life Time Achievement Award from the Government of India.

20, Bharathi Nagar, Gerugembakkam,
Chennai, Tamilnadu-600 122, India.
91 44 - 658 55176 or 2382 1812
Mobile 0 944497 1077 or 94445 21267
E-mail: aiwt_welding@yahoo.co.in
sridhar305@yahoo.com
vrajasaker@yahoo.com
www.advanceweldinginstitute.com

Advanced Welding Institute

Founded 2003

Advanced Welding Institute is a post-secondary welding school committed to assisting all individuals in developing marketable welding skills. We offer a Structural Welding Program (600 hr) and Combination Structural and Pipe Welding Program (960 hr). During the program students focus on SMAW, GMAW, FCAW, and GTAW with class sizes no larger then 20 students. Classes start in March and September every year. In addition, we perform specialized training to meet individual and company needs. Financial aid is available for those who qualify.

2 Green Tree Drive, Suite 3
South Burlington, VT 05403
(802) 660-0600
Fax: (802) 660-0689

Akron Testing Lab. & Welding School Ltd.

Founded 1953

Akron Testing Lab and Welding School Ltd., has been training and qualifying welders for over 50 years. Founded in 1953 and located in Northeast Ohio, offers certificate classes or a dipolma program in "Welding Technology." Classes offered include SMAW, pipe welding, GMAW steel and aluminum, GTAW, FCAW, oxyfuel, and blue print reading. Customized training is offered to employers. Ohio Registration 79-01-0631T.

Akron Testing Laboratory
and Welding School
1171 Wooster Road N.
Barberton, OH 44203
atweldsch@att.net
(888) 859-0664
Fax: (330) 753-2268
www.akronweldingschool.com

Alfred State College SUNY College of Technology

Founded 1908

Alfred State College offers welding training on its Wellsville, N.Y. campus. Earn an associate in occupational studies degree. Employer-driven curriculum teaches the skills needed in today's workforce: oxyfuel, SMAW, GTAW, GMAW, and pipe welding. Program includes key support courses such as metallurgy, blueprint reading, and quality control. Benefit from AWS Level I and II certification. Enjoy small classes, tutoring and personal attention. Customized courses available for employers.

Hit the ground running!

10 Upper College Drive
Alfred, NY 14802
(800) 4-ALFRED
www.alfredstate.edu
admissions@alfredstate.edu

SCHOOL PROFILES APRIL 2011

American River College

Founded 1955

The Welding Technology degree provides skills and knowledge in manual and semi-automatic welding processes used in the metal fabrication and construction industries. Instruction covers materials, equipment, testing procedures, safety, mathematics and blueprint reading. Competencies include techniques of joining ferrous and nonferrous metals by the use of shielded metal arc welding (SMAW), gas metal arc welding (GMAW), flux cored arc welding (FCAW), gas tungsten arc welding (GTAW), and welding procedures. The American Welding Society (AWS) nationally accredits American River College's welding program. ARC has met all the requirements of the AWS QC4 Standards for Accreditation of Test Facilities for their Certified Welder Program. American River College is a level 2 SENSE program.

4700 College Oak Drive
Sacramento, CA 95841
(916) 484-8354
ramos@arc.losrios.edu
www.arc.losrios.edu

Brevard Community College

Founded 1960

Brevard Community College, located in the heart of the nation's space coast, offers a one and one-half year Welding Technology certificate program. The program provides the theoretical and practical experience necessary to develop a basic foundation in the skills of welding, and is designed to train students to become certified welders in pipe and structural steel. AWS, ASME, API and ANSI welding codes apply. Graduates of the program will be prepared for entry-level positions as welders and are eligible to take the AWS weld certification exam. And, as always, OSHA industry standards will be reinforced.

Mr. Kenneth Cox, Asst. Prof, CWE/CWI
1519 Clearlake Road, Cocoa, FL 32922
(321) 433-7499
coxke@brevardcc.edu
www.brevardcc.edu

Bellingham Technical College Welding Technology Program

Founded in 1956

Bellingham Technical College's Welding Technology Program offers AAS and AAS-T degrees in certified welding and fabrication for a vibrant community of pipelines and Northwest Washington refineries, ship building and repair, transportation, and shops and fabricators. Our award-winning program is in an 80,000 sq. ft. state-of-the-art facility that houses our 200 plus enrollment in pipe welding, aluminum welding and fabrication, steel fabrication, and creative welding. Our Annual Welding Rodeo Sculpture Contest is a one-of-a-kind experience for Amateurs and professional artists throughout the Pacific Northwest.

3028 Lindbergh Ave.
Bellingham, WA 98225-1599
(360) 752-8301
www.btc.ctc.edu or www.weldingrodeo.com
rjones @btc.ctc.edu

Bellingham Technical College Welding Rodeo

BTC's 10th annual team welded sculpture competition and auction will be held Friday and Saturday, May 20th and 21st, 2011. The theme for 2011 is "Free Style." Friday we will showcase 10 amateur high school and college level teams, and on Saturday we will showcase 10 professional level teams competing for prizes and cash. The public is invited both days. Contact us for more information or visit our website.

3028 Lindbergh Ave.
Bellingham, WA 98225-1599
(360) 752-8301
www.btc.ctc.edu or www.weldingrodeo.com
danderson@btc.ctc.edu
jdonnelly@btc.ctc.edu
mkuebelbeck@btc.ctc.edu

Butte-Glenn Community College

Founded 1967

The Welding Technology Program is a vocational core of courses designed to produce qualified personnel for certified welding jobs. Program performance standards are in accordance with the AWS SENSE Program and follows NCCER curriculum, ASME, and API codes. Courses are held in a completely modern and well-equipped welding lab. Program is designed to produce entry-level welding technicians in the 6-G pipe position (qualifies for all positions in plate and pipe). SMAW, FCAW, GMAW, GTAW, OAW, OFC, PAC and AAC in all positions with a variety of metals and alloys are taught. Certification in AWS, ASME, and API according to individual skills. The **PG&E Power Pathway Gas Pipeline Welding Capstone**: Courses within this pathway help prepare students for careers within the petrochemical/natural gas pipeline industry. The power pathway specifically trains welders for potential apprentice welding positions within Pacific Gas and Electric.

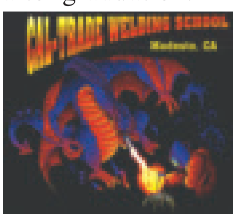
3536 Butte Campus Drive
Oroville, CA 95965
Don Robinson, robinsondo@butte.edu
(530) 895-2469, Fax: (530) 895-2302
Miles Peacock, peacockmi@butte.edu
(530) 879-6162, Fax: (530) 895-2302

SCHOOL PROFILES APRIL 2011

Cal-Trade Welding School of Modesto

Founded 1975

Cal-Trade Welding School of Modesto has been operating since 1975. Using the industry employers as a guide, we teach SMAW, GMAW, GTAW, FCAW and pipeline welding. Welding technique training is primary and students are given one-on-one instruction. In the 20 week Combination Welding Course students have the opportunity to earn multiple certifications. Welding theory, mathematics for welders and blue print reading are also offered. Lifetime job placement assistance is available to students after graduation.



424 Kansas Ave.
Modesto, CA 95351
(209) 523-0753
Fax: (209) 523-8826

The Calhoon MEBA Engineering School

The Calhoon MEBA Engineering School (CMES), located in Easton, Maryland, provides welding courses that include technical and skill training. Curriculum teaches skills in SMAW, GTAW, GMAW, FCAW, OAW, OAC, PAC, soldering, and brazing of ferrous and nonferrous metals. CMES offers AWS SENSE level 1 welding training programs. Basic metallurgy, welding codes and specifications, standards-of-practice, welding terminology, blueprint reading and distortion control, will be reviewed and practiced. Job specific training programs are available.

27050 St. Michaels Road
Easton, MD 21601
(410) 822-9600
Bryan Jennings
bjennings@mebaschool.org
www.mebaschool.org

Calumet Welding Center

Calumet Welding Center provides welder education and certification for Northwest Indiana and the Chicagoland area. Welding classes offered include SMAW, GMAW, and GMAW-Spray Arc, GTAW, FCAW, and blueprint reading. Our customized training programs can focus on a company's specific needs and accommodate diverse skill levels. Instruction space is available for corporate rental. In partnership with an AWS accredited testing facility, we offer certifications and procedure qualification.

1947 N Griffith Blvd
Griffith IN, 46319
(219) 923-9353
info@calumetwelding.com
www.calumetwelding.com

Capital Region Career and Technical School

Welding and metal fabrication students learn the skills and techniques necessary for success as a certified welder. Students will learn SMAW, GMAW, Flux cored, GTAW welding and orbital GTAW welding. Students also learn about the operation of welding and metal fabrication machinery, blueprint reading, clean room environments and shop theory. This program offers students the opportunity to take multiple AWS, ASME and N.Y. Dept. of Transportation welder qualification tests. Upon completion of the program, students are prepared to seek employment as a certified welder.

1015 Watervliet –Shaker Road
Albany, NY 12205
(518) 862-4707
Welding Teacher
Chris Lanese
clanese@gw.neric.org

Center For Employment Training

Founded 1967

Center for Employment Training is accredited by the Western Association of Schools and Colleges (WASC). We are employer-driven teaching a curriculum that meets the workforce demands. Graduates will receive a welding fabrication certificate, along with the opportunity to receive eight AWS D1.1 approved Certifications. Welding Certifications available are: SMAW-E7018, FLUX CORE-NR 211 E71T-1, FLUX CORE-NR 232 E71T-8, GMAW-ER-70S-6, TIG ALUMINUM-ER-4043, TIG CARBON STEEL-ER-70S-2, TIG STAINLESS STEEL-308-L, DUAL-SHIELD-E71T-1M. Customized training is available to employers. We are certified to train veterans and offer financial aid to those who qualify.

Center For Employment Training
1430 Cooley Court
San Bernardino,CA 92408
(909) 478-3818 or (888) 379-5358
Fax: (909) 478-9506
Office hours: 8:00 am to 5:00 pm PST
Email: sanbernardino@cet2000.org
www.cetweb.org

Central Piedmont

Community College James Turner Institute of Welding Technology

Founded 1963

CPCC offers welding training at its Charlotte, North Carolina campus. Earn a Certificate or Associate in Applied Science Degree in Welding Technology. We teach the skills needed for today's work force: Oxyfuel, SMAW, GTAW, GMAW, FCAW and more. Key support courses such as Metallurgy, Blueprint Reading, Quality Control, and Nondestructive Examination. We have been an AWS Accredited Testing Facility since 2000 and have NCCER certified instructors. In addition to our AWS student chapter we have an active blacksmithing group on campus.

Get There.
CENTRAL PIEDMONT COMMUNITY COLLEGE

PO Box 35009
Charlotte, NC 28235
(704) 330-2722
www.cpcc.edu/welding

SCHOOL PROFILES APRIL 2011

Central Wyoming College

Central Wyoming College, located in the beautiful Wind River Valley, offers an employer-driven welding curriculum designed to provide graduates with entry-level backgrounds in the different aspects of welding. Central Wyoming College welding students receive rigorous hands-on training in various welding and cutting processes including oxyfuel, SMAW, GMAW, FCAW, GTAW, and pipe welding. Students have a choice of earning a credential, certificate or an associate of applied sciences degree. Check out our program at www.cwc.edu.

2660 Peck Avenue
Riverton, WY 82501
(307) 855-2119
www.cwc.edu
Dudley Cole, (307) 855-2138
Admissions (800) 865-0193

College of the Canyons

An AWS SENSE affiliated and AWS Accredited Testing Facility that has trained and certified welders for over 34 years. College of the Canyons is also a Certified Educational Center for the Fabricators Manufacturers Association. Courses are offered in metal fabrication in addition to many of today's most popular welding processes, including welding automation and laser welding. Day and night courses are offered with program completion obtainable in less than one year.

26455 Rockwell Canyon Road
Santa Clarita, CA 91355
(661) 259-7800
Email: tim.baber@canyons.edu
www.canyons.edu

Commercial Diving Academy

Founded in 1995

Commercial Diving Academy (CDA) is the only fully-accredited diver training program with IMCA-recognized training, on-campus housing and a full meal plan. CDA offers the most comprehensive and rigorous (20 weeks) program of all the accredited commercial diver training schools. CDA's graduates may earn certifications from the Association of Commercial Diving Educators, Association of Diving Contractors International, Diver Certification Board of Canada, National Center for Construction Education and Research, American Petroleum Institute, American Welding Society, Hazwoper Environmental Training, National Board of Diving and Hyperbaric Medical Technicians, National Academy of Scuba Educators, and National Registry Emergency Medical Technician.

Allen G. Garber
Chief Administrative Officer
8137 North Main Street
Jacksonville, FL 32208
(888) 974-2232 toll free
(904) 766-7736
Fax: (904) 766-7764
www.cda.edu

Community College of Denver

The CCD welding program offers four certificate programs and one option to earn your Associate of Applied Science Degree Complete your Fabrication Welder certificate in three, 16-week semesters. You'll be prepared to take the SMAW, GMAW and 6G pipe certification test to become an arc, plate, industrial, production, fabrication, GMAW/GTAW or construction welder. Credits earned toward your certificate can be applied toward an AAS degree. Contact us for more information.

1111 W Colfax Ave.
Denver, CO 80204-2026
(303) 556-2600
Christine Smith Olsey
christine.smitholsey@ccd.edu

Commercial Diving Academy Maritime Welding Program

CCDA's Maritime Welding Program prepares graduates for the exciting and fast-paced career of welding, both offshore in the Gulf of Mexico and in shipyards, building everything from oil tankers to battleships. We developed the curriculum by working closely with the leading companies in these industries. This program was designed to fulfill the ongoing demands for entrylevel welders. Unlike traditional welding schools that teach students how to weld in a booth, CDA simulates the environment of a real maritime welder with ship fitting, crane operations, rigging and offshore survival. Our curriculum is associated with NCCER, supports the AWS SENSE guidelines, and is accredited by API to ensure our students exceed employer's expectations.

Drew Duffy
Admission – CDA Welding Program
Jacksonville, FL 32208
(888) 974-2232 toll free, (904) 766-7736
Fax: (904) 766-7764
www.cdawelding.com

Cuesta College Welding Technology

Founded 1965

Located on the central coast of California, the Cuesta College Welding Technology program has a strong history of preparing students for work in industry. Students certify to AWS D1.1 and ASME Section IX and have the opportunity to obtain associative science degrees in welding technology. Our curriculum is well rounded with courses ranging from basic welding through certification, as well as courses in metallurgy, blueprint reading and welding power. The shop facility includes twenty multiprocess welding stations with current power supply technology. There are a total of eight part-time instructors and one full-time instructor. Four of our instructors are CWI's. We are about to unveil our new 8 station mobile welding lab. Article sponsored by CBI of San Luis Obispo, California.

P.O. Box 8106
San Luis Obispo, CA 93403-8106
(805)546-3100 ext 2737
Rob Thoresen, rthorese@cuesta.edu

Cosumnes River College

Cosumnes River College offers a "hands on" style welding certificate program. Students can become certified in SMAW, GMAW, FCAW and GTAW processes. The advanced welding courses offer AWS certifications in ASME and AWS D1.1 code standards. Graduating students can become a certified welding operator, welding inspector and shop supervisor for construction and manufacturing companies. The lead instructor, Jason Roberts is an AWS CWE/CWI and Federal OSHA Trainer.

For more information please contact:
Jason Roberts
(916) 691-7386
8401 Center Parkway
Sacramento, CA 95823
robertj@crc.losrios.edu

Dabney S. Lancaster Community College

Founded 1967

Dabney S. Lancaster Community College offers welding training on its western Virginia campus. Earn a certificate or associate in applied science degree. Employer-driven curriculum teaches the skills needed in today's workforce: oxyfuel, SMAW, GTAW, GMAW, and pipe welding. Key support courses such as metallurgy, blueprint reading, and quality control. Benefit from free qualification testing. Enjoy small classes, free tutoring, and personal attention. Customized courses available for employers. Offering quality, affordable education, and training since 1967.

1000 Dabney Drive,
Interstate 64, exit 24
Clifton Forge, VA 24422-1000
(540) 863-2895
Email: mbryant@dslcc.edu
www.dslcc.edu

Dalus, S.A. De C.V. Welder Training & AWS Certification Center In Mexico

Founded 2000

DALUS was founded in 2000 for the purpose of training and testing people in certifiable skills and knowledge that will help to integrate them into a world class workforce. DALUS is an AWS Accredited Test Facility (ATF) and a member of the S.E.N.S.E. (Schools Excelling through National Skills Education) program and administers SCWI, CWI and CWE prep course and exams three times a year. DALUS also offers courses designed to meet employer's specific needs.

Parque Industrial Kalos
Monterrey, NL - MEXICO
+52 (81) 8386-1717
info@dalus.com
www.dalus.com

Lynnes Welding Training, Inc.

Founded 2004

Fast track your welding career in just a few weeks or a few months. Our students have the option of choosing the process they want to learn and the time of year they want to be in school. Upon passing a welding test in GMAW, SMAW, GTAW or pipe, they will receive a certification. All of our instructors are AWS CWI's and have several years of welding experience. Maximum class size of ten students per instructor. We accept the G.I. Bill. (combination course only).

2717 3rd Ave. N
Fargo, ND 58102
(701) 373-0658

Bismarck, ND
(701) 751-4256
www.learntoweld.com

Delaware Area Career Center

Welding students at the Delaware Area Career Center design, engineer, build, and troubleshoot complex manufacturing solutions for actual clients. They learn to interpret blueprints and specifications using math and computer technology. They also develop the strength, work ethic, and stamina necessary for a career in fabrication. Upon completion, the students are prepared for NCCER (National Center for Construction Education and Research) welding certificate, AWS (American Welding Society) certifications, immediate employment as an apprentice, and further education.

Scott Laslo
(740) 203-2238
www.DelawareAreaCC.org

The Divers Academy International

Founded 1977

Divers Academy International offers the highest quality Underwater Welding and Commercial Deep Sea Diving training in the shortest amount of time to jumpstart your career. For over 30 years, it has been known for its full-immersion training methodology and its state-of-the-art facilities. Underwater cutting and welding is just one part of a comprehensive 5-month curriculum. Upon completion of your education from Divers Academy International, your skills can be applied to a variety of commercial diving careers. Commercial divers maintain, repair, inspect, construct and install pipelines, oil platforms, power and communication cables, industrial plants, power plants, bridges, tunnels, piers, and dams. Our training for Commercial Deep Sea Diving and Wet Welding provides students with an employer's most sought-after qualification: on-the-job experience. Financial aid is available to those who qualify.

Lakeside Business Park
1500 Liberty Place
Erial, NJ 08081-1139
(800) 238-DIVE
admissions@diversacademy.com
www.diversacademy.com

SCHOOL PROFILES APRIL 2011

Earlbeck Gases & Technologies

Earlbeck Gases & Technologies as a training partner with Anne Arundel Community College offers welding training in the Baltimore/DC area. The fundamentals course instructs in the basics of oxyfuel, GTAW, GMAW and SMAW. Successful students may then progress through intermediate and advanced classes in SMAW, GMAW and GTAW. Intermediate classes offer certification testing in plate. Advanced classes offer certification testing in pipe. Customized and mobile training is also available for employers.

Don Hodges
8204 Pulaski Highway
Baltimore, MD 21237
(410) 687-8400
dhodges@earlbeck.com
www.earlbeck.com

Eastern Maine Community College

Founded 1966

EMCC offers a comprehensive welding program in Bangor, Maine. Students may earn a diploma or associate degree in welding or pipefitting technology including metallurgy and QA/QC to prepare them to successfully enter the workplace. SMAW, FCAW, GMAW, GTAW and cutting processes in both structural and piping applications are studied in a spacious training facility equipped with modern welding equipment. AWS testing facility offering weld testing, welder certification and customized training to the public and industry.

354 Hogan Road,
Bangor, ME 04849
(207) 974-4643
cmaseychik@emcc.edu
www.emcc.edu

Ferris State University

Ferris State University's nationally recognized TAC-ABET Welding Engineering Technology program is the largest of its kind in the United States. Since its inception, more than 25 years ago, the program is designed to produce plant-level welding engineering technology graduates who are involved in the concept, design and engineering of weldments and implementation of welding processes.

Welding Engineering Technology
915 Campus Drive, Swan 107
Big Rapids, MI 49307
(231) 591-2952
Jeff Carney, associate professor/ program coordinator
carneyj@ferris.edu
www.ferris.edu/welding

Florida State College of Jacksonville

Florida Coast Career Tech is your smart choice for welding training. Our hands-on, affordable, intensive (9 month) program includes all welding processes SMAW, GMAW, FCAW and GTAW on plate and pipe in steel, stainless steel and aluminum. We can also customize the training to meet specific needs. At our state-of-the-art facility (40 booths), faculty are AWS CWI/CWE and can provide the training you need to gain immediate employment or increase your skill. Florida Coast Career Tech is a division of Florida State College at Jacksonville. Florida State College at Jacksonville is accredited by the Commission on Colleges of the Southern Association of Colleges and Schools ("SACS") to award the baccalaureate and associate degree. Contact the Commission on Colleges at 1866 Southern Lane, Decatur, Georgia 30033-4097, or call (404) 679-4500 for questions about the accreditation of Florida State College at Jacksonville.

401 W. State St.
Jacksonville, FL 32202
904) 633-8295
uwurie@fscj.edu
www.floridacoastcareertech.org/welding

Gadsden Technical Institute

Gadsden Technical Institute is an American Welding Society SENSE school that prepares students for employment or advanced training in a variety of occupations in the welding industry. The applied welding technology program is 1170 hours in length with certificates offered in SMAW, GMAW, FCAW, GTAW, and pipe welding. GTI also facilitates certification to AWS and ASME codes. Applied course work includes design and fabrication of challenging projects and participation in Skills USA activities.

Gadsden Technical Institute
201 Martin Luther King Jr. Blvd.
Quincy, FL 32351
(850) 875-8324
Fax: (850) 875-7297
clark_m11@firn.edu
www.gti.gcps.k12.fl.us

Great Basin College Welding

Founded 1967

Great Basin College offers an Associates of Applied Science Degree and a one-year Certificate in Welding Technology, established in 1990. Currently, 20 students are enrolled in a program that prepare them with skills to create new products; repair existing products; and work in the mining, manufacturing, construction, transportation and agricultural industries. Program highlights include instruction in welding theory, blueprint reading, fabrication, quality control, metallurgy, qualification testing, destructive and nondestructive testing principles, and safety.

Elko, Nevada
(775) 753-2207 or (775) 753-2170
Rich Barton e-mail:
richardb@gwmail.gbcnv.edu
Jon Licht e-mail:
jonl@gwmail.gbcnv.edu
www.gbcnv.edu

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Harper College

Harper College's 16 credit-hour certificate program provides students with entry-level skills in welding fabrication and repair. The program emphasizes advanced welding theory, extensive practice in major arc welding process, and out-of-position and multipass arc welding including GMAW, SMAW, and GTAW. Upon completion of the certificate program, students are prepared to pass guided bend tests to become certified welders in accordance with AWS (American Welding Society) D1.1 Structural Welding Code. Harper's program also provides custom training in welding and fabrication for employees of area businesses.

Kurt J. Billsten
Coordinator of Maintenance Technology
1200 West Algonquin Rd.
Palatine, IL 60067
(847) 925-6149
Fax: (847)925-6049
kbillste@harpercollege.edu
www.harpercollege.edu

Hill College

Founded 1923

Hill College offers comprehensive welder training on both its Hillsboro and Cleburne, Texas campuses. Students can choose from several program options ranging from marketable skill awards to an Associate of Applied Science degree. Employer-driven curriculum covers SMAW, GMAW, FCAW, GTAW, pipe welding, and blueprint reading. State-of-the-art technology combined with hands-on curriculum give Hill College students the experience to jump start their careers. Hill College also offers continuing education credits and customized courses for employers.

Welding Department
2112 Mayfield Parkway
Cleburne, Texas 76033
(817) 556-2809 ext.201
Email: bbennett@hillcollege.edu
www.hillcollege.edu

Hobart Institute of Welding Technology

Founded 1930

Hobart Institute of Welding Technology's course catalog explains in detail the wide range of welding classes and certifications offered by Hobart Institute of Welding Technology. More than 25 separate welding courses are described by course objective, content, and testing requirements. Also inside the catalog are course schedules, training rates, and enrollment forms. Training may be done at our facility or yours. Also offered are complete training programs including DVDs, Instructor Guides, and Student Workbooks.

400 Trade Square East
Troy, OH 45373
(800) 332-9448
FAX: (937) 332-5200
www.welding.org

Hutchinson Community College/AVS

HCC offers Certificate, Associate in Applied Science degrees and industry training in welding technology. The AWS certified program includes all welding processes, as well as experience in fabrication and manufacturing methods. The welding and employability skills taught result in excellent graduate placement, as well as job opportunities while students pursue their education. Morning, afternoon and evening classes are available, with multiple entry opportunities. Our locations include Hutchinson and Newton, Kansas. The Ade-Wifco Reno County Industrial Center in Hutchinson features newly remodeled and expanded welding and fabrication labs and classrooms.

1300 N. Plum
Hutchinson, KS 67501
(620) 665-3502
www.hutchcc.edu/weldit
fitzgeraldsd@hutchcc.edu in Hutchinson
(316) 273-7000
jensenl@hutchcc.edu in Newton

Illinois Valley Community College

Founded 1924

Illinois Valley Community College offers welding training and fabrication classes. Over 100 students are trained each semester in all the major welding processes: SMAW, GMAW, GTAW, FCAW, and Oxyacetylene. Welding Blueprint Reading and Metallurgy are also taught. IVCC is an AWS Accredited test facility and has 20 welding stations in a very modern lab and a fully equipped fabrication lab. The training helps prepare students to pass nationally recognized plate and pipe tests. Customized training is also available to area employers.

Paul Leadingham
Welding Program Coordinator
815 N. Orlando Smith Road
Oglesby, IL 61348
(815) 224-0319
paul_leadingham@ivcc.edu
www.ivcc.edu

Kenai Peninsula College

Kenai Peninsula College is a branch of the University of Alaska located 150 miles south of Anchorage on the Kenai Peninsula. KPC offers certification on AWS D1.1, D .375 steel plate 3G and 4G SMAW, ASME Section IX pipe certification on steel 6-inch schedule 80 6G SMAW. Our welding certificate program includes math, blueprint reading, and English (students must certify on pipe to complete certificate). KPC students are provided with 3M® powered air purifying respirator welding hoods. Nonresident tuition is waived for students taking classes at KPC for the Fall 2011 and the Spring 2012 semesters. This waiver does not apply to students taking distance-delivered courses while residing outside the state of Alaska.

156 College Road
Soldotna, AK 99669
(907) 262-0300
Fax: (907) 262-0395
Fritz Miller, Welding Instructor
(907) 262-0356
iffwm@uaa.alaska.edu
www.kpc.alaska.edu

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Lincoln Electric Welding School

Founded 1917

Learn to weld at the Lincoln Electric Welding School. We have trained over 150,000 welders in many different trades (ironworkers, boilermakers, pipefitters, and sheet metal). Learn to weld with the latest technology in equipment and consumables, on different base metals (carbon steel, stainless, aluminum and cr/mo) and all arc welding processes (SMAW, GMAW, GTAW, FCAW, SAW). Our instructors, have real world experience in factory and motorsports welding, including trackside welding at NASCAR®, IRL® and NHRA® events. We also can complete jobsite training at your location.

22801 St. Clair Ave.
Cleveland, OH 44117
(216) 383-2259
www.lincolnelectric.com

Maysville Community and Technical College Rowan Campus

This program offers plate and pipe weld training using the SMAW, GMAW, and GTAW processes. Training can lead to a certificate, diploma, or Associate Degree as well as certification on structural steel with the SMAW and GMAW processes. Program is certified by the AWS as an Educational Institution Member and certified by the United Association of Plumbers and Pipefitters as an orbital tube welding training/certification center.

Welding Technology
609 Viking Dr.
Morehead, KY 40351
Dean Howard / Stanley Click
(606) 783-1538 ext. 66347 or 66334
Deanb.howard@kctcs.edu
Stanley.click@kctcs.edu

Mesabi Range Community & Technical College

Mesabi Range offers a rigorous welding curriculum following national skills standards developed by the American Welding Society. The Entry Level Welder Diploma and the Advanced Welder Diploma, established in 1997, give the successful graduate very marketable skills in the welding industry. Experienced, knowledgeable instructors, a great staff, up-to date equipment, and a modern shop provide a great learning environment. We have 100% job placement in the last ten years. Welding certifications are available.

P.O. Box 648
1100 Industrial Park Drive
Eveleth, MN 55734
(218) 741-3095
Fax: (218) 744-7644
www.mr.mnscu.edu

Mid-Plains Community College

Mid-Plains Community College's Welding and Machine Shop Technology is offered at North Platte and McCook campuses. The program is an open-entry, open-exit program that leads to a diploma or associate of applied science degree and employment in the welding/machine shop field. Students will progress according to his/her abilities and efforts. Upon completion of a set of prescribed technical competencies, students will be able to perform skills necessary to be successfully employed at the entry level.

1101 Halligan Dr.
North Platte, NE 69101
(800) 658-4308
info@mpcc.edu
www.mpcc.edu

Missouri Welding Institute

Founded 1994

Become an AWS and ASME certified welder in 18 weeks. Established in 1994 MWI teaches pipe and structural welding and fitting. Each day you will spend 7 hours performing hands-on welding and fitting with the remaining hour of your day spent in the classroom or the country's largest state of the art pipe fitting laboratory. MWI offers day, evening and graveyard shifts to accommodate everyone's schedule.

Missouri Welding Institute
3300 N. Industrial Parkway
PO Box 445
Nevada, MO 64772
(800) 667-5885
Fax: (417) 667-5885
www.mwi.ws

Monroe County Community College

Founded 1964

Monroe County Community College located in Monroe, Michigan offers a welding technology program which includes training in SMAW, GMAW, FCAW, and GTAW, plate and pipe in all positions, using mild steel, stainless steel and aluminum. Courses may be applied towards an associate degree in applied science, welding certificate or transferrable to a four year bachelor degree. American Welding Society QC-10 (Entry level) and QC-11 (Advanced level) classes are available.

Roop Chandel (734) 384-4165
rchandel@monroeccc.edu
Cameron Albring (734) 384-4112
calbring@monroeccc.edu

SCHOOL PROFILES APRIL 2011

Moraine Park Technical College

Moraine Park Technical College offers a one-year welding diploma program focusing on GMAW, FCAW, SMAW and GTAW in all positions. Instruction includes AWS and ASME welding codes, print reading and fabrication courses. Moraine Park also offers a one-year Metal Fabrication Diploma and a two-year Fabrication Technologies Associate Degree. Both programs emphasize the manufacturing process of taking a product from conception to final product using lasers, plasma and flame tables, rollers, press brakes and welding equipment.

235 N. National Avenue,
Fond du Lac, WI 54935
www.morainepark.edu
Jeremiah Johnson, (920) 887-4490
jjohnson10@morainepark.edu
Gary Watry, (920) 887-4494
gwatry@morainepark.edu
Jeff Beach, (920) 924-6438
jbeach@morainepark.edu
Larry Clark, (920) 924-3433
lclark@morainepark.edu

North American Trade Schools

Founded 1971

Since 1971 North American Trade Schools has been providing skilled training to accommodate the needs in the Baltimore area for entry level technicians. North American Trade Schools offers a Combination Welding program that includes SMAW, GTAW, GMAW, Pipe and many other relevant disciplines of Welding. Please give us a call to see what our graduates can do to help fill your hiring needs.

6901 Security Boulevard
Baltimore, MD 21244
(410) 298-4844
www.natradeschools.com

North Central Texas College

North Central Texas College Division of Lifelong Learning offers a welding program unlike most others. With its 16 booth state-of-the-art facility, built in 2009, the welding program at NCTC has become well-known for its successful program completers. Students can come and go as needed for class thanks to our clock-hour program. Our biggest asset is our one-on-one instructional style, as well as our low-cost courses. Call (940) 668-4272 to ask about our welding programs, or e-mail mfuhrmann@nctc.edu.

1525 West California St.
Gainesville, TX 76204
(940) 668-4272
www.nctc.edu/LifelongLearning/Welding_Technology

North Dakota State College of Science

North Dakota State College of Science is a two-year college located in Wahpeton, N.D, with an additional commuter site, NDSCS-Fargo, located in Fargo, N.D. NDSCS' Welding Technology curriculum provides students experience in assembly, manufacturing, energy and construction, plus training in robotics, inspection, fabrication and more. NDSCS offers a one-year certificate, a two-year diploma and an A.A.S. degree. The facilities are American Welding Society S.E.N.S.E. certified; NDSCS is an education partner to the National Center for Welding Education and Training (Weld-Ed). In 2010, 100 percent of NDSCS welding graduates entered the work force or continued their education.

NDSCS-Wahpeton
800 Sixth St. North
Wahpeton, N.D. 58076
(800) 342-4325
www.ndscs.edu

NDSCS-Fargo
1305 19th Avenue North
Fargo, N.D. 58102
(701) 231-6900
www.ndscs.edu/fargo

Email: joel.johnson@ndscs.edu

Northeast Wisconsin Technical College

Northeast Wisconsin Technical College offers training in welding, weld inspection and nondestructive testing in Green Bay, Marinette, Sturgeon Bay, Wisconsin, and by contract at worksites nationwide. NWTC welding graduates can build and repair metal components using major welding processes used by industry and knowledge of blueprints, metallurgy and layout; can weld to AWS and ASME codes; can work as maintenance welders, qualified welders, structural welders, welder/fabricators, and pipe welders.

2740 West Mason Street
P.O. Box 19042
Green Bay, WI 54307-9042
(800) 422-NWTC, ext. 5444
www.nwtc.edu

Ozarks Technical Community College

Founded 1990

Ozarks Technical Community College offers multiple welding programs, providing opportunities for full- or part-time students, as well as customized training for employers. The Welding Technology program includes courses in several types of welding and welding inspection, leading to either a certificate or an A.A.S. The College also offers an accelerated 20-week Master Welder certificate program. The Center for Workforce Development offers short-term, non-credit welder training for local businesses. OTC is a fully equipped, fully accredited AWS certified test facility.

1001 E. Chestnut Expwy
Springfield, MO 65802
(417) 447-7500
www.otc.edu
ask@otc.edu

SCHOOL PROFILES APRIL 2011

Pennsylvania College of Technology

Penn State affiliate since 1989

Penn College offers the complete package for those who wish to pursue a welding career: recently renovated facilities, industry-standard equipment, comprehensive curriculum, and full campus experience (on-campus housing, athletics, and more). In addition to associate degree and certificate programs, Penn College offers a B.S. degree in welding and engineering technology that prepares graduates for supervisory, sales, and research positions. A public television series featuring the program is available for viewing at www.degreesthatwork.tv.

One College Avenue
Williamsport, PA 17701
(800) 367-9222
PCTinfo@pct.edu
www.pct.edu/aws

Portland Arts and Technology High School

Portland Arts and Technology High School in Portland, Maine offers excellent welder training. AWS certifications in SMAW/FCAW, Structural D1.1., GTAW, GMAW on carbon, aluminum, and stainless plate and pipe are also taught. The 2-or 3-year course (800-1000 hr) is designed to give students plenty of practical application and theory in oxyfuel, plasma cutting and SMAW. Blueprint reading and black smithing are also practiced. Adult education welding is offered four times a year.

William Presby
Welding Instructor
presbb@portlandschools.org
(207) 874-8165
Fax: (207) 874-8170

Renton Technical College

Founded 1942

Renton Technical College, located just southeast of Seattle, Washington, offers preparatory welder training (AAS degree), supplemental training and up-grading classes. We offer welder certification in all of the popular processes, related training, blueprint for welders and metallurgy. Curriculum is constantly updated to stay current with industry. Day, evening, and weekend classes are available in oxyfuel, SMAW, GMAW, FCAW, GTAW, fabrication, and inspection. Our instructors are AWS-CWI/CWE with over 80 years collective experience.

3000 NE Fourth Street
Renton, WA 98056-4195
(425) 235-2352 x5554
Dave Parker at dparker@rtc.edu
www.rtc.edu

South Plains College

Founded: 1957

South Plains College, located near Lubbock TX, offers basic and advanced certificates of proficiency as well as an associate of applied science degree in welding technology. Training is done according to AWS SENSE level I and level II guidelines. Specific areas of training include: OFC, PAC, SMAW plate and pipe, GMAW plate and pipe, FCAW plate and pipe, GTAW sheet and pipe, welding symbols, blueprint reading, welding metallurgy, and structural & pipe layout & fabrication. Instructors are AWS CWI/CWE's.

Pete Stracener
South Plains College
1401 College Avenue
Levelland, TX 79336
(806) 716-2284
pstracen@southplainscollege.edu
www.southplainscollege.edu/welding

Southeast Community College Welding Technology Program

Southeast Community College offers associate degree, diploma and certificate programs using a comprehensive curriculum and modern equipment. Students enjoy extensive hands-on training from experienced and knowledgeable instructors in all major welding processes. Students also will gain valuable experiences with CNC plasma, fabrication, blueprints, and related equipment. The program also is an American Welding Society-accredited test facility and offers welder qualification/certification and training services to business and industry. Contact us for more information.

Two Campus Locations
Mark Hawkins, Program Co-Chair-Lincoln
(402) 437-2694
mhawkins@southeast.edu
Dan Zabel, Program Co-Chair-Lincoln
(402) 437-2692
dzabel@southeast.edu
Shannon Hansen, Program Chair-Milford
(402) 761-8226
shansen@southeast.edu
or the College Admissions Office
Lincoln (402) 437-2600
Milford (402) 761-8243

Southern Maine Community College

Southern Maine Community College offers courses in introduction to welding process in accordance with NCCER, Modern Welding, and the AWS D1.1; Advanced Welding Process (GTAW, FCAW, and GMAW), plate and pipe welding, and metal art classes. Earn a Certificate in Welding or an Associate Degree in Integrated Manufacturing that combines welding with machining. In addition to small classes and personal attention, students enjoy a picturesque campus surrounded by the ocean with a beach, a pier, and a lighthouse.

2 Fort Road
South Portland, ME 04106
(207) 741-5500
Email: jbolduc@smccme.edu
www.smccME.edu

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Southern Union State Community College

Southern Union State Community College, located near Auburn, Alabama, offers an associate degree in welding technology and certificates in plate welding and pipe welding. We have 50 weld booths with the capabilities to weld GMAW (MIG), FCAW (Flux core), SMAW (Stick) and GTAW (TIG) on carbon, aluminum, and stainless steel. Southern Union is a certified NCCER training facility and an AWS accredited Testing Facility.

1701 LaFayette Pkwy
Opelika, Alabama 36801
(334) 745-6437
Welding Instructors:
Chet Fomby
Scottie Smith
www.suscc.edu

SouthWest Collegiate Institute for the Deaf of Howard College

Founded in 1980

The Welding Technology Program is unique in that we specialize in educating only deaf and hard of hearing students. The program offers a Level I Certificate. Some of the courses offered are: Blueprint reading, SMAW, GMAW, FCAW, GTAW and pipe welding. In addition, the welding program follows the AWS SENSE Entry Level guidelines for welder training.

Randy Key
3200 Ave. C
Big Spring, Texas 79720
(432) 264-3753
(432) 264-3700
(866) 954-5729 VP
Fax: (432) 264-3774
rkey@howardcollege.edu
www.howardcollege.edu

Southwestern Oregon Community College

SWOCC is located in Coos Bay on the beautiful Southern Oregon coast. The college offers 1-year certificates, and an associate in applied science degree (AAS). A comprehensive curriculum trains students in SMAW, GTAW, GMAW, FCAW, oxyfuel, plasma cutting, and CNC operations. Students learn from brand new state of the art equipment funded 100% through a $1,998,815 US Dept of Labor grant, including a computer numerically c ontrolled (CNC) Plasma Cutter, robotic welder, virtual motion welding simulator, and the only mobile welding training lab of its kind in the Northwest. On campus housing is available. SWOCC is "Putting Education to Work" as a west coast leader in welding education. Auxiliary aids and services are available upon request to individuals with disabilities.

1988 Newmark
Coos Bay, OR
(541) 888-1507
www.socc.edu

SPARX Welding & Technology Institute:

Founded in 2009

SPARX Welding & Technology Institute is dedicated to producing world class Welders and Welding Inspectors. We provide students with a team dedicated to their success in the welding industry. Our training programs incorporate the newest welding technologies, with availability for as many as 36 students. Our welder program will produce graduates in as little as 7 weeks with our real world approach to learning.

280A Equity Boulevard
Houma, LA 70360
(985) 655-7779
Fax: (985) 655-7781
info@sparxwelding.net
www.sparxwelding.net

Timpview High School

Established 1978

Timpview High School located in Provo, Utah, serves 1,930 students in grades 9-12. Courses offered: Metals I, II and Vocational Metals. Areas of training include oxyfuel, plasma-arc, and carbon-arc cutting; SMAW, GTAW, GMAW and FCAW welding processes. Students may earn a Welding Skills Certificate through the Utah State Office of Education. Students continue at the MATC to receive their SMAW and FCAW certifications. The instructor is a CWE through the American Welding Society.

3570 North 650 East
Provo, UT 84604
(801) 226-2747
annd@provo.edu

Tri-County Technical College

Founded 1965

The welding department at Tri-County Technical College has trained welders for industry since 1965. We offer an associate degree, diploma, and two shorter certificate programs. With two CWI/CWEs on staff we can provide welder certification testing, as well as customized company training.

7900 Highway 76
P.O. Box 587
Pendleton, SC 29670
(864) 646-1405
pphelps@tctc.edu

Tulsa Welding School Oklahoma

Founded 1949

Tulsa Welding School is one of the largest accredited* welding schools in the nation with training centers in Tulsa, Okla. and Jacksonville, Fla. Founded over 60 years ago. Diplomas and occupational associate degrees (Tulsa campus only) are awarded. Welding competencies include structural, pipe, pipeline, and thin alloy welding. Associates degrees also include numerous NDT techniques plus QA/QC methods. Graduates are available every three-weeks along with thousands of alumni who contact TWS. *ACCSC

TULSA WELDING SCHOOL "A Smart Investment"

Tulsa, OK
Alan Curler, Graduate Employment
(918) 587-6789
Email: acurler@twsweld.com
Jacksonville, FL
Sharice Reaves, Graduate Employment
(904) 646-9353
sreaves@twsweld.com

Tyler Junior College

Tyler Junior College is a comprehensive community college in Tyler, Texas that enrolls approximately 12,000 credit students annually. Its one-year certificate and two-year associate degree pathways in welding technology prepare students for entry-level code welding for industry. Training is provided in SMAW, GMAW, FCAW, GTAW and pipe welding. In addition, the welding program follows the AWS SENSE entry level guidelines for welder training. Many TJC welding graduates secure a great job before graduation. Let us help you prepare for a rewarding career in a high-demand field. Call 1-800-687-5680 or visit our website. All of our full-time instructors are AWS Certified Welding Educators.

TYLER JUNIOR COLLEGE

P.O. Box 9020
Tyler, TX 75711
(903) 510-2390
or (800) 687-5680
www.tjc.edu

University of Alaska Southeast Ketchikan Campus

The University of Alaska Southeast Ketchikan is the leading post-secondary welding program in the region. Located in the heart of the Tongass National Forest and Alaska's Inside Passage, the intensive 9-month program prepares students for AWS certification in a state-of-the-art weld shop. Students train in multiple processes including SMAW, GMAW and FCAW with an emphasis on understanding and building welding skills throughout training. Weld instructor is an AWS CWI with 25+ years of production experience.

UAS UNIVERSITY OF ALASKA SOUTHEAST learn · engage · change

2600 Seventh Avenue
Ketchikan, Alaska 99901
Steve Brandow
(907) 228-4534
steven.brandow@uas.alaska.edu

Washtenaw Community College

Founded 1965

Washtenaw Community College has been a leader of welding technology for decades. The program grants a welding certificate, advanced welding mechanics certificate and an associate's in applied science. It is the most popular site for the AWS accredited testing facility in Michigan. Training areas include GMAW, FCAW, GTAW, SMAW, OAW, OFC, PAC on plate and pipe. WCC has more welding Skills USA gold medal winners than any other school.

Washtenaw Community College

4800 E. Huron River Dr.
Ann Arbor, MI 48105
(734) 973-3443
Coley McLean
camclean@wccnet.edu
www.wccnet.edu

Welder Training and Testing Institute

Founded in 1968

WTTI maintains a freestanding campus in Pennsylvania housing a weld lab equipped with sixty-five work stations. Training is provided in all major welding processes. Classrooms are fully equipped to support lessons in theory, blueprint-reading, and fitting. Specialized on-site training is available to industry with the option of a 10 station multi-process mobile welding lab. WTTI also offers CWI and NDT training and certification, as well as, welder certification through our AWS Accredited Test Facility.

WELDER TRAINING & TESTING INSTITUTE

729 E. Highland Street
Allentown, PA 18109
(800)223-WTTI
info@wtti.edu

Western Area Career & Technology Center

Founded 1972,

Western Area Career & Technology Center is a certificate granting institution offering secondary and adult industry training programs and services. Courses include instruction on SMAW, FCAW, GMAW, GTAW in the 1F to 4F and 1G to 6G positions and oxyfuel, carbon arc and plasma cutting. Students have the opportunity to take AWS certification tests. Courses can be customized for any employers needs. We produce highly-skilled, work-ready graduates.

WACTC Western Area Career & Technology Center

688 Western Avenue
Canonsburg, PA 15317
(724) 746-2890, Ext. 182
tangert@wactc.net
www.wactc.net

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York County School of Technology

York County School of Technology, located in York, Pennsylvania, offers 28 technical programs and rigorous comprehensive academic education for 1500 students in grades 9 thru 12. Welding and Metal Fabrication highlights include: 100 student enrollment and 2 full-time career educators, Cooperative education is available to seniors. 100% NOCTI pass rate, AWS SENSE approved. Local AWS Student Chapter with local Advisory Committee support. Pictures available at www.ycstech.org Welding/Metal Fabrication. Email: byarrison@ycstech.org.

2179 S. Queen St.
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If for some reason you could not participate this year and would like for us to send you information on how your school can be included in the 2012 edition, just e-mail your request to Rob Saltzstein at salty@aws.org or to Ms Lea Garrigan at garrigan@aws.org.

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SUPPLEMENT TO THE *WELDING JOURNAL,* APRIL 2011
Sponsored by the American Welding Society and the Welding Research Council

Filler Metal Influence on Weld Metal Structure of Microalloyed Steel

The impact of changes in filler metal chemical composition and heat input on microstructure and mechanical properties during welding X65 steel was evaluated

BY N. BAJIC, V. SIJACKI-ZERAVCIC, B. BOBIC, D. CIKARA, AND M. ARSIC

ABSTRACT

This paper investigates the impact of the chemical composition of the filler metal and welding parameters on the structure of weld metal and the heat-affected zone (HAZ) of microalloyed steel of increased strength, class Nb/V, mark X65 (according to API 5L standard). Experimental welding of steel strip samples (thicknesses of 9.5, 11.0, and 14.5 mm) was performed by shielded metal arc welding (SMAW), with different welding parameters, using two filler metals of different chemical compositions. Based on the analysis of the structure of the weld metal and the HAZ, the proportion of individual microconstituents was determined in order to select the optimal composition of the filler metal and welding parameters. It was shown that filler metal marked NM1 (1.4% Ni, 0.35% Mo) achieved the optimal microstructure (AF, SF, FS), which was confirmed by testing fracture toughness at low temperatures. It was also shown that finer microstructure in the HAZ area could be achieved at low heat input.

Introduction

The main feature of microalloyed high-strength steel for Class-X tube is a fine-grained ferrite-pearlite structure obtained by thermal-mechanical processing. This structure favorably affects the flow stress and toughness of steel. The basic microalloying element in fine-grained microalloyed steels is niobium in combination with vanadium and titanium (Nb/V, Nb/Ti, and Nb/V/ Ti) (Refs. 1–3).

Weldability of steels depends on the base metal and filler metal, as well as the conditions in which the welded construction was made and the quality of construction. Of all the factors, the base metal has the greatest impact. Mechanical and technological properties of welded joints are directly dependent on the chemical composition (base metal and weld metal) and the structure of the weld metal and the heat-affected zone (HAZ) (Ref. 3).

The microstructure of the weld metal in joints of fine-grained steel consists of three basic modifications of ferrite: needle ferrite (acicular ferrite, AF), polygonal ferrite (primary ferrite, PF), and Widmanstätten ferrite (WF). These modifications occur due to different mechanisms of transformation and differently influence the values of strength and toughness of welded joints. Fine needle ferrite grains are mutually separated by boundaries with high-carbon content. This structure provides maximum resistance to crack development (Refs. 3–5). Depending on the thermal cycle of welding and the chemical composition of the weld metal in the high-temperature field, different morphological modifications of ferrite (primary, lamellar-plate, and needle-acicular) occur. High strength and plasticity in the weld metal of microalloyed steel is achieved by alloying the weld metal with various elements.

The chemical composition of the weld metal is characterized by significantly higher content of oxygen in relation to the chemical composition of steel (Ref. 3). Oxygen influences the transformation of austenite in the weld metal only if it is present in the form of oxide and oxide-sulfide inclusions. With increasing concentration of oxygen, the bainite in the microstructure of the weld metal is replaced by acicular ferrite. If the weld metal has less oxygen in it (which implies a smaller number of inclusions), the length-width ratio of the needles of acicular ferrite increases, which causes a decrease in toughness of weld metal (Ref. 3).

In the process of welding, the speed of metal cooling in the stage of crystallization is determined by the operating power of the welding machine. It was shown (Refs. 1–5) that during welding with low-alloyed weld metal, greater operating power affected the formation of polygonal ferrite within the primary austenite grains. The increase of cooling speed leads primarily to the formation of needle ferrite in the structure.

The structure of the HAZ depends on the properties of the base metal, welding

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KEYWORDS

Ferrous Metals
Steel Alloys
Welding
Microstructure

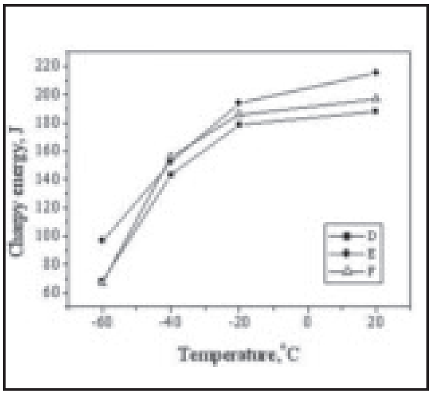

Fig. 1 — Variation in Charpy impact energy depending on temperature for different thicknesses of X65 steel strip: D, t_0 = 9.5 mm; E, t_1 = 11.0 mm; F, t_2 = 14.5 mm.

heat input, and the cooling speed (Refs. 1–5). The width of the HAZ depends on the welding parameters (current intensity, voltage, and welding speed) that are specific to heat input. To select the optimal parameters for welding, it is necessary to monitor the transformation of austenite under the influence of the welding thermal cycle, using the CCT diagram (Ref. 6).

The main criteria for the selection of a filler metal are yield stress, tensile strength, and toughness of the weld metal. Microalloyed steels of increased strength are sensitive to formation of cracks, and it is necessary that the filler metal, in addition to containing elements that improve the properties of the weld metal, contains elements that increase the resistance to the formation of cracks. Elements that are most commonly used for alloying weld metal are Mn, Cr, Ni, and Mo (Refs. 7–12).

The main objective of this study was to assess the impact of changes in chemical composition of the filler metal and the level of heat input during welding microalloyed steel X65 on the improvement of microstructural and mechanical properties of welded joints, especially the toughness at low temperatures.

Experimental Procedure

Materials: Base and Filler Metals

Base metal. Hot-rolled strips of microalloyed steel quality Nb/V mark X65 (according to API-5L) produced in Smederevo plant were chosen for experimental research.

Samples of steel strips were of different thicknesses and were obtained from three batches of microalloyed steel and marked D, E, and F. The chemical compositions of the microalloyed X65 steel from different batches and different thicknesses of steel strips (D, t_0 = 9.5 mm; E, t_1 = 11.0 mm; F, t_2 = 14.5 mm) are given in Table 1.

The results of testing the mechanical properties of the X65 steel strip samples and the calculated values of carbon equivalent (C_{eq}) are given in Table 2.

Samples for mechanical testing were taken perpendicular to the direction of rolling, and the results are expressed as the mean of three tests. Carbon equivalent values are calculated according to the formula $C_{eq} = C + Mn / 6 + (Cr + Mo + V) / 5 + (Ni + Cu) / 15)$ (Ref. 5).

Impact values for toughness of the base metal (X65 steel) at different test temperatures are given in Fig. 1.

Filler metal. For experimental welding using the shielded metal arc welding (SMAW) process, coated electrodes intended for welding microalloyed steels were chosen with different chemical compositions. Basic electrodes E8018-C1 (standard AWS A5.5-69) were selected and marked NM1 (alloyed with Ni and Mo), and N1 (alloyed with Ni). Marks of the mentioned electrodes and their size as well as chemical composition and mechanical properties of the weld metal according to the producers catalog are given in Table 3.

Experimental Welding

Preparation of Samples and Welding

Samples for experimental welding were cut from hot-rolled steel strips, so that the longer sample side-plate was in the direction of rolling, and then machine finishing of the sample edges was done.

Dimensions of samples were 300 × 125 × *t* mm, where *t* denotes the sample thickness. During welding the following parameters were varied: thickness of steel strip, t_0 = 9.5 mm, t_1 = 11.0 mm, t_2 = 14.5 mm; content of nickel in the electrode, NM1 contains 1.4% while N1 contains 1.10%; content of molybdenum in the NM1 electrode was 0.35%; heat input was varied on two levels for each steel strip thickness as follows: E_1 = 7.3 kJ/cm and E_2 = 18.5 kJ/cm.

Experimental welding of samples in horizontal position was performed continuously by SMAW with LKA-250 device using the welding parameters listed in Table 4. The interpass temperature during welding was controlled by contact thermometer. Experimental welding was performed without preheating the base metal because the calculated values for C_{eq} for all qualities of microalloyed X65 were below the borderline allowance. The number of weld passes for the experimental plates ranged from 5 to 10, and depended on the following factors: the diameter of the electrode, energy parameters, and planned heat input.

Microstructural Analysis of the Weld Metal

Microstructure of the weld metal (obtained with different filler metals and welding parameters) was compared with the expected microstructure that would be obtained according to CCT diagrams for different cooling speeds (Ref. 6). Investigations of the microstructure were performed by optical microscopy (OM) and scanning electron microscopy (SEM).

Microphotographs of characteristic places in the structure of the weld metal are given in Fig. 2A–F. The presence of different morphological forms of ferrite was noticed in the weld metal of all the welded joints. Acicular ferrite (AF), ferrite with a secondary phase (FS), and Widmanstätten ferrite (WF) were mostly found.

The microstructure of the weld metal (using electrode N1 on X65 steel strips) at low heat input consisted mainly of AF. For the smallest thickness of the steel strip (D), the AF was ~ 50%. With increasing thickness (E and F), the AF was lower (~ 35%), while the rest consisted of proeutectoid ferrite (PF) and secondary ferrite (FS) separated at grain boundaries — Fig. 2A, C, E. The expected effects of the nickel influence in forming needle ferrite were realized.

Table 1 — Chemical Composition of Microalloyed Steel X65

Steel Grade	Designation	C	Si	Mn	P	S	Al	Cu	Nb	V	N_2
		Chemical Composition*(wt-%)									
Nb/V	D	0.066	0.179	1.440	0.013	0.006	0.031	0.068	0.039	0.066	0.0099
	E	0.067	0.201	1.490	0.013	0.007	0.028	0.080	0.039	0.065	0.0099
X65	F	0.076	0.231	1.511	0.013	0.004	0.019	0.034	0.037	0.067	0.0103

*Fe is remainder.

In the weld metal microstructure of electrode NM1, about 35% AF was found in the strip of smallest thickness (D). The amount of AF increases with increasing thickness of strips (E and F) and reaches ~ 50%, while the rest consists of FS + SF — Fig. 2B, D, F. The expected effects of nickel in forming needle ferrite in the weld metal were realized, as well as the effect of molybdenum on the optimal relations of structural components.

The obtained results concerning the share of certain microconstituents were compared with the expected shares according to the appropriate CCT diagram. It was concluded that for all the examined samples, satisfactory microstructure was obtained in terms of content of microconstituents (results obtained within the limit values). Some deviation was obvious for the sample thickness D welded by electrode NM1 (Table 5).

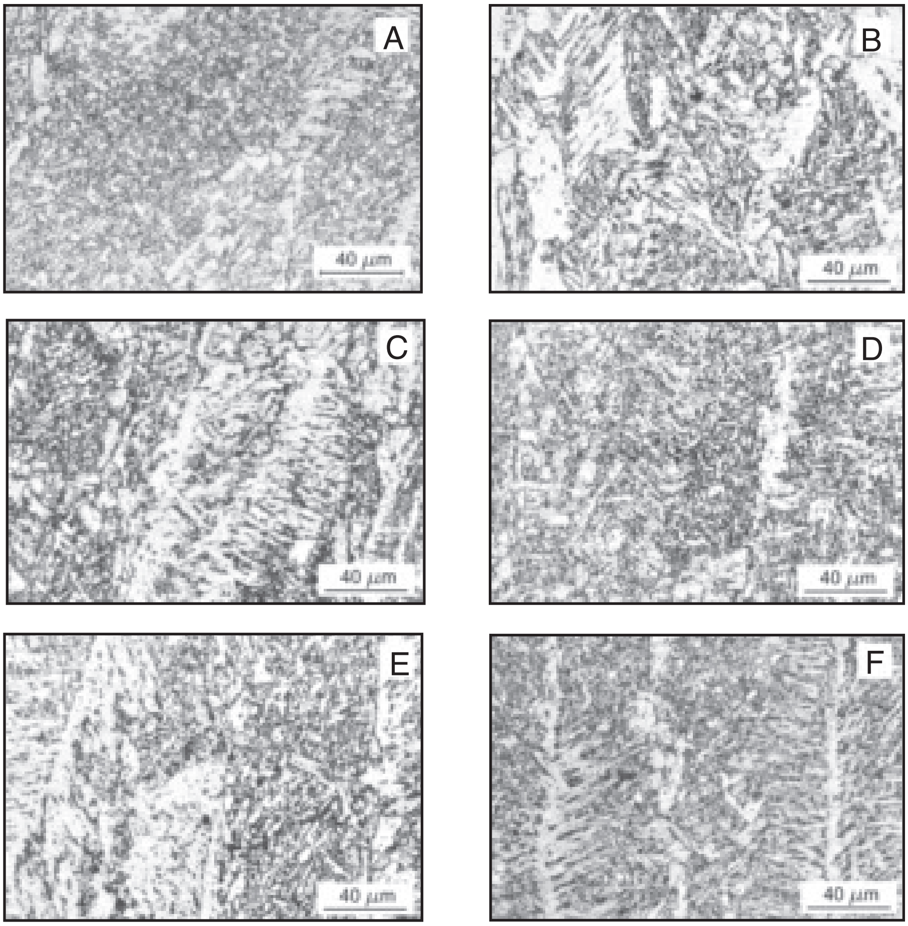

Fig. 2 — Microstructure of weld metal in the last pass. Welding of microalloyed steel X65 strips of different thicknesses (D, E, F) derived by SMAW process with electrodes N1 and NM1.

Microstructural Analysis of the HAZ

The microstructure of the base metal (steel X65) was fine-grained ferrite-pearlite — Fig. 3A–C. The appearance of the microstructure of the HAZ in the recrystallization zone at the weld interface is shown in Fig. 4A–I. The structure of pretransformed pearlite in the HAZ in the low-temperature zone (A_1 to A_3, according to the Fe-C diagram) depends on the starting structure, which differs in grain size — Fig. 4A–C. The appearance of the HAZ structure in the overheated zone at the weld interface are seen in Fig. 4D–I.

An analysis of the HAZ structure of the welded joints of X65 steel (quality E) along the interface of the base metal to the weld metal was performed, using SEM. The changes in the structure of the HAZ are shown in Fig. 5. A fine-grained ferrite-pearlite structure with small carbides distributed along the grain boundaries is shown in Fig. 5A, and in Fig. 5B, the structure in the recrystallization zone (below A_1), which is finer in relation to the structure of the base metal, is shown. In the precrystallization zone (Fig. 5C), the grain size is nonhomogenous. Untransformed ferrite grains are larger than in the previously observed structure, but the share of pearlite-ferrite structure, which occurred due to austenite transformation, is significantly smaller.

The appearance of the ferrite-bainite structure formed from the transformation in the area immediately above the A_3 temperature (normalization zone) is shown in Fig. 5D. In the overheated zone (Fig. 5E), a coarse ferrite-bainite structure occurred. Size, shape, and layout of the carbides along the boundaries of former austenite grains can be seen. The appearance of the structure at the weld interface is shown in Fig. 5F.

Table 2 — Mechanical Properties of Microalloyed Steel X65 and Carbon Equivalent C_{eq}

Steel Grade	Designation	Thickness, mm	0.2 YS, MPa	UTS, MPa	0.2 YS/ UTS	E_5, %	Carbon Equivalent C_{eq}
Nb/V	D	9.5	531	619	0.85	35	0.310
	E	11.0	537	635	0.84	35	0.320
X65	F	14.5	456	568	0.80	41	0.330

Table 3 — Basic Mark of Electrodes and Characteristics of the Weld Metal

		Chemical Composition of Weld Metal (wt-%)					Mechanical Properties of Weld Metal			
Designation	Diam. mm	C	Si	Mn	Ni	Mo	0.2 YS, MPa	UTS, MPa	E_5, %	kV, J (–40°C)
NM1	4.0	0.06	0.40	0.90	1.40	0.35	>520	640–710	>22	>125
N1	3.25	0.06	0.5	0.90	1.10	—	>460	570–650	>22	>47

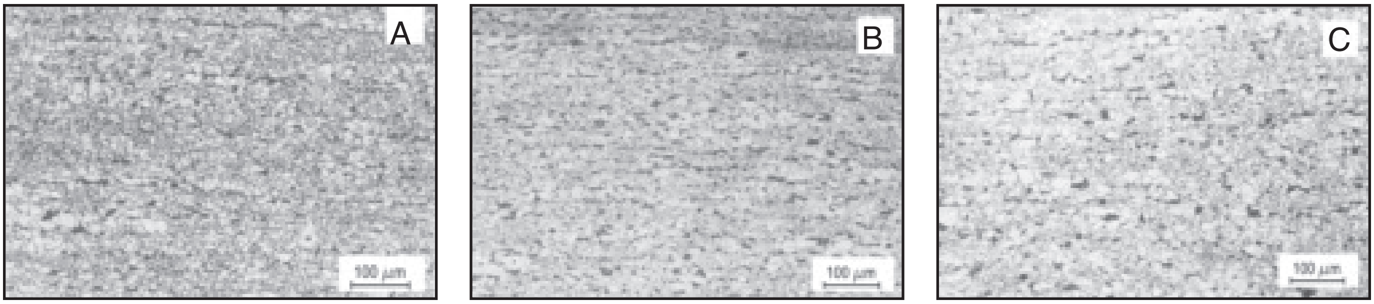

Fig. 3 — Microstructure of base metal (microalloyed steel X65) for different thicknesses of strip: D, t_0 = 9.5 mm; E, t_1 = 11.0 mm; F, t_2 = 14.5 mm.

Fractographic Analysis of the Weld Metal Fracture

After testing fracture toughness of the weld metal at temperatures of +20°, –40° and –60°C, fractographic analyses of the samples were carried out. Welded joints were made by using electrode N1 or NM1. The appearance of fracture surface of the weld metal made by using electrode N1 on microalloyed steel X65 (quality E) is shown in Fig. 6A–F.

The surface of all tested samples indicated the presence of a mixed or typical brittle fracture depending on the test temperature. The weld metal fracture of mixed character was also obtained when testing at –40°C — Fig. 6C, D. Morphological characteristics correspond to the dominant transcrystal brittle fracture that formed by tearing, with a ductile phase around the grains. General appearance of the fracture in the zone that is at the root of the weld metal is shown in Fig. 6C, while the presence of pores and microfractures in the zone of the weld metal face can be observed in Fig. 6D.

The morphological appearance of the characteristic fracture surface of weld metal obtained at –60°C, is shown in Fig. 6E, F. In this case, the fracture is completely of a brittle character (transcrystal and intercrystal). General appearance of the fracture in the middle of the weld metal, which is typically brittle (transcrystal and intercrystal), is shown in Fig. 6E. The transcrystal brittle fracture with microspaces (pores) in the weld metal is presented in Fig. 6F. Figure 7A–F shows the appearance of the fracture surface of the weld metal made with electrode NM1 on X65 steel (quality E, t_1 = 11.0 mm).

Figure 7B shows the appearance of ductile fracture in the middle of the tube (middle of the weld metal). Elongation of dimples in the direction of deformation and partial filling of the dimples with carbide and other particles was noticed.

In the welded joint sample that was broken at –40°C, the fracture surface has a typical appearance of a brittle fracture of transcrystal and intercrystal character. Also, the fracture surface in the middle of the weld metal tested at –40°C shows brittle fracture of transcrystal and intercrystal character — Fig. 7C. Figure 7D shows brittle fracture caused by tearing.

Figure 7E, F shows the fracture surface along the height of weld metal of the sample that was tested at –60°C. The analyzed sample showed brittle fracture caused by tearing — Fig. 7E. Figure 7F shows general appearance of a brittle fracture in the middle of the weld metal.

The results of fractographic analysis of weld metal (using electrode N1) showed that the fracture was mixed (Fig. 6A, B), while in the weld metal (when using electrode NM1), the fracture was ductile on the entire cross section — Fig. 7A, B. The results were obtained at 20°C. The share of brittle fracture in the weld metal when lowering the temperature significantly increases and at –40°C a transcrystal fracture was observed — Fig. 6C, D and 7C, D. In both groups of samples tested at –60°C, brittle fracture of transcrystal and intercrystal character was clearly observed — Figs. 6E, F and 7E, F. Fractographic analysis has also shown that a more favorable weld metal structure was achieved when using electrode NM1 (1.4% Ni, 0.35% Mo) in relation to the weld metal structure when using electrode N1 (1.0% Ni) at all test temperatures.

Table 4 — Welding Parameters of Microalloyed Steel X65 Samples

Base Metal			Filler Metal		No. of	Energy Parameters			$\bar{E}$
Steel Grade	Designation	Thickness, mm	Designation	∅ mm	passes	U, V	I, A	V, cm/min	kJ/cm
			N1	3.25	6	25	120	17.2	16.8
	D	9.5	N1	3.25	9	25	115	24	6.8
			NM1	4.0	5	25	135	16	12.3
Nb/V			N1	3.25	9	27	125	26	9.2
	E	11.0	N1	3.25	9	25	118	25	7.3
X65			NM1	4.0	5	25	140	15	13.7
			N1	3.25	10	25	125	18	10.8
	F	14.5	N1	3.25	4	25	118	19	9.1
			NM1	4.0	7	25	150	17	16.6

Mechanical Properties of Welded Joints

Tensile strength. Results of tensile strength tests of base metal of various thicknesses are given in Fig. 8A, and the results of tensile strength of welded joints are clearly given in Fig. 8B. Tensile strength testing was performed on three samples for each thickness of the steel strip. It was noted that the location of fracture of specimens depended on the thickness of the base metal, as follows: at thickness t = 9.5 mm, the fracture occured in the base metal; at thickness t = 11 mm, the fracture occured in the weld metal; at thickness t = 14.5 mm the fracture occcured in the HAZ regardless of the type of filler metal, the number of passes, and the level of heat input during welding.

Hardness. A change of hardness in welded joints depends on the chemical composition of filler metals, welding parameters, and number of passes. In samples of welded joints, hardness measurements were performed in the cross section along the line that runs 2 mm parallel to the weld metal face (L_1), and along the middle of the height of the weld metal (L_s). For certain qualities of base metal and filler metal, change in hardness curves through the welded joint were constructed. Measuring points are shown on the sketch in Fig. 9A–C. A somewhat larger decline of hardness in the HAZ and a larger increase in hardness in the weld metal (in line L_1) in relation to the meas-

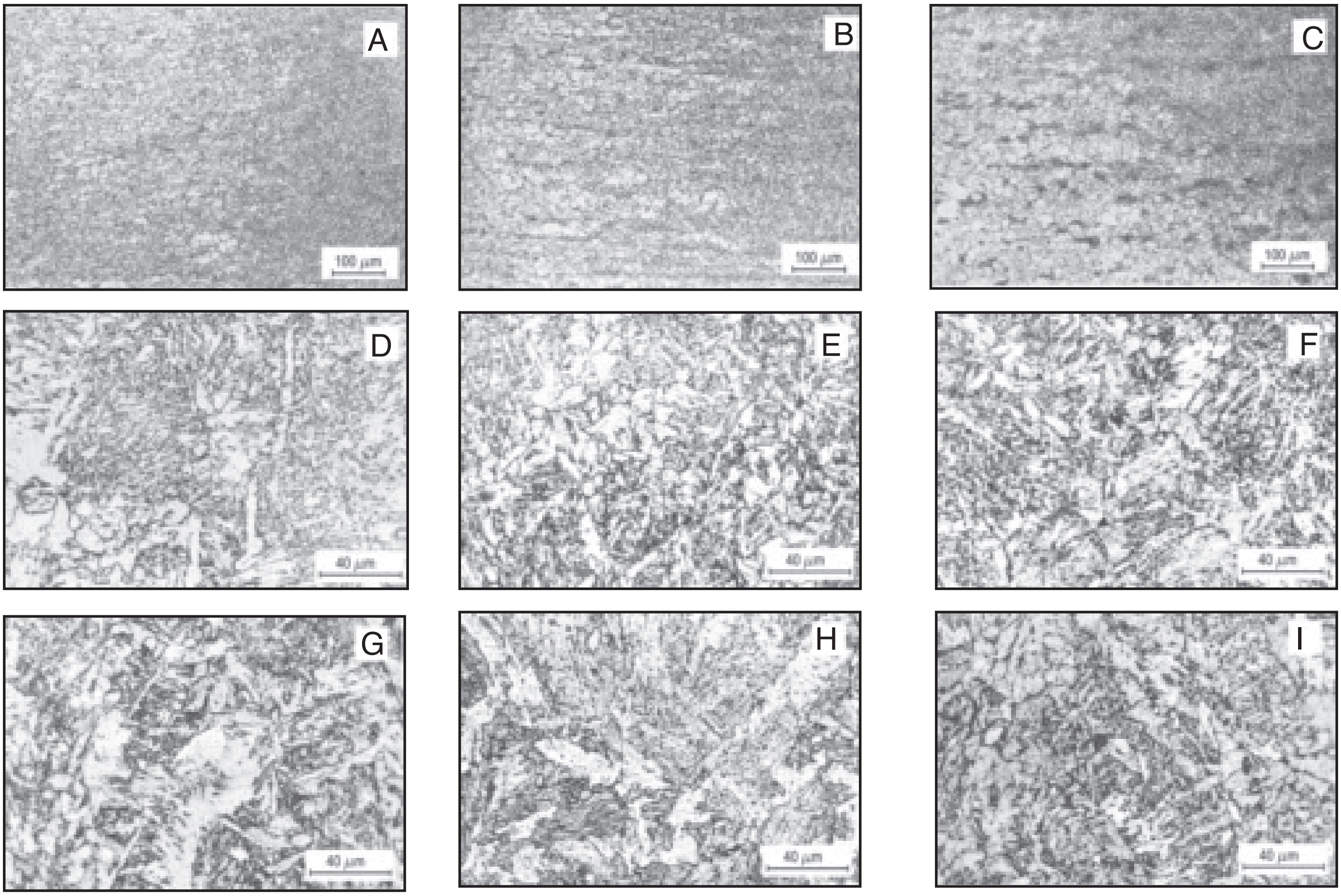

Fig. 4 — Microstructure of HAZ of welded joints of microalloyed steel X65 of different quality (D, E, F). A, B, and C recrystallization and precrystallization zone: A — D, E_1 = 12.3 kJ/cm; B — E, E_2 = 3.7 kJ/cm; C — F, E_3 = 16.6 kJ/cm. D–I weld interface: D — D, E_1 = 6.8 kJ/cm, N1; E — E, E_2 = 9.2 kJ/cm, N1; F — F, E_3 = 10.8 kJ/cm, N1; G — D, E_1 = 12.3 kJ/cm, NM1; H — E, E_2 = 13.7 kJ/cm, NM1; I — F, E_3 = 16.6 kJ/cm, NM1.

uring points that are in the middle of the height of the weld metal (L_s) was observed. In samples of welded joints in steel F, a lower hardness was observed in the HAZ and the weld metal compared to steels D and E. It was also noticed that an increased number of passes had an impact on the reduction of hardness in the weld metal (L_s).

Toughness. The impact test was carried out using the standard Charpy pendulum. The results obtained depending on test temperature are given in Fig. 10A–C. A change of toughness in the weld metal from electrodes N1 and NM1 in steel D, with different levels of heat input is shown in Fig. 10A. Some improvement of toughness was noted at lower temperatures in weld metal from electrode NM1.

Discussion of Results

The results of microstructural examinations and fractographic analyses of weld metal and HAZ of welded joints in steel X65 have shown the impact of filler metals (N1 and NM1) and welding parameters on improving the structure of the weld metal and HAZ. The microstructure of steel X65 is a homogeneous ferrite-pearlite one and strip-like directed toward the rolling direction — Fig. 3A–C. For steel strip thickness of 9.5 mm, the grain size is 11; for thickness of 11.0 mm, the grain size is 9.5; and for thickness of 14.5 mm, the grain size is 9. It can be seen that steel strip

Table 5 — Share of Certain Ferrite Morphologies in Microalloyed Steel X65

Base Metal	D(t_0 = 9.5 mm)		E (t_1 = 11.0 mm)		F (t_2 = 14.5 mm)	
Filler Metal	N1	NM1	N1	NM1	N1	NM1
Line Energy	E_1=6.8 kJ/cm	E_3=16.8 kJ/cm	E_2=9.2 kJ/cm	E_3=13.7 kJ/cm	E_1 =9.1 kJ/cm	E_3+16.6 kJ/cm
Microstructure of Weld Metal	~50% AF remainder PF partially coarse grain in blocks and FS	~35%AF coarse WF and coarse grain PF+FS	~36%AF Rest PF+FS and coarse WS	~50%AF Rest PF+FS and a small amount of WF	~35%AF Rest very coarse PF WF	~50%AF Rest PF+FS+WF
Microstructure CCT diagram	20–48%AF Rest FS	5–75%AF Rest PF+FS+WF	20–48% AF Rest PF+FS+WF	50–75% AF Rest PF+FS+WF	20–48% AF Rest PF+WF	50–75% AF Rest PF+FS+WF

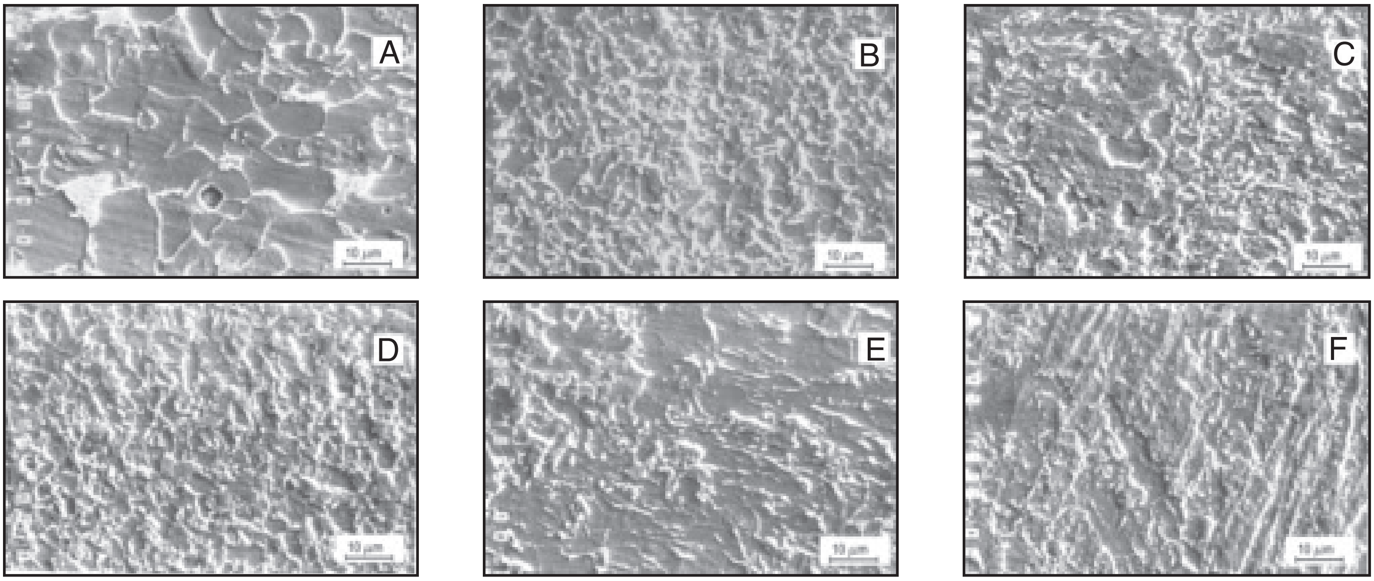

Fig. 5 — SEM, microstructure of HAZ of welded joint of microalloyed steel X65 (quality E, t_1 = 11.0 mm). A — Base metal (ferrite + pearlite); B — normalization zone; C — overheating zone; D — fine-grain zone (ferrite + pearlite); E — overheating zone; F — weld interface (column-like crystals).

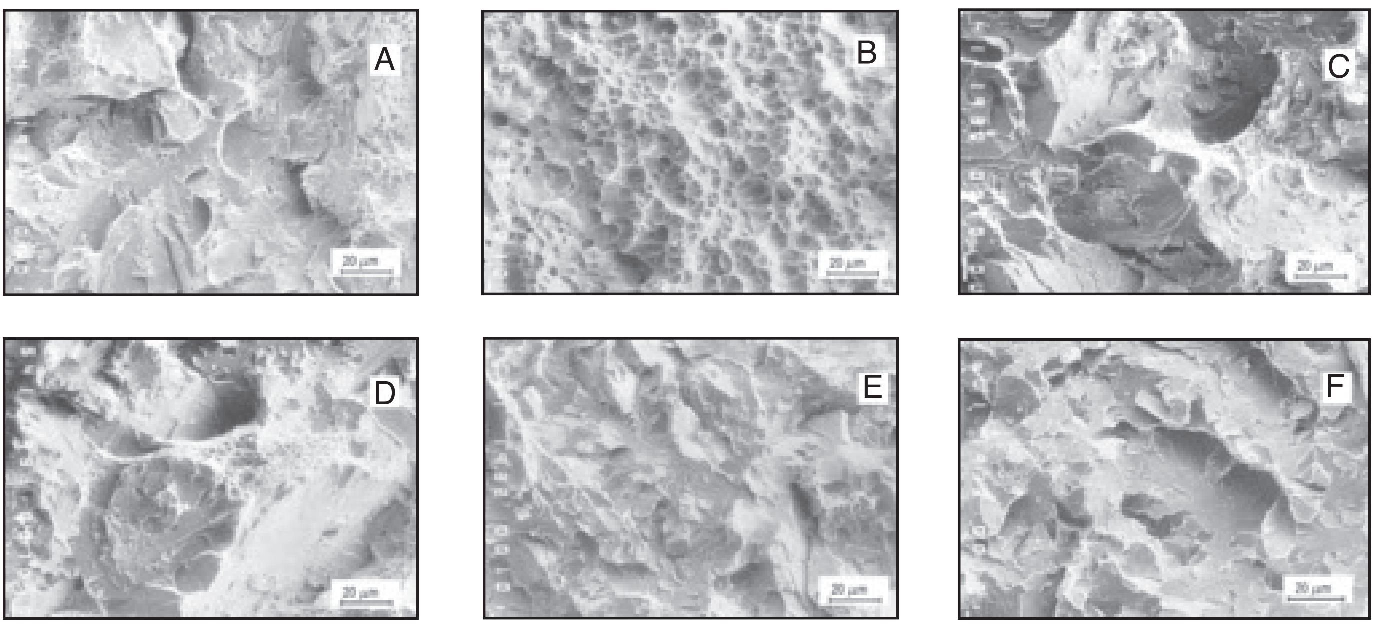

Fig. 6 — SEM, fracture surface of weld metal made by using electrode N1 on microalloyed steel X65 (quality E, t_1 = 11.0 mm). A — Mixed fracture with dominant transcrystal brittle fracture (+20°C); B — ductile fracture with small cavities containing particles of sediment (+20°C); C — transcrystal brittle fracture in the middle of the weld metal (–40°C); D — mixed fracture mainly transcrystal (–40°C); E — brittle fracture of transcrystal and intercrystal character (in the middle of the weld metal) (–60°C);F — transcrystal brittle fracture with the presence of micro openings (in the middle of the weld metal)(–60°C).

of a minimal thickness (9.5 mm) has the finest structure and a satisfactory homogeneity in the cross sections of samples.

The appearance of weld metal microstructure at characteristic places in the welded joints can be seen in Fig. 1A–F. The presence of different morphological forms of ferrite was noticed in the weld metal structure of all samples. Mostly present were acicular ferrite (AF), ferrite with a secondary phase (FS), and Widmanstätten ferrite (WF).

For the samples welded with electrode N1 and with low heat input, the weld metal microstructure consisted of AF, in amounts to ~ 50% for the minimal thickness of steel strip. With the increase in and strip thickness, the share of AF was reduced and to ~ 35%, while the rest of the structure consisted of PF and FS separated along grain boundaries — Fig. 1A, B.

In the weld metal samples welded with electrode NM1, approximately 35% of AF was found (for the minimal thickness of steel strip, t_0 = 9.5 mm). With an increase in strip thickness, the amount of AF increased and reached ~ 50%, while the rest consisted of FS + SF — Fig. 1C–F.

By comparison of weld metal microstructures of both groups of tested samples with the expected microstructure, which would be derived from the appropriate CCT diagram, it can be concluded that satisfactory compliance has been achieved in terms of microstructure.

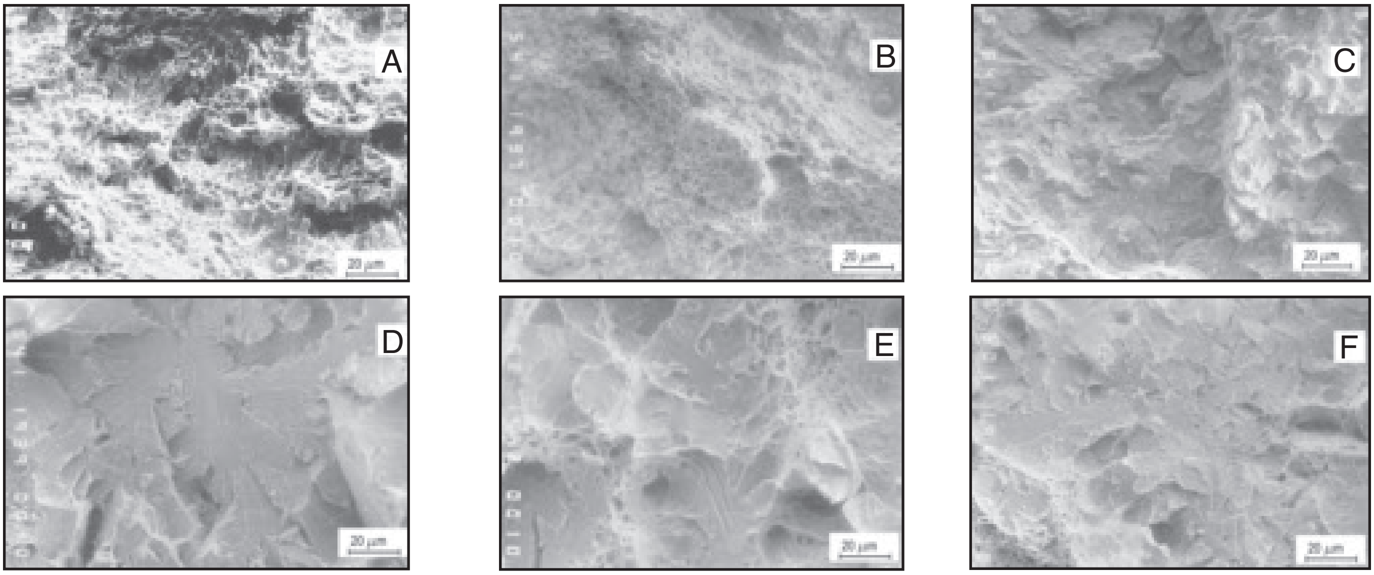

Fig. 7 — SEM, fracture surface of the weld metal made by using electrode NM1 on microalloyed steel X65 (quality E, t_1 = 11.0 mm). A, B — Ductile fracture (–20°C); C — brittle fracture of transcrystal and intercrystal character, (–40°C); D — brittle fracture caused by tearing (–40°C); E — brittle fracture of trans crystal and intercrystal character in the middle of the weld metal, (—60°C); F — brittle fracture in the middle of the weld metal (–60°C).

In the HAZ, changes in grain size were observed, as well as their growth toward the weld interface in the overheated zone where a coarse ferrite-bainite structure was formed with carbides arranged along boundaries of former austenite grains — Figs. 3–5.

The results of fractographic analysis after tests performed at temperatures of +20°, –40°, and –60°C are given in Figs. 6 and 7. Comparative analysis of these results indicated a better quality of weld metal structure when using electrode NM1 (1.4% Ni, 0.35% Mo) in relation to the weld metal structure when using electrode N1 (1.0 % Ni) at all test temperatures. The content of nickel and molybdenum in the filler metal, in addition to C and M, is significant for achieving the optimum ratio of structural components in the weld metal. Based on the analysis of measured values of tensile strength of the welded joints, it can be concluded that values are higher than the base metal (for steels D and E), and at the level of the base metal (for steel F) as shown in Fig. 8A and B.

Analysis of the results of hardness testing showed that an increased number of passes had an impact on lowering weld metal hardness (as measured at the middle of the height of the weld metal) — Fig. 9A–C. Results of impact toughness testing of welded joints showed that higher toughness values at lower temperatures were achieved with electrode NM1 — Fig. 10A–C.

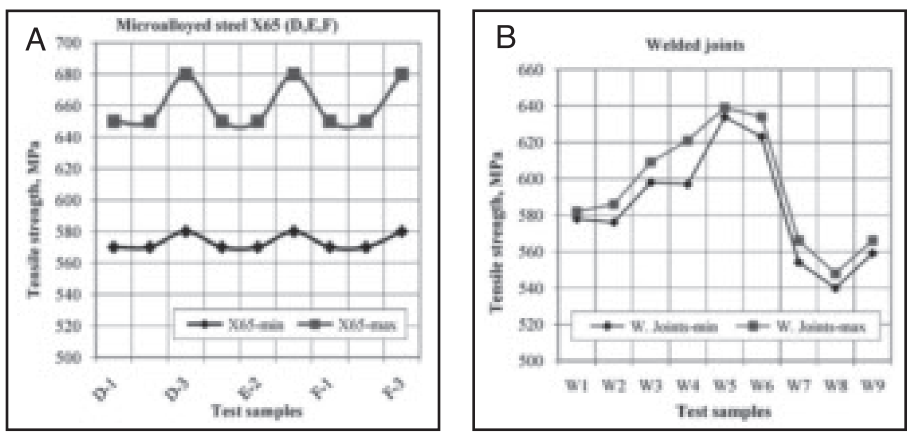

Fig. 8 — Tensile strength. A — Base metal, microalloyed steel X65; B — welded joints:
W1 (D-N1/E_1 = 6.8 kJ/cm, 6 passes)
W2 (D-N1/E_2 = 12.3 kJ/cm, 9 passes)
W3 (D-NM1/E_3 = 16.8 kJ/cm, 5 passes)
W4 (E-N1/E_1 = 7.3 kJ/cm, 9 passes)
W5 (E-N1/E_2 = 9.2 kJ/cm, 9 passes)
W6 (E-NM1/E_3 = 13.7 kJ/cm, 5passes)
W7 (F-N1/E_1 = 9.1 kJ/cm, 10 passes)
W8 (F-N1/E_2 = 10.8 kJ/cm, 4 passes)
W9 (F-NM1/E_3 = 16.6 kJ/cm, 7 passes)

Conclusions

Based on the experimental results obtained by examining the impact of filler metal quality and welding parameters on the structural change in the weld metal and HAZ of microalloyed X65 steel, the following conclusions were made:

1) Addition of Ni into the weld metal with the filler metal marked N1 (1.0% Ni) improved the formation of acicular ferrite, while the addition of Ni and Mo with the filler metal marked NM1 (1.4% Ni, 0.35% Mo) had an effect on achieving the optimum ratio of structural components (AF + PF, FS).

2) In the weld metal for electrode NM1 (steel strip thickness t_2 = 14.5 mm, heat input E_2 = 16.8 kJ/cm, electrode NM1), the AF amount was over 50% in the last pass, and the rest consisted of PF and FS. The same proportion of AF was achieved in the weld metal when using electrode N1 (steel strip of minimum thickness t_0 = 9.5 mm and heat input E_1 = 6.8 kJ/cm).

3) Microstructural analysis of the HAZ of welded joints obtained with different levels of heat input (E_1 = 13.7 kJ/cm and E_2 = 16.5 kJ/cm) showed that the structure was finer with a lower level of heat input in the normalizing and overheated zone.

4) Fractographic analysis of the fracture surface of the weld metal obtained by using electrode NM1 at +20°C shows ductile fracture. On specimens tested at –40°C, a mixed fracture with a large share of transcrystal fracture was observed. At –60°C, a brittle fracture is evident of transcrystal and intercrystal character.

5) In microalloyed X65 steel, the best quality of welded joints was achieved with electrode NM1 and a heat input of 13.7 to 16.5 kJ/cm.

6) The test results for mechanical properties of welded joints confirmed the re-

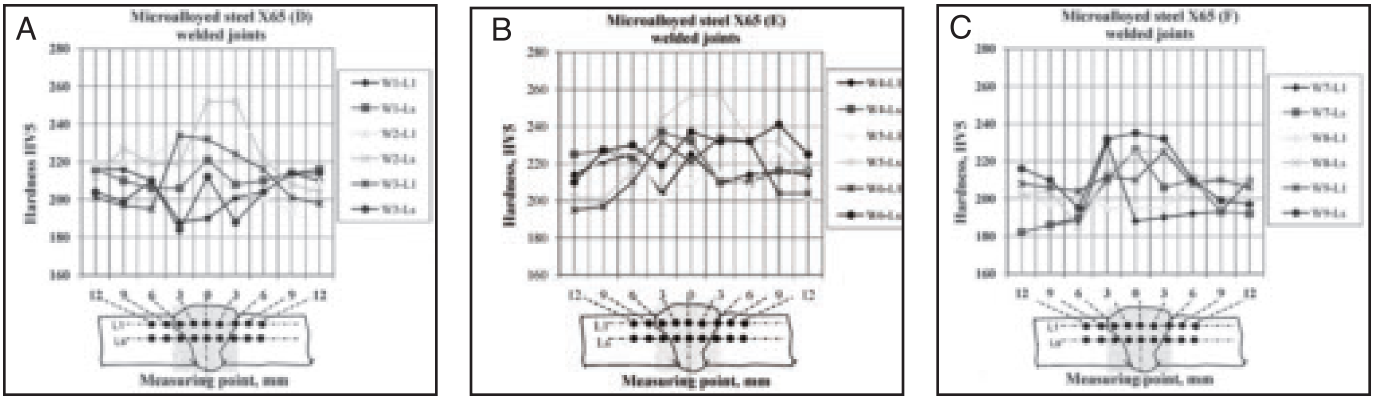

Fig. 9 — Change of hardness in the cross section of welded joints. A — W1 (D-N1/E_1 = 6.8 kJ/cm, 6 passes), W2 (D-N1/E_2 = 12.3 kJ/cm, 9 passes), W3 (D-NM1/E_3 = 16.8 kJ/cm, 5 passes); B — W4 (E-N1/E_1 = 7.3 kJ/cm, 9 passes), W5 (E-N1/E_2 = 9.2 kJ/cm, 9 passes), W6 (E-NM1/E_3 = 13.7 kJ/cm, 5 passes); C — W7 (F- N1/E_1 = 9.1 kJ/cm, 10 passes), W8 (F-N1/E_2 = 10.8 kJ/cm, 4 passes), W9 (F-NM1/E_3 = 16.6 kJ/cm, 7 passes).

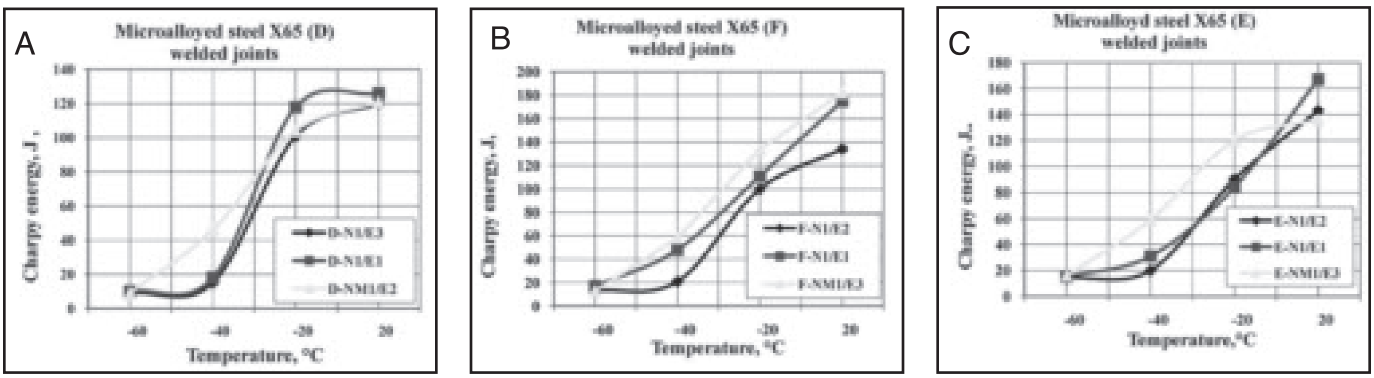

Fig. 10 — Impact toughness of weld metal depending on test temperature. A — D (N1/E_1 = 6.8 kJ/cm, N1/E_2 = 12.3 kJ/cm i NM1/E_3 = 16.8 kJ/cm); B — E (N1/E_1 = 7.3 kJ/cm, N1/E_2 = 9.2 kJ/cm i NM1/E_3 = 13.7 kJ/cm); C — F (N1/E_1 = 9.1 kJ/cm, N1/E_2 = 10.8 kJ/cm i NM1/E_3 = 16.6 kJ/cm)

sults of metallographic examinations. Welded joints with better characteristics were obtained with the electrode NM1.

Acknowledgments

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A New Chromium-Free Welding Consumable for Joining Austenitic Stainless Steels

A novel Ni-Cu-based consumable was developed to reduce Cr(VI) in the fume generated during welding of Type 304L stainless steel

BY J. W. SOWARDS, D. LIANG, B. T. ALEXANDROV, G. S. FRANKEL, AND J. C. LIPPOLD

ABSTRACT

Federal legislation was enacted in 2006 reducing the permissible exposure limit (PEL) of workers, including welding-related personnel, to Cr(VI) by an order of magnitude. Achieving the new level may not always be practical during fabrication or repair of stainless components in tightly enclosed locations. Therefore, the current study was performed to evaluate the use of Ni-Cu-based welding consumables to weld Type 304L stainless steel while achieving significant reductions of Cr(VI) bearing compounds in welding fume. Consumables were made in bare wire form for gas tungsten arc welding (GTAW) and in coated form for shielded metal arc welding (SMAW). During the development of these consumables, several generations were produced with each improving on the previous generation. Weldability was a primary focus during the development process because switching from a stainless steel welding consumable to a Ni-based alloy could potentially exacerbate weldability issues such as solidification, liquation, and ductility dip cracking. Welds were deposited on Type 304L base metal with the consumables developed during the study and subjected to various tests to evaluate mechanical and corrosion behavior, resistance to weld cracking issues typical of Ni-based alloys, and fume generation characteristics. Weld mechanical properties and weldability performance were similar in nature to other austenitic Ni-based alloys and stainless steels. By using the Ni-Cu based consumable to weld stainless steel, Cr(VI) in the welding fume was reduced by two orders of magnitude from conventional stainless steel welding electrodes.

Introduction

Environmental and occupational safety awareness is becoming increasingly important in today's workplace. This is impacting the welding industry because government standards are decreasing the allowable levels of certain elements and species present in welding fume (Ref. 1). Cr is typically found in stainless steel welding fume because it is one of the major alloying additions used in such consumables. Welding fume generated during stainless steel welding has been shown to contain compounds such as CrO_3, Na_2CrO_4, and K_2CrO_4, which contain Cr in its hexavalent state, i.e., Cr(VI) (Refs. 2–4). Since at least the mid 1970s, United States government agencies such as the National Institute for Occupational Safety and Health (NIOSH) have labeled Cr(VI) compounds as suspected carcinogens (Ref. 5). Starting in 1988, the Occupational Safety and Health Administration (OSHA) began to consider all Cr(VI) compounds as potential carcinogens (Ref. 6). Most recently in 2006, OSHA released its latest ruling that drastically reduced the permissible exposure limit (PEL) of Cr(VI) compounds in the vicinity of welding personnel from 52 to 5 μg m^{-3}. This ruling is a result of their findings that workers are at an elevated risk of developing lung cancer and asthma, as well as nasal and skin damage due to Cr(VI) exposure. The exposure level for total welding fume prior to 1989 was set at 5 mg m^{-3} over an 8-h work day (Ref. 7). This limit was abandoned after 1989 and no longer became enforceable since the composition of welding fume was deemed to vary too widely, and because of possible interactions between various constituents in the fume.

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KEYWORDS

Cr(VI)
Ni-Cu
Type 304L
GTAW,
SMAW
Permissible Exposure Limit
Generation I, II, III, and IV Consumables

With regard to Cr(VI) fume control, in particular, several options have been suggested to remediate overexposure once it has been found that the PEL is exceeded (Ref. 8). The welding process may be changed from a process that uses alkali metals in the flux to a bare wire process. The presence of alkali metals can greatly increase Cr(VI) formation and have higher inherent fume generation rates. Changing shielding gasses or making welding parameter adjustments may also reduce fume generation rates. In addition to process modifications, some research has suggested compositional modifications. Zn additions made to metal cored stainless steel wires showed that Zn preferentially reacts with available oxygen during fume formation, thus reducing the oxidation of chromium, but with increased fume generation rates (Ref. 9). The replacement of potassium with lithium was also performed demonstrating the reduction of Cr(VI) by reduction of potassium chromate, although it was unclear how these additions would affect weld soundness. A secondary gas mixture has been applied to interfere with the reaction between ozone and chromium to prevent CrO_3 formation (Ref. 10).

For situations where it is difficult to implement engineering controls, alternative

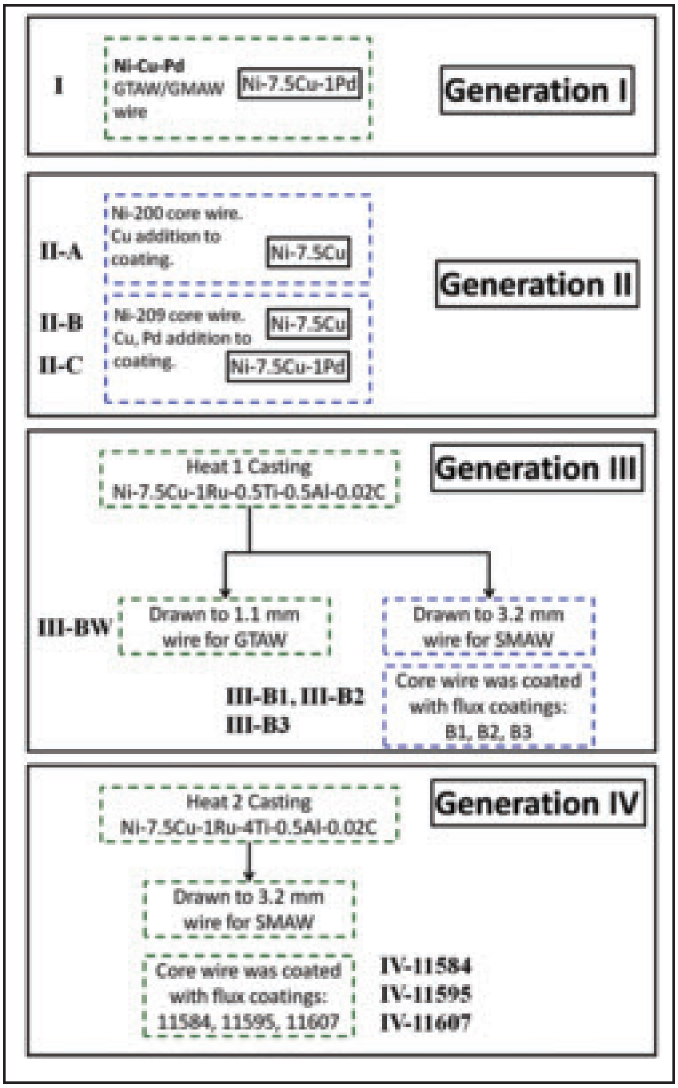

Fig. 1 — Ni-Cu welding consumable development chart showing nomenclature used to identify consumables for this study.

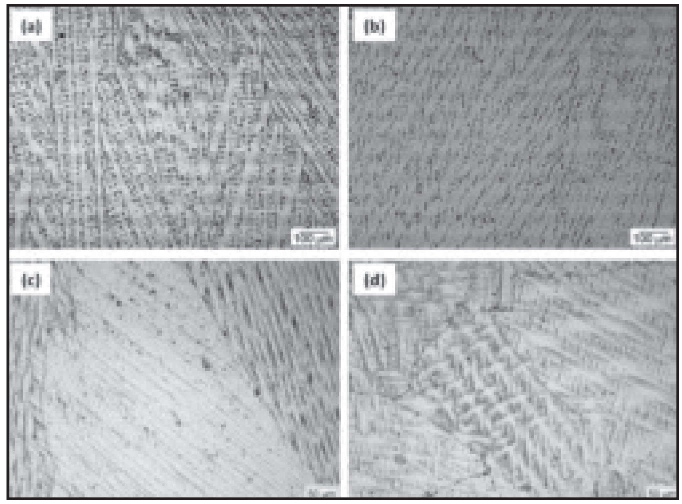

Fig. 2 — Representative weld metal microstructures of weld deposits. A — Generation II-B; B — II-C; C — III; D — IV.

approaches have been considered to minimize welder exposure to Cr(VI). One such approach was to investigate the possibility of using a filler metal that will produce satisfactory welds on stainless steel while minimizing the generation of Cr(VI) to acceptable limits in the welding fume (Refs. 11–15). Such a filler metal would need to have good weldability, corrosion characteristics comparable to common stainless steel alloys (such as Type 304), and ultimately lack the element Cr to prevent formation of Cr(VI) compounds during fume formation. Previous research showed that use of a welding consumable based on the Ni-Cu (Monel®) system to join stainless steel exhibited suitable corrosion resistance (Refs. 11–14), as well as weld compatibility and acceptable mechanical properties (Ref. 15).

The Ni-Cu system was selected based on its galvanic compatibility with austenitic stainless steel in chloride environments, and noble alloying elements such as Pd were added to increase resistance to localized corrosion phenomena such as pitting and crevice corrosion. The optimal composition to achieve adequate corrosion resistance was determined to be Ni-(5-10) Cu-1Pd (Ref. 12). Concentrations of Cr in the welding fume were reduced by a factor of 20 during welding of Type 304 stainless steel with Monel as a consumable (Ref. 15). Because the element Cr was not alloyed in the consumable, Cr present in the fume resulted only from vaporization of the base metal. The contribution to fume generation from the base metal has been shown to produce fume at a rate four orders of magnitude lower than the consumables themselves (Ref. 2); thus, Cr reductions in welding fume produced by a Cr-free consumable are expected to be significant.

Previous studies have focused primarily on testing the feasibility of using Ni-Cu consumables during welding of Type 304L austenitic stainless steel (Refs. 11–15). The studies utilized the gas metal arc welding (GMAW) and gas tungsten arc welding (GTAW) processes to deposit welds for evaluation of mechanical properties and corrosion resistance. Another target form of this welding consumable was for the shielded metal arc welding (SMAW) process because it is highly versatile, portable, and widely used. Also, stainless steel SMA welding generally has greater concentrations of Cr(VI) in the welding fume compared to bare wire processes (Refs. 2, 3). The current study reports on the development of a Ni-Cu-based consumable for the SMAW process as well as a bare wire consumable for the GTAW process. This study focused on evaluations of weldability throughout the development process to promote direct implementation of such a consumable. Weldability is defined by the American Welding Society as the capability of successfully fabricating a material by welding and the ability to have that material perform satisfactorily once placed into service (Ref. 16). Based on this definition, the following aspects of weldability were evaluated: mechanical behavior, corrosion resistance, weld cracking resistance, and fume generation rates and composition.

Consumable Development Summary

Welding consumables used in this study were developed in an iterative manner to achieve the optimum deposit composition and minimize potentially harmful fabrication-related issues (Ref. 17). Two types of welding consumables were used during experimentation: a bare wire electrode deposited with the GTAW process and several different SMAW consumables. These are defined using a "Generation" scheme based on the composition of the consumable. The generation classification is provided in Fig. 1, which includes the nominal composition and type of welding consumable. Directly outside of each box containing the different consumables of each generation are an abbreviation for each consumable type, for example II-A, II-B, and III. These abbreviation names are used for the remainder of the document. To meet corrosion require-

Table 1 — Generation II SMAW Consumable Compositions (wt-%) Determined with Mass Spectrometry and Interstitial Analysis

Consumables	C	Mn	Si	Fe	Cr	S	P	Cu	Ni	Al	Ti	Pd
Ni-209 core wire	0.021	0.24	0.21	—	—	—	—	—	94.5	0.046	4.29	—
Ni-Cu deposited weld metal	0.022	0.32	0.7	0.09	0.01	0.001	0.003	8.01	89.07	0.07	1.56	—
Ni-Cu-Pd deposited weld metal	0.016	0.147	1.08	0.08	0.04	0.005	0.005	4.94	bal	0.05	0.97	0.24

Table 2 — Compositions (wt-%) of Wire Drawn from Castings Used for Generation III and IV Wire Consumables as Determined with Mass Spectrometry and Interstitial Analysis

Consumables	C	N	O	S	P	Si	Cu	Ni	Al	Ti	Ru
Heat 1 (Generation III)	0.014	<0.001	0.0031	<0.001	<0.005	—	8.20	89.3	0.56	0.53	1.36
Heat 2 (Generation IV)	0.019	—	—	<0.002	<0.002	0.10	7.78	85.85	0.83	4.31	1.11

Table 3 — Compositions (wt-%) of Base Metals Used for Weld Deposits

Heat	Composition (wt-%)									
	C	Cu	Fe	Mn	Mo	Ni	Cr	Si	N	P	S
BM1 304L (6.4 mm)	0.03	—	bal	1.24	—	8.08	18.1	0.37	NA	NA	NA
9JA7 304L (6.4 mm)	0.02	—	bal	1.76	—	8.11	18.1	0.36	0.08	0.030	0.003
95L9 304L (9.5 mm)	0.01	0.41	bal	1.78	0.28	8.36	18.3	0.29	0.1	0.030	0.003

ments as shown below, target compositions of the consumables were Ni-7.5Cu-1Pd and Ni-7.5Cu-1Ru with other alloying additions to improve weldability.

The Generation I consumable was produced in limited quantity to evaluate the corrosion behavior and mechanical properties of the Ni-Cu-Pd target composition as reported elsewhere (Ref. 18). This consumable was used in conjunction with both the GTAW and GMAW processes to make high-quality welds.

Generation II consumables were the first SMAW consumables developed. Cu and Pd powders were added to a flux coating, which was extruded over Ni-200 and Ni-209 (Ni-209 provided better weld deoxidation than Ni-200) core wire. Compositions of the Ni-209 core wire, as well as Ni-Cu and Ni-Cu-Pd all-weld-metal deposits are shown in Table 1. All-weld-metal deposits were obtained by making a single weld pass with the SMAW consumables on a copper chill block.

Beginning with the Generation III consumables, additions of Cu and Ru were made directly to the core wire because transfer efficiency was determined to be insufficient to reach target levels in Generation II welds (see Table 1). The noble element Ru was found to be an acceptable alternative to Pd from a corrosion standpoint and at reduced cost (Ref. 19). A custom heat of filler metal material (target composition Ni-7.5Cu-1Ru-0.5Al-0.5Ti-0.02C) was cast with a two-stage vacuum induction melting and electroslag remelting (VIM/ESR) process to ensure alloy purity and homogeneity. The actual composition of the Ni-Cu-Ru casting (Heat 1) is provided in Table 2. The casting was extruded into 3.2-mm- (0.125-in.-) and 1.1-mm- (0.045-in.) -diameter wires for use with SMAW and GTAW, respectively. The SMAW wires were coated with three different batches of flux coatings. All of the coated consumables produced multipass welds that contained unacceptable levels of porosity. Surprisingly, single-pass welding was successfully performed, and it is surmised that some elements in the Type 304L base metal (probably Cr, Mn, and Si) aided in reducing porosity as they mixed with the molten weld pool during welding trials. Welds made with the bare wire GTAW process were free of porosity because argon shielding gas was used. In the current work, when Generation III welds are mentioned with regard to corrosion and weldability testing, they were deposited with the GTAW process (Generation III-BW) because the SMAW deposits contained significant levels of porosity in multipass welds. Gas tungsten arc welds contained the nominal composition that was desired of the SMA welds; therefore, much of the weldability evaluation utilized GTAW deposits. It should be noted that the GTAW wire has potential use with the GMAW process; however, such an evaluation was beyond the scope of the current study and further work would be required to evaluate GMA weldability.

A second heat of filler metal material (Generation IV) was produced containing increased Ti content (target composition of Ni-7.5Cu-1Ru-0.5Al-4Ti-0.02C). The actual heat composition is shown in Table 2. This ingot was reduced to 3.2-mm wire electrodes, which were coated with several iterations of flux coatings (designated 11584, 11595, and 11607) until satisfactory electrode operability was achieved as deemed by certified welders and staff who specialize in the development of flux-based consumables.

Experimental Procedures

Welding Procedures

Shielded metal arc welds were produced using 3.2-mm Generation II, III, and IV welding electrodes on 6.4- and 9.5-mm-thick Type 304L base metal (Table 3). Welding current was maintained in the range of 120–130 A, voltage between 24–25 V in the DC electrode positive configuration, and travel speed at approximately 2.5 mm s^{-1} for all welded samples produced with the SMAW consumables. During GTA welding with Generation III-

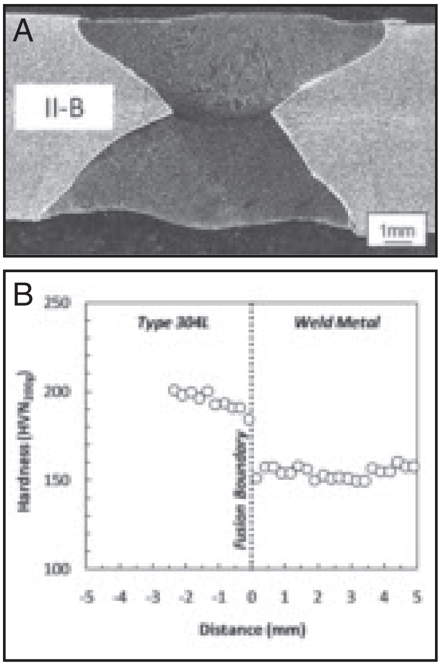

Fig. 3 — Representative across Generation II weld deposited on Type 304L stainless steel. A — Weld cross section; B — microhardness traverse.

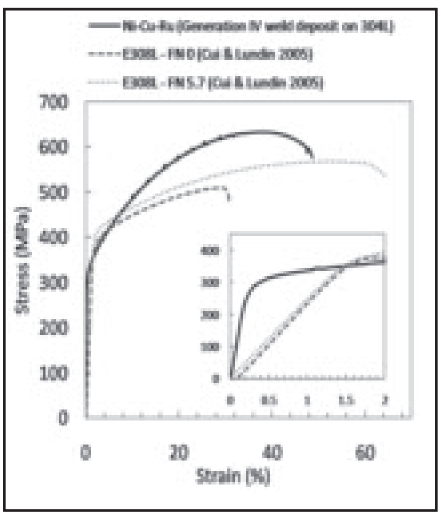

Fig. 4 — Stress-strain curve of Generation IV-11607 all-weld-metal deposit on Type 304L. Also included are stress-strain curves of E308L weld metal with (FN 0) and without (FN 5.7) microfissures for comparison (Ref. 29).

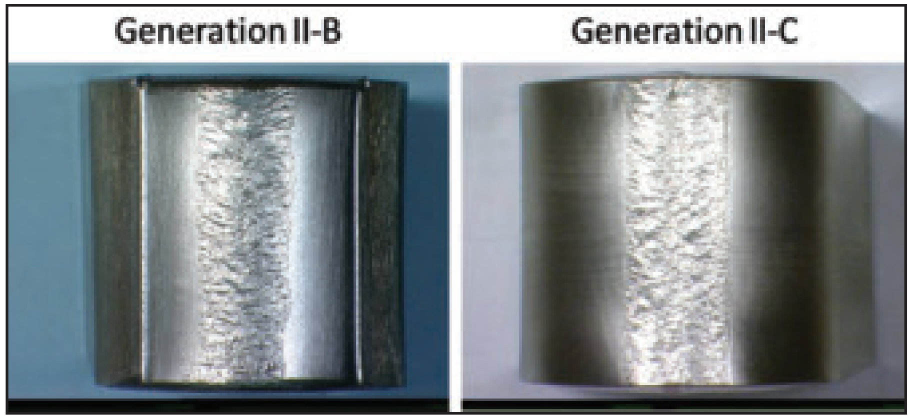

Fig. 5 — Bend test specimens that passed AWS guide bend testing requirements.

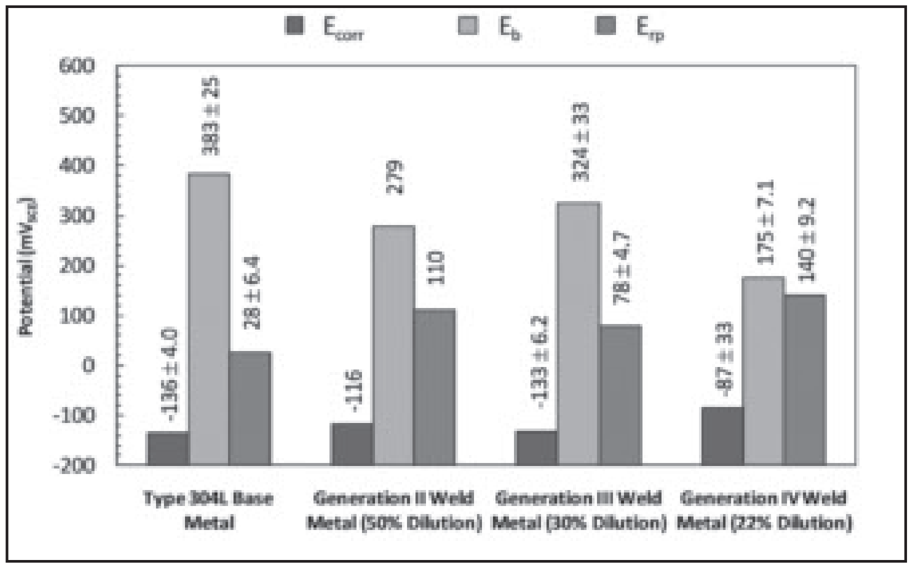

Fig. 6 — Summary of critical potentials of Generation II, III, and IV welds on Type 304L measured in 0.1 M NaCl solution. Corrosion potential (E_{corr}), breakdown potential (E_b), and repassivation potential (E_{rp}) are included.

BW consumable, the weld deposits were made with a current of 200 A, voltage of 13.5 V, travel speed of 2.1 mm s^{-1}, and wire feed speed of 25.4 mm s^{-1} under 100% argon shielding gas. Gas tungsten arc welding was performed on a sidebeam carriage with automatic arc voltage control (set to 10% sensitivity) and a 300-A constant current power supply.

Mechanical Testing

Mechanical properties of welds were determined by tensile testing, guided bend testing, and Vickers microhardness tests. Transverse weld tensile and bend specimens were tested according to the ANSI/AWS B4.0 standard (Ref. 20). Tensile testing was performed using a 500-kN servohydraulic load frame. Displacement rate was maintained at 0.085 mm s^{-1} during testing. Guided bend testing was performed on die blocks with either a 12.7- or 19.1-mm radius. Microhardness testing was performed with a diamond indenter at a load of 200 g and measurements were made on the Vickers scale.

Metallurgical Evaluation

Welds were sectioned for analysis with light optical microscopy (LOM) and scanning electron microscopy (SEM). Samples were mounted in conductive mount resin and then progressively ground with 240, 600, and 800 grit SiC paper. Final polishing was accomplished using 3 and 1 μm diamond suspension followed by a vibratory polish in 0.02-μm colloidal silica for 2 to 4 h. Etching was performed by swabbing with Marble's Reagent (10 g $CuSO_4$, 50 mL HCl, 50 mL distilled H_2O) for 2 to 10 s to achieve the desired effect. Light optical microscopy images were acquired with an inverted metallograph and digital camera. Scanning electron microscopy was performed at accelerating voltages of 10 to 30 kV. Semiquantitative chemical analyses were performed with energy-dispersive spectroscopy (EDS) using the ZAF correction method.

Corrosion Testing

Electrochemical corrosion tests were conducted on samples sectioned from GTA and SMA welds. Cyclic polarization tests were performed in aerated 0.1 M NaCl solution using a potentiostat set at a scan rate of 10 mV min^{-1}. A saturated calomel electrode (SCE) and a pure platinum mesh were used as reference and counter electrode, respectively. Air was

Table 4 — Mechanical Properties of Weld Deposits on Type 304L Stainless Steel

Material Type	0.2% Proof Stress (MPa)	Tensile Strength (MPa)	Elongation (%)	Reduction in Area (%)	Failure Location
304L Minimum	170	480	40	50	—
II-B	—	597	—	—	Weld metal
II-C	—	531	—	—	Weld metal
III-BW	279*	540	52*	54*	Weld metal
IV-11607	295*	618	48*	44*	Weld metal
E308L-XX	—	520 min	35 min	—	—

*Values obtained from all-weld-metal tensile tests.

Table 5 — Summary of Guide Bend Test Results of Generation II, III, and IV Weld Deposits

Consumable	Sample	Radius (mm)	Approximate Outer Ligament Strain (%)	Comments
II-B	1	19	13	Few small microcracks*
	2	19	13	No microcracks*
	3	12.7	18	No microcracks*
	4	12.7	18	No microcracks*
II-C	1	12.7	18	Crack originating from weld defects
	2	12.7	18	Crack originating from weld defects
	3	12.7	18	No microcracks*
	4	12.7	18	No microcracks*
III-BW	1	12.7	18	No microcracks*
	2	12.7	18	<10 microcracks
	3	12.7	18	No microcracks*
	4	12.7	18	1 microcrack*
IV-11607	1	12.7	18	1 microcrack*
	2	12.7	18	<10 microcracks
	3	19	13	No microcracks*
	4	19	13	No microcracks*

*Passes the requirements of AWS D1.6:1999/4.6.5.

bubbled through the solution for aeration. Prior to initiating scans, the sample open circuit potential was allowed to stabilize for a period of 1–2 h.

Slow strain rate testing (SSRT) was employed to assess the susceptibility of the samples to stress corrosion cracking (SCC). Tensile specimens were made according to ASTM standard E8 (Ref. 21). For welded samples, the tensile specimens were fabricated transverse to the weld with the weld in the center of the gauge section. The surface of the tensile bar was polished to 1 μm to prevent microcracks. Specimens were tested at a strain rate of 3×10^{-7} s^{-1} both in air and in 25 wt-% NaCl solution at pH 1.5. After experiments, fracture surfaces were examined by SEM. All SSRT experiments were performed at ambient temperature.

Weldability Testing

Gleeble®-based weldability testing was performed on transverse weld deposits to determine weld metal liquation cracking and ductility dip cracking (DDC) susceptibility using the hot ductility and strain-to-fracture (STF) tests, respectively. Hot ductility testing was performed using a sample free span of 25.4 mm and heating rate of 111°C s^{-1} (200°F s^{-1}). On-cooling hot ductility tests were free cooled at a rate of approximately 30°C s^{-1} (54°F s^{-1}). Samples were tested in tension at a stroke rate of 50.8 mm s^{-1} at the desired test temperature for both on-heating and on-cooling tests. Area reduction was used as an indication of ductility and was calculated based on measurements of initial and final cross section using calibrated precision calipers. Strain-to-fracture testing was performed by making an autogenous spot weld at the center of a dogbone specimen with weld metal deposited at the reduced cross section. The specimens were heated to the desired test temperature and strained. Cracking was evaluated in the spot weld as a measure of DDC susceptibility. Detailed STF testing procedures used in the current study are reported elsewhere (Ref. 22).

Transvarestraint testing was performed on weld deposits made on Type 304L base metal with Generation II and III-BW consumables to evaluate solidification cracking susceptibility. Deposits were machined flat and cleaned with acetone prior to performing the Varestraint test. Welding parameters were set to 180 A, 10 V (~2 mm arc length), at a travel speed of 2.1 mm s^{-1}. The total weld length was 50.4 mm, and the welds were strained at a length of 38.1 mm and ram speed of 152.4 mm s^{-1}. The amount of augmented strain imparted into the samples was controlled by changing die blocks where an increase in strain was accomplished with smaller die block radii. Type C thermocouples were plunged along weld centerlines at the back of the weld pool to acquire time-temperature history on-cooling after the bending portion of testing. Time-temperature data were recorded with a data acquisition system at 4 kHz acquisition rate.

Fume Analysis

Fume generation rates (FGR) were measured using a bulk fume collection hood that was modified from an American

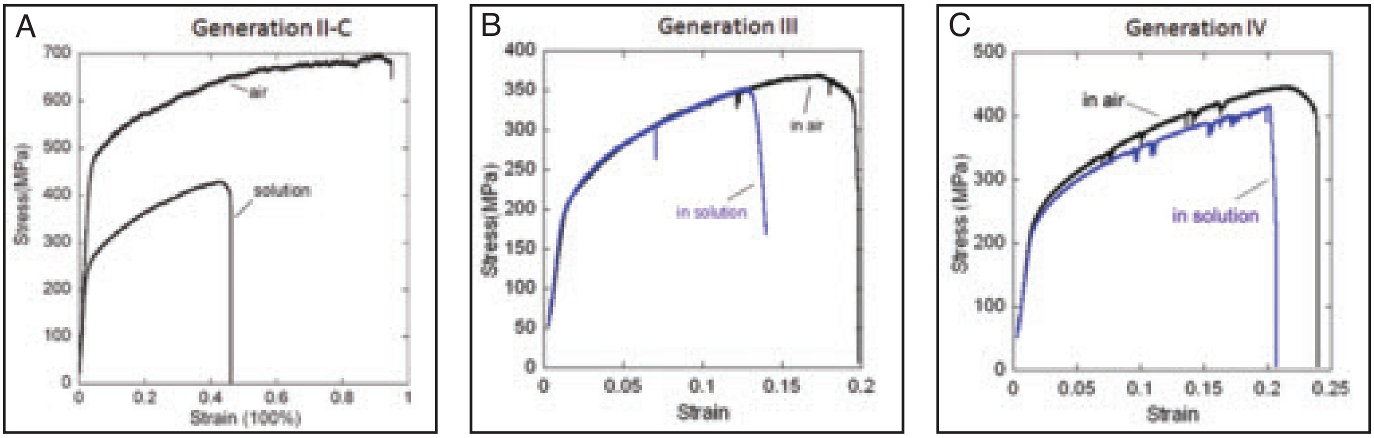

Fig. 7 — Slow strain rate testing curves for welds in air and 25 wt-% NaCl solution at pH 1.5 at strain rate of 3 × 10^{-7} s^{-1}. A — Generation II; B — Generation III; C — Generation IV. Note different scales on horizontal and vertical axes.

Welding Society standard (Ref. 23). The modified system employed glass fiber (HEPA-type) filters during collection, which have more than 99.9% collection efficiency of fume particle sizes greater than 0.3 μm. Filters containing the collected fume were subject to phase identification with X-ray diffraction (XRD) and wet chemical analysis for determination of Cr(VI) concentration. Fume collection was performed in accordance to a procedure described in detail elsewhere (Ref. 24). Fume was collected on 0.3-μm glass fiber filters that were weighed before and after collection. Fume generation rates were determined by the mass increase on the filter divided by the welding time. Filters were subject to XRD using step size of 0.03 deg (2θ deg) and dwell time of 22 to 25 s per step. Samples were submitted to an ISO certified testing lab for determination of Cr(VI) with standardized visible absorption spectrophotometric techniques. The Cr(VI) content was reported by the testing lab to an accuracy of 0.001 wt-%.

Results and Discussion

Weld Microstructure

Microstructural observation of deposited weld metal made with Generation II, III-BW, and IV consumables on Type 304L revealed a primary austenite (gamma fcc) solidification structure with indications of secondary phases along solidification grain (SGB) and subgrain boundaries (SSGB). Secondary phases were extracted from the matrix of various weld deposits by electrolytic dissolution of weld metal in a 10% HCl-methanol solution. Solutions were filtered through 0.2-μm pore size filters to collect the extract. X-ray diffraction analysis of the secondary phase extract identified particles as titanium-carbonitrides, i.e., Ti(C,N). Regardless of the amount of dilution by Type 304L, all welds were fully austenitic as is consistent with predictions from weld constitution diagrams such as the Schaeffler Diagram (Ref. 25). The weld metal exhibited a columnar grain structure characteristic of austenitic welds observed in fully austenitic Ni-based and stainless steel weld deposits (Ref. 26). Single-pass welds exhibited epitaxial nucleation from the Type 304L base metal, and multipass welds exhibited epitaxial nucleation from prior weld deposits. A primarily cellular or cellular-dendritic substructure was observed within the columnar grains. The primary cell or dendrite arm spacing was on the order of 20 μm regardless of the welding consumable or heat input. Representative weld metal microstructures are shown in Fig. 2A–D for Generations II-B, II-C, III-BW, and IV, respectively.

Migrated grain boundaries (MGB) were observed in the microstructure of all weld deposits. The grain boundary migration behavior of Generation III-BW and IV-11607 deposits varied significantly, even though weld target compositions were nominally the same. The MGBs in the Generation IV deposits were much more tortuous in nature than those observed in the Generation III deposits. Qualitative metallographic estimates revealed a higher volume fraction of precipitates in the Generation IV weld microstructure, which resulted in more grain boundary pinning and a higher degree of tortuosity than observed in the Generation II weld microstructure. The observed differences in precipitate distribution were primarily due to variations in Ti and C concentrations in the two types of weld deposits. Generation III-BW weld metals contained only 0.5 wt-% Ti whereas the Generation IV wires contained approximately 1 wt-% Ti. (Note that the core wire contained 4 wt-% Ti, but much of this was lost in the arc.) The Generation IV fluxes contained approximately 12% $CaCO_3$ whereas the Generation III-BW welds were produced under inert Ar gas during GTA welding. Carbonates are typically used to create a protective atmosphere over the weld pool and to facilitate arc stability and welding electrode operability (Ref. 27), and can result in an increase in C concentration in weld deposits. Higher C and Ti concentrations present in the Generation IV-11607 deposits result in a higher fraction of carbides in the weld metal of this consumable. The formation of these carbides appeared to have an effect on the solidification substructure, which exhibited more branching of secondary dendrite arms. The boundary pinning effect on the IV-11607 weld metal migrated grain boundaries was also observed to be much greater in comparison to the III-BW deposits. This is caused by the increased Ti(C,N) content (Ref. 28) and the more tortuous nature of SGB intersections associated with the cellular dendritic structure (Ref. 29). The effect of Ti(C,N) on solidification and solid-state cracking is discussed below.

Mechanical Properties

Vickers microhardness traverses typically exhibited lower hardness levels in the weld metal relative to the Type 304L base metal and heat-affected zone (HAZ). Figure 3A shows a double V-groove weld made with the Generation II consumable on Type 304L base metal, and B is a microhardness traverse (250 μm indent spacing) taken across the cross section. Note that Vickers hardness number (VHN) values in the base metal were approximately 200 VHN while weld hardness values were on the order of 150 to 160 VHN for all generations of weld deposits.

Tensile testing was performed transverse to the weld according to ANSI/AWS B4.0-98 standard to evaluate mechanical performance of welds produced with the Ni-Cu consumables on Type 304L base material. Results of tensile testing are summarized in Table 4 where each value is an average of four tests. Ultimate tensile strength of Generation II, III-BW, and IV weld deposits exceeded the minimum required values of Type 304L. All deposits exceeded the minimum strength values required for E308-XX SMAW deposits, where XX stands for 15, 16, and 17. Mechanical property values of Type 304L (hot finished and annealed) and E308-XX class consumables (all-weld-metal deposits) are from handbook (Ref. 31) and standard sources (Ref. 32), respectively. Generation II-B and IV-11607 weld deposits had the highest measured strength levels whereas Generation II-C deposits had the lowest mechanical performance based on tensile strength. Some of the welds deposited with this electrode contained incomplete fusion defects and a higher degree of slag inclusions based on radiographs. This is believed to be the cause of the lower mechanical performance. The III-BW had lower tensile strength values than Generation II and IV deposits. This was due to the fact that welds were made with the GTAW process, which typically lacked the inclusions (and had a lower volume fraction of precipitates) that could have promoted strengthening and decreased ductility. All transverse tensile test failures occurred in the weld metal, indicating that the tensile strength of the Type 304L base metal was well above the required minimum.

Additional tensile specimens were made so that all-weld-metal properties could be determined. This was accomplished by depositing multiple weld passes in a groove (~19 mm wide × 3.3 mm deep) machined into Type 304L plate. The Type 304L backing was machined away after filling the groove with weld metal, resulting in a reduced section containing all weld metal. A 12.7-mm extensometer was used during tensile testing of the Generation III-BW and IV-11607 weld deposits, thus the extensometer was entirely within the width (~19 mm) of the multipass transverse weld deposit. In using an extensometer gauge length that was narrower than the weld deposit, erroneous measurements induced by nonhomogenous dissimilar weld mechanical properties were avoided. Although these are not the standard all-weld-metal tensile tests, this method provided a good estimate of weld metal properties (including proof stress, elongation, and area reduction) in the transverse direction. A typical stress-strain curve obtained with this procedure is shown in Fig. 4, which was measured for a Generation IV-11607 all-weld-metal deposit. Note that the inset in the figure is an enlarged portion of the elastic region of the curve. Also included on the plot are stress-strain curves for two E308-type consumables with different ferrite numbers (FN) – FN 5.7 and FN 0 (Ref. 30). The weld with FN 0 contained some small cracks whose nature was not identified. In the past, these have been termed “microfissures” (Ref. 30), but this term has no meaning with respect to the cracking mechanism. This test method showed that Generation III-BW and IV-11607 deposits exceeded minimum elongation requirements of E308-XX SMAW deposits. It is evident from the reported values of mechanical properties that Ni-Cu consumables are able to meet the minimum mechanical performance requirements of current Type 308 stainless steel consumables based on the AWS design code for filler metals.

Guided bend tests were performed on samples made from Generation II-B, II-C, III-BW, and IV-11607 weld deposits on 304L. Results of the bend tests are summarized in Table 5. The four II-B welds passed the requirements of AWS D1.6:1999, *Structural Welding Code — Stainless Steel*. Two of the II-C samples passed these requirements and two cracked due to preexisting, incomplete fusion defects associated with sample fabrication. Bend testing of III-BW deposits showed microcracks in two of the tested weld deposits though there were no macroscopic failures. Three of the four samples passed AWS standard minimum requirements. The Generation IV weld deposits were tested over two bend radii, 12.7 mm (0.50 in.) and 19 mm (0.75 in.). Samples passed the code requirements at the lower elongation values, which conforms to AWS consumable qualification standard minimums for Ni-based alloys (19-mm die block). Representative bend test samples that passed the requirements of AWS D1.6 are shown in Fig. 5.

Table 6 — Calculated SCTR and DDC-TR Values for Generation II and III Weld Deposits. Other Nickel-Based Alloys and Stainless Steels Are Included for Comparison (Ref. 34)

Material	Dilution Level by Type 304L	SCTR (°C)	DDC-TR (°C)
Generation II-B	~14%	111 ± 7	855–1055
Generation II-C	~10%	109 ± 6	770–1140
Generation III-BW	~11%	113	920–1130
Type 304L (FN6)	—	31	—
Alloy 617	—	85	—
Type 310 SS	—	140	—
Alloy 625	—	210	—

Table 7 — Summary of Important Hot Ductility Parameters of Generation II-C and III Deposits on 304L. Data Are Reported in °C

Hot Ductility Parameter	Generation II-C (~40% dilution)	Generation III-BW (~20% dilution)
NDT	1300	1360
NST	1333	1374
DRT	1300	1320
CSR (NST-DRT)	33	54
DDC-TR	850–1150	800–1100

Corrosion Evaluation

Corrosion compatibility of the Ni-Cu consumables with austenitic stainless steel was a requirement from the start of this work because stainless steels are used in corrosive environments (Refs. 11, 12, 14). The results of initial work showed corrosion compatibility in chloride-containing environments of dissimilar welds consisting of a Ni-Cu-based welding consumable containing the noble element palladium and austenitic stainless steel. Further work showed that a GTA and SMA consumable based on the Ni-Cu-Pd system were also compatible for stainless welding (Ref. 18). The use of ruthenium was investigated as an alternative to Pd because the cost of platinum group metals fluctuate with time, and Ru is typically the least expensive of the platinum group metals. This compatibility was obtained based on the following corrosion design criteria (Ref. 11): 1) the breakdown potential and repassivation potential of the weld metal were required to be greater than the corrosion potential of the stainless steel base metal to avoid localized corrosion such as pitting or crevice corrosion; and 2) the corrosion potential of the weld metal was required to be equal to or greater than the corrosion potential of the stainless steel to cathodically protect the weld.

Based on electrochemical corrosion testing of Generation II, III-BW, and IV weld deposits on Type 304L, the corrosion design requirements were satisfied. A summary of the critical electrochemical potentials is shown in Fig. 6 where measured potentials are plotted for each generation of consumable in comparison to Type 304L. Potentials were measured vs. a saturated calomel electrode (SCE). Aver-

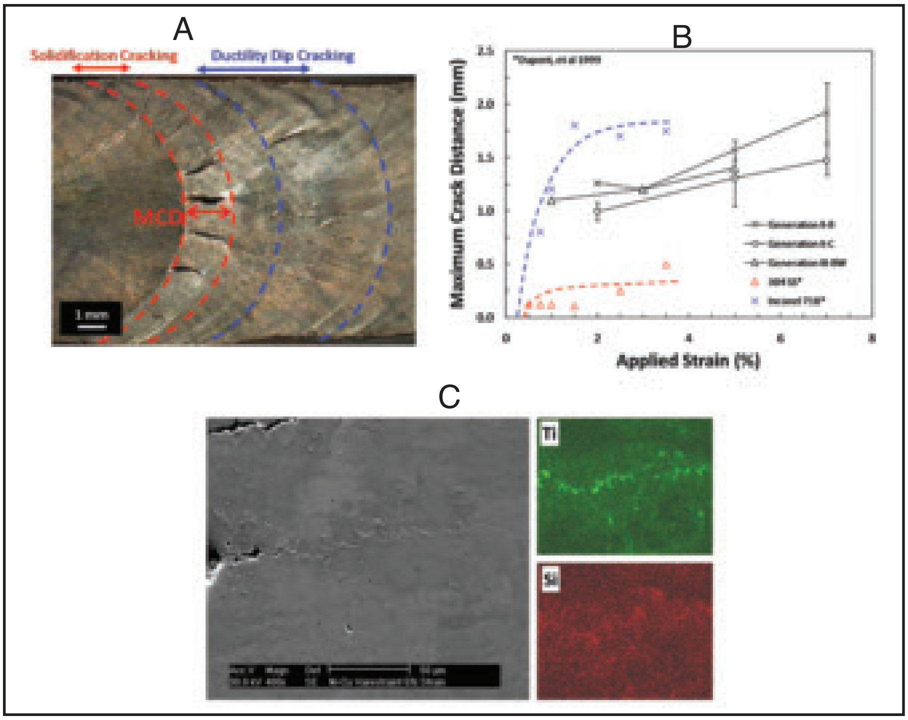

Fig. 8 — Analysis of the following: A — Cracking regions associated with Generation II deposit; B — solidification cracking envelope of Generation II and III weld deposits, including data of 304L and Alloy 718 (Ref. 35); C — composition map of solidification crack in Generation II-B weld deposit.

age values were calculated from at least three experimental runs, and standard deviations are indicated for Generations III and IV of those runs. The breakdown (E_b) and repassivation (E_{rp}) potentials of the Generation II, III, and IV welds on Type 304L were greater than the corrosion potential (E_{corr}) of Type 304L, thus satisfying the first corrosion design requirement. Also, the corrosion potential of the Generation II (–116 mV_{SCE}), III (–133 mV_{SCE}), and IV (–87 mV_{SCE}) weld metals were greater than the corrosion potential of Type 304L (–136 mV_{SCE}), satisfying the second design requirement. Differences in corrosion potentials between the various generations of weld deposits may be attributed to slight variations in consumable composition and the extent of weld dilution. The higher volume fraction of secondary phase particles in the Generation II and IV deposits may also have resulted in increased pitting susceptibility with respect to Generation III deposits, hence the lower breakdown potentials (Ref. 33). However, even with large variations of weld dilution levels, weld deposits met the design criteria. This suggests that these consumables would be considerably tolerant to variations in dilution from a corrosion perspective.

Slow strain rate testing (SSRT) was performed to assess the stress corrosion cracking (SCC) susceptibility of welds in a chloride-containing environment. Slow strain rate testing specimens were machined from welds deposited with Generations II, III, and IV consumables. These samples were tested in 25 wt-% NaCl solution (pH 1.5) at a strain rate of 3×10^{-7} s^{-1} and at ambient temperature. Results of tests conducted in air and in the solution are shown in Fig. 7A–C. As the figure shows, ductility was higher in air than in the NaCl environment for all three generations of weld deposits. The observed disparity between air and solution was most pronounced in Generation II welds. Examination of fracture surfaces of the Generation II welds tested in solution revealed that failure occurred in the weld metal and was associated with brittle transgranular features. Generation III-BW welds had lower ductility than Generation II, which may be attributed to some welding defects that occurred during sample fabrication (such as incomplete fusion). However, comparing the Generation III SSRT in air to that in solution still shows reduction in strength and ductility suggesting some susceptibility to SCC. Generation IV weld deposits also showed some reduction in strength and ductility, although the observed difference was not as great as that seen in Generation III welds. Most of the fracture surface of Generation III and IV SSRT samples was in the Type 304L HAZ adjacent to the fusion boundary. Fe-Ni-Cr alloys containing high concentrations of Ni generally have good resistance to SCC according to the well-known Copson curve (Ref. 34), and all of the weld deposits in the current study contained high concentrations of Ni. Based on the Copson curve, one would expect the weld deposits to have significantly longer failure times than Type 304L base material used, which have the shortest failure times on the curve. Because the fabricated samples were not all weld metal, it is probable that the SCC susceptibility of the stainless steel HAZ is dominating the sample failure behavior during the testing. This concept is supported by the observation that fractures of Generation II and III deposits occurred mostly in the stainless steel (Refs. 18, 19).

Weldability Evaluation

During fabrication, Ni-based alloys can be susceptible to solidification and liquation cracking, as well as the solid-state cracking phenomenon known as ductility dip cracking (DDC) (Ref. 26). Therefore, three different weldability tests were performed to assess susceptibility to high-temperature weld cracking. The Varestraint test was used to evaluate weld solidification cracking susceptibility. The hot ductility test was used to evaluate propensity to weld metal liquation cracking and to assess overall weld metal ductility. The strain-to-fracture test was used to evaluate susceptibility to DDC. Results of these tests are presented and discussed below.

Solidification Cracking

Based on previous transvarestraint testing results, Ni-based alloys have been shown to have a higher solidification cracking susceptibility than Type 304L/308L stainless steels (Refs. 35, 36). These stainless steels solidify under the ferrite-austenite (FA) mode, where primary ferrite solidification is followed by a peritectic-eutectic transformation to austenite (Ref. 37). Weld metal that solidifies under the FA mode generally has high resistance to cracking due to the tortuous nature of SGB intersections, which prevents continuous wetting of liquid films along grain boundaries, and the generally poor wetting of liquid films along ferrite-austenite boundaries. Fully austenitic solidification results in welds with lower inherent resistance to solidification cracking because SGB intersections tend to be straight and susceptible to liquid film wetting. The austenite phase also has a greater tendency to promote segregation of solute elements to grain boundaries than ferrite due to lower inherent solubility of solute elements. For example, the impurity elements S and P have lower solubility in austenite resulting in higher concentrations along grain boundaries as a result of solidification-induced segregation (Ref. 38). Therefore, solidification cracking is of concern when switching from a stainless steel consumable to a Ni-based welding consumable. Consequently, the

Table 8 — Fume Generation Rates of Generation II and IV SMAW Consumables

Consumable	Current (A)	Arc voltage (V)	Arc Power (kW)	Weld Heat Input (kJ/mm)	Average Fume Generation Rate (g/min)	Standard Deviation	Cr(VI) Content in Bulk Welding Fume (wt-%)
E308-16 low HI	80	24.0	1.92		0.09		2.60
E308-16 high HI	115	28.3	3.25	0.68	0.20	0.031	
Generation II-B	115	28.5	3.27	0.73	0.55	0.027	
Generation II-C	110	25.5	2.81	0.61	0.41	0.003	0.020
Generation IV-11607 low HI	90	22.5	2.03	1.1	0.41	0.042	0.057
Generation IV-11607 high HI	120	24.5	2.94	1.4	0.58	0.025	0.097

cracking susceptibility of Ni-Cu-based welds deposited on Type 304L was investigated using the transvarestraint test.

Generation II-B, II-C, and III-BW deposits were made by filling machined grooves in stainless steel to achieve dilutions of approximately 14, 10, and 11%, respectively. The deposits were subjected to at least three strain levels during transvarestraint testing to develop a cracking envelope. Maximum crack distances (MCD) were measured on each tested coupon. Solid-state cracks were observed and counted as well, and the results of the observations are reported in Table 6. Note that only one test was performed at each strain condition for the Generation III-BW deposit due to limited availability of filler metal, so statistical analysis was not performed for those measurements.

Two distinct regions of cracking were observed in all three types of weld deposits. The first range was directly behind the instantaneous liquid-solid interface at the moment strain was applied. This region was associated with weld solidification cracking because it was within the solidification temperature range. The second region where cracking was observed was remote to the solidification cracks, and it was typically observed several millimeters behind the weld region where grain boundary liquid films were not present. Therefore, the second region of cracking occurred in the solid state and is indicative of DDC. Both regions of cracking are shown in the Generation II-B Varestraint test weld depicted in Fig. 8A. The particular sample shown was tested at 7% strain. Note that because a root opening of more than 1 mm exists between the two regions of cracking, the mechanism for cracking is clearly different and associated with a different temperature range.

Maximum crack distances were plotted as a function of applied strain, as shown in Fig. 8B, for each of the three weld deposits. For comparative purposes, the maximum crack length (MCL) of Type 304 and Alloy 718 transvarestraint tests were included on the plot (Ref. 36). Type 304 has a low susceptibility to solidification cracking whereas Alloy 718 has a moderate to high solidification cracking susceptibility. The MCD values of Ni-Cu welds deposited on 304L fall between those of the other two alloys. Although MCD and MCL are not equivalent (MCD is usually slightly less than MCL), the values are usually sufficiently close to allow comparison of solidification cracking behavior. Based on this assumption, the Ni-Cu consumables appear to have a moderate susceptibility to solidification cracking, according to measured crack distances at strain levels between 1 and 7%.

Note that threshold cracking strains were not measured as shown for the Alloy 718 and Type 304 alloys. Threshold strain is the minimum strain to cause solidification cracking and appears to be less than 0.5% for 718 and 304. The II-B deposits appeared to have the highest cracking susceptibility of the three types Ni-Cu weld deposits. The II-C and III-BW deposits appeared to have similar cracking susceptibility but based on the error bars of the II-C deposit, and the lack of replications of the III-BW deposit, this similarity may not be statistically significant.

Analysis with SEM and EDS composition mapping revealed that solidification cracks were associated with liquid films rich in Ti and possibly Si, as shown in Fig. 8C. The figure shows the leading edge of a solidification crack of a Generation II-B deposit. This deposit had the highest Ti concentration of the three deposits and also the highest cracking susceptibility. The dense distribution of Ti(C,N) particles was a result of a eutectic reaction at the end of solidification. Such a reaction would effectively promote solidification cracking because a continuous liquid film develops along the solidification grain boundaries (Ref. 26). These liquid films provide little accommodation for any augmented strain (or solidification-induced shrinkage strain during welding), which results in cracking. This indicates why the II-B deposit exhibited the highest susceptibility.

The susceptibility to solidification cracking was further quantified by calculating the solidification cracking temperature range (SCTR). Saturated strain levels are determined by plotting MCD as a function of applied strain. When MCD reaches a value where it does not increase with further increases in strain, it has reached the saturated value. This represents the maximum length along the weld where susceptible microstructure exists. That is to say, cracking extends over the entire length of a grain boundary where a continuous liquid film is present along a grain boundary, assuming there is no crack propagation in the solid state (i.e., DDC). Based on the cracking envelope shown in Fig. 8B, the saturated MCD might not have been reached because values of MCD appear to be increasing even up to 7% strain. Therefore, the MCD at the highest applied strains for each material was used for calculating SCTR values with the following equation:

$$SCTR = CR\frac{MCD}{V}$$

where the cooling rate (*CR*) was measured with a thermocouple in the solidification temperature range (~170° to 200°C s^{-1}), and *V* was the torch travel speed (2.1 mm s^{-1}) during the test.

Calculations of SCTR values at maximum strain are presented in Table 6 for the Generation II and III-BW weld deposits. Several other stainless steels and Ni-based alloys are included for comparison (Ref. 35). The SCTR assessment shows a similar trend as seen in the cracking envelope in Fig. 8. The Type 304L stainless steel has the lowest SCTR value (31°C) and hence the lowest propensity for solidification cracking. Generation II and III-BW weld deposits have SCTR values of approximately 110°C indicating a higher susceptibility to cracking than Type 304L, although similar in value to other Ni-based alloys such as Alloy 617.

Temperatures over which DDC occurred were estimated using a similar ap-

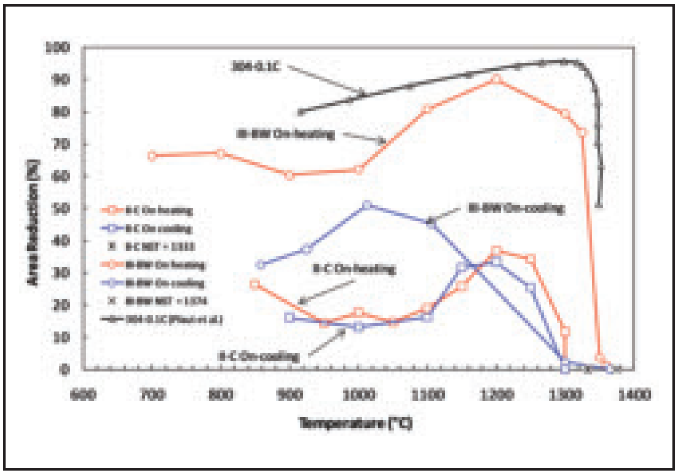

Fig. 9 — Hot ductility curves of Generation II-C and III-BW welds deposited on Type 304L and wrought Type 304 from (Ref. 40).

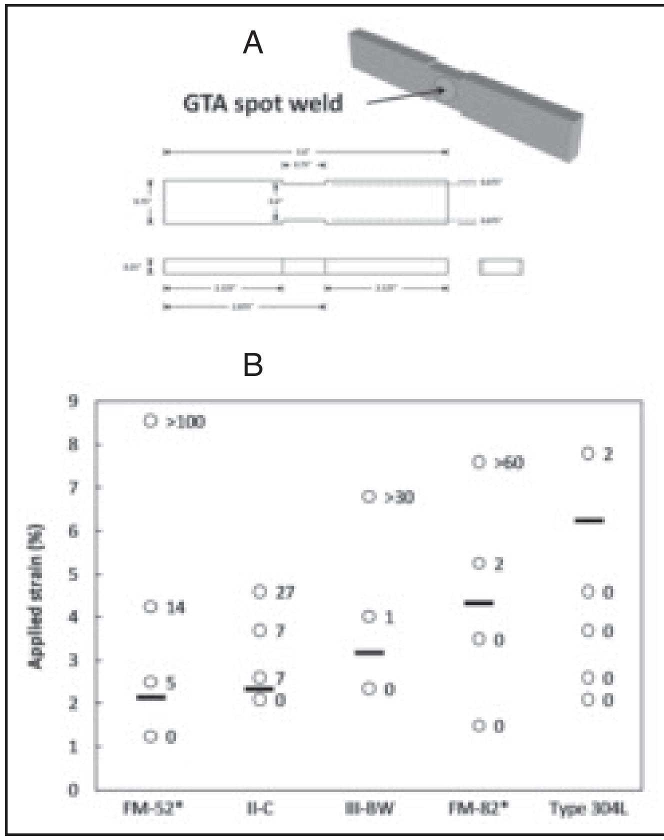

Fig. 10 — A — Strain-to-fracture test sample schematic; B — test results of Generation II and III welds compared to other Ni-based filler metals (Ref. 42) and Type 304L tested at 950°C. The number of cracks observed on each specimen is listed.

proach to the SCTR calculation. Ductility dip cracking occurred in multiple locations and orientations relative to travel direction and had a variety of lengths between fractions of a millimeter to several millimeters in length. The upper and lower temperatures of the cracks were calculated by including the entire range where cracks were observed. The calculated ranges are also included in Table 6, which shows the lower and upper temperature limits. These temperature ranges are discussed below.

All of the weld deposits analyzed during the present work solidified as austenite. Austenite solidification is promoted by the high Ni-equivalent values of the weld deposit. Therefore, it is suggested that impurities be minimized when welding stainless steels with Ni-Cu consumables because they will easily wet austenite grain boundaries. This is generally achieved by proper handling of welding consumables and base metals to ensure cleanliness. Weld zones must be kept cleaner to avoid entrapment of oxides and embrittling elements such as S, P, and Pb (Refs. 39, 40). Weld procedures should call for low P + S grades of base material to ensure weld deposits do not pick up impurities from the base metal. However, impurity pickup may be an issue during weld repair of older heats of stainless steel that may have been put into service before impurity refining became tightly controlled. An upper limit of approximately 0.01 wt-% P + S is necessary to avoid solidification cracking in stainless steel weld deposits with high Ni equivalency, i.e., fully austenitic (Ref. 41). Such values would likely be an acceptable upper limit for impurity control during welding of vintage stainless alloys with the Ni-Cu consumables developed here. It was also evident that segregation of Ti and Si contribute to solidification cracking suggesting that levels of these elements should be controlled to values within those of the current weld deposits. Weld dilution plays a critical role on solidification cracking susceptibility as demonstrated in a study of Monel welding on Type 304L, which showed cracking could be avoided if dilution was less than 30% (Ref. 12). Another study of the Fe-Ni-Cu ternary system showed that solidification cracking was exacerbated as Cu contents were increased above approximately 10–15 wt-% over a broad range of Ni-Fe concentrations in GTA welds (Ref. 42). While these two studies considered higher Cu concentrations than the current study, they both suggest that controlling dilution is a critical factor in maintaining solidification cracking resistance. Therefore, as general practice, it is recommended that dilution for the current consumables be limited to approximately 30%.

Weld Metal Hot Ductility

The hot ductility test has been widely used (Ref. 26) to evaluate the weldability of Ni-based alloys and stainless steels because elevated-temperature cracking can usually be directly associated with a loss in available ductility. Using the hot ductility test, on-heating and on-cooling curves were produced for transverse multipass weld deposits of Generation II and III consumables on Type 304L. The dilution levels (by Type 304L) of the weld deposits were approximately 40% and 28% for the Generation II-C and III-BW deposits, respectively. Hot ductility curves for both weld deposits are shown in Fig. 9 and a summary of measured hot ductility behavior is listed in Table 7.

On-heating curves for both deposits increased in ductility up to peak temperatures of approximately 1200°C. Ductility decreased as test temperatures were increased above this temperature and reached zero ductility above 1300°C. The temperature of zero ductility on-heating corresponds to the nil-ductility temperature (NDT). The NDT is the temperature where the weld metal grain boundaries were coated with continuous liquid films resulting in a complete loss of ductility although the films still maintain some load-carrying capacity. Nil-ductility temperature values of the Generation III deposit was approximately 1360°C, a value considerably higher than that observed in the II-C deposit.

An additional test was performed on-heating called the nil-strength temperature (NST) test. Approximately 25 kg of tensile load was placed on the test samples, and they were heated until failure. The value for NST represented the temperature at which sufficient grain boundary liquid was present to allow failure at very low loads. Nil-strength temperature values were found to be 1333° and 1374°C for the Generation II-C and III weld deposits, respectively. The LOM and SEM

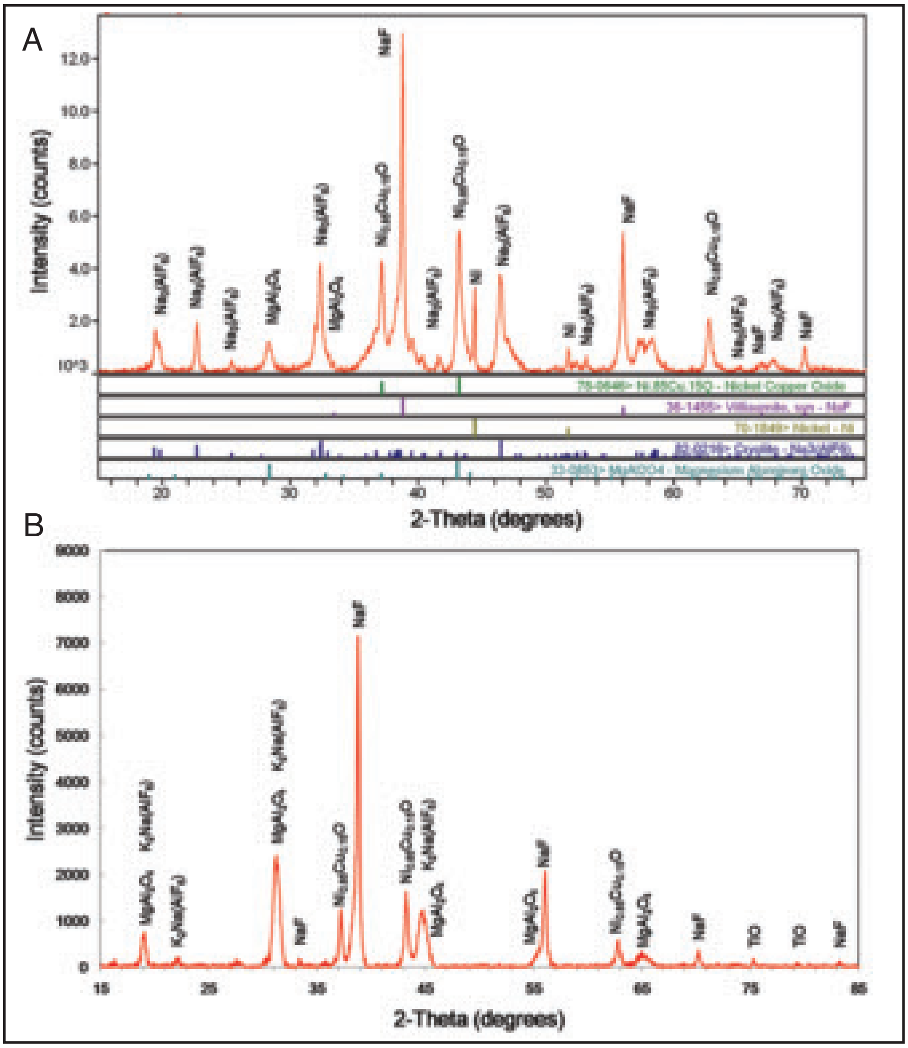

Fig. 11 — X-ray diffraction spectra of welding fume produced by SMAW consumables during welding of Type 304L. A — Generation II; B — Generation IV.

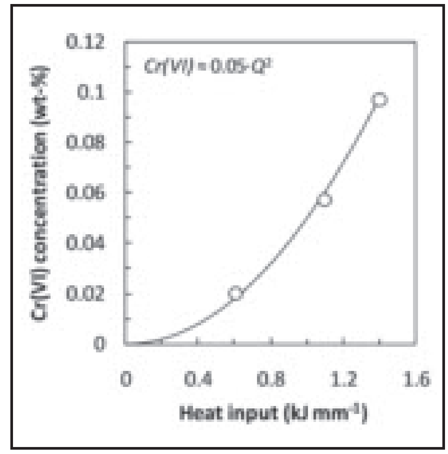

Fig. 12 — Concentration of Cr(VI) in welding fume as a function of heat input.

evaluation of the NST fracture specimens revealed that cracking occurred extensively along SGB and SSGB locations and that fractures were dendritic in nature. EDS of the fractures indicated that the liquid films coating the dendrite regions were rich in Ti and Si. This suggests that the eutectic containing Ti(C,N) particles in lower freezing point interdendritic regions undergo liquation.

On-cooling hot ductility tests were performed by heating test samples to a temperature midway between NDT and NST (II-B samples were heated to 1315°C and III-BW samples were heated to 1365°C), then cooling to a predetermined temperature before pulling the sample to failure. The temperature at which the alloy recovers some ductility (~5%) on-cooling is termed the ductility recovery temperature (DRT). These DRT values were determined to be approximately 1300° and 1320°C for the II-C and III-BW weld deposits, respectively. Ductility of both deposits appeared to recover at similar rates upon decreasing temperature from the DRT, although the Generation III deposit recovered more overall ductility upon cooling, which implies that it has a higher resistance to solid-state cracking below approximately 1150°C.

The difference between the NST and DRT is considered the crack-susceptible region (CSR = NST – DRT). Ductility in a multipass weld HAZ is essentially zero within this temperature range due to the presence of liquated grain boundaries. If a weldment experiences prolonged duration in this region, stress will accumulate during cooling of the weld increasing the likelihood of cracking (Ref. 43). The Generation II-C weld deposits had a CSR of approximately 33°C, which represents the temperature range in which the weld metal may be susceptible to cracking phenomena such as weld metal liquation cracking in the HAZ of a multipass weld. The Generation III deposit had a CSR of approximately 54°C, which was larger than the CSR of II-C welds. However, the CSR values are both relatively low, suggesting that the multipass welds would have good resistance to weld metal liquation cracking. For austenitic stainless steels and Ni-based alloys, CSR values above 100°C are thought to be indicative of weld metals susceptible to weld metal liquation cracking (Refs. 26, 37).

If single-pass welding is being performed, then liquation cracking susceptibility in the HAZ is determined by the hot ductility of the base metal material. Plaut et al. have reviewed the hot ductility of wrought 304 stainless steel alloys tested at a strain rate of 6 s^{-1} (Ref. 44). They noted ductility loss in the range of 1250° to 1350°C for a range of stainless steel compositions. This was associated with a lack of grain boundary cohesion and the onset of liquation. Hot ductility of Type 304 is included in Fig. 9 for comparison with the Ni-Cu weld deposits (Ref. 44). The NDT temperature was not provided but appears to be in the range of 1350° to 1375°C if extrapolated to the zero ductility line. The CSR of Type 304 cannot be determined from on-heating curves alone. However, a comparison of Type 304 and the weld deposits provides some insight into mechanical performance. Clearly, the Type 304 wrought alloy has superior ductility to both types of weld deposits. Wrought 304 stainless steel tensile samples would likely contain a smaller equiaxed grain structure whereas the Ni-Cu deposits contain large columnar grains due to weld solidification. Larger grain sizes are typically associated with a decrease in ductility and toughness. This suggests that liquation cracking susceptibility would be low in single-pass dissimilar welds of this type because more ductility will always be available in Type 304 than in the weld deposit. This observation is made based on the on-heating hot ductility of Type 304 and the observation that Type 304 may also form ferrite at the grain boundaries in the HAZ, which further reduces susceptibility (Ref. 37).

Note that the Generation II-C on-heating and on-cooling hot ductility curves

Table 9 — Bulk Fume Compositions (wt-%) of Generation II and IV Welding Fumes Measured with EDS

Element	Generation II	Generation IV
O*	—	—
F*	—	—
Na	65.7	33.8
Al	—	21.5
Mg	0.4	2.5
Si	4.2	6.4
Cl	0.4	0.3
K	2.3	22.5
Ca	4.9	1.4
Ti	4.2	3.7
Cr	0.4	0.3
Mn	0.4	0.2
Fe	0.7	0.4
Ni	10.4	5.0
Cu	6.1	2.0

*Oxygen and fluorine were present but were not measured due to limitations of light element analysis with the EDS technique.

show a ductility dip in the temperature range from 850° to 1150°C. A similar observation was made in the on-heating curve of the Generation III deposit, where ductility was reduced in the range of approximately 800° to 1100°C. The on-cooling curve of the Generation III deposit also decreased at the lower temperatures. These temperature ranges correlate reasonably well with the solid-state cracking temperature ranges found during Varestraint testing of the weld deposits shown in Table 7. To further examine cracking susceptibility due to this ductility dip, and determine threshold strains necessary to induce DDC, samples of II-C and III-BW weld metal were subjected to the strain-to-fracture test.

Ductility Dip Cracking

It was not possible to determine threshold strains necessary to induce DDC during transvarestraint testing because the die blocks imposed fixed levels of strain (at 2% strain increments) to the weld metal during bending. The strain-to-fracture test is better suited to determine the threshold strains necessary to cause DDC because strain can be applied at smaller increasing increments until crack initiation occurs (Ref. 22). A test temperature of 950°C has been proposed as a suitable temperature for comparing DDC susceptibility of different alloys because it is typically the temperature where the minimum in the ductility trough occurs (Ref. 45). Therefore, this temperature was utilized to determine threshold strains necessary to induce DDC in Generation II and III-BW weld metals. Test samples were utilized with the configuration shown in Fig. 10A. Note that the base metal used for the samples was Type 304L. Weld deposits were made with Generation II and III consumables on one side of the sample during fabrication. Autogenous GTA spot welds were then placed on the weld deposit and on the Type 304L on the opposing side of the Generation III welds. Gauge marks were placed on the reduced center section. These were measured before and after testing to determine the average strain level imparted into the center section during the test. Note that strain is nonuniform across the gauge section due to the presence of a temperature gradient, which results in localized deformation. Samples of the configuration shown were heated to 950°C and strained to induce cracking, then carefully inspected under a binocular microscope after testing to determine the total number of cracks.

A comparison of cracking susceptibility at 950°C of Generation II-C and III deposits with other Ni-based filler metals (Ref. 46) and Type 304L is shown in Fig. 10B. The number of cracks observed on each specimen is listed. The plot shows that Generation III welds had a higher threshold strain than II-C deposits and is comparable to FM-82. The II-C deposits have a cracking susceptibility similar to FM-52. Type 304L had the highest threshold strain values and is generally considered very resistant to DDC. Nickel-based alloy FM-52 has a high DDC susceptibility in high-restraint, thick-section welds. It has the lowest cracking threshold of any of the weld metals included in Fig. 10. Note that the II-C deposit had similar threshold values as the FM-52 weld metal. Thus, it is likely that II-C would have a high cracking susceptibility in high-restraint welds. The III-BW weld metal appears to have a cracking threshold similar to FM-82 at intermediate temperatures. FM-82 is considered to have a better resistance to DDC than FM-52 (Ref. 47), therefore Generation III welds would be considered to have a similar cracking resistance in high-restraint welds as FM-82.

In addition to the threshold cracking strain, the transition to "massive cracking" has been established as an important indicator of cracking susceptibility (Ref. 46). Materials that transition from the threshold strain to massive cracking over a short strain interval were typically observed to have higher susceptibility to DDC. This was described as the strain where the number of cracks exceeded 50 in the spot weld or when they became too numerous to accurately count. Based on that criterion, the transition to massive cracking was not observed in Generation II-C or III deposits within the strain envelope of testing (less than 5% in Generation II-C and less than 7% in Generation III).

The Generation IV weld deposits exhibited higher grain boundary tortuosity due to grain boundary pinning by medium sized Ti(C,N) particles. Grain boundary pinning with medium-sized intergranular (Nb,Ti)C carbides and has been shown decrease DDC susceptibility in Ni-based weld deposits (Ref. 28). Other work showed that DDC susceptibility in Ni-based welds was decreased with an increase in intergranular carbide coverage, regardless of carbide type (Ref. 48). Therefore, future STF testing of Generation IV welds may reveal additional improvements in DDC resistance based on those observations.

Fume Characterization

A thorough analysis of fume produced by these consumables was necessary to ensure that Cr(VI) was sufficiently reduced to levels that would support their implementation. Welding fumes produced by the Generation II and Generation IV consumables were evaluated by performing fume generation rate measurements followed by composition analysis with EDS, and chemical analysis with XRD and visible absorption spectrophotometry to evaluate bulk fume phases and Cr(VI) content, respectively.

The measured FGR values are shown in Table 8 for E308-16, and Generation II and IV SMAW consumables. Welding parameters are also listed for each collection performed. Comparing the FGR measurements of the Generation II and IV consumables to values obtained for E308-16 shows the Generation II chromium-free electrodes have higher FGR values at similar heat inputs to the E308-16. The Generation IV consumables were tested at higher heat input conditions than Generation II because those different weld parameters were required to produce good quality weld deposits. The higher heat inputs used during Generation IV testing resulted in higher FGR values than the

E308-16 as well. However, the Ni-Cu consumables have lower FGR values than other flux-based processes such as the E308LT1-1 electrode used for flux cored arc welding (Ref. 49).

Bulk fume composition was measured with EDS as listed in Table 9. Note that some Cr was observed in the bulk fume, although this is much lower than levels observed in fumes of stainless steel welding consumables (Ref. 3). Phases in bulk welding fume were readily identified with XRD because the fumes collected on filters during FGR measurements were essentially in powder form. Particles analyzed with this technique varied across a broad size range based on observations with SEM. The XRD scan results are shown in Fig. 11A and B for the Generation II and IV bulk fumes, respectively. Note the different scales on the axes of the two spectra. Multiple phases were observed in both spectra; however, no phases were observed that contained Cr(VI) such as K_2CrO_4 or Na_2CrO_4 as previous evaluation of stainless steel welding fume has shown (Ref. 3).

The Cr(VI) concentrations in Generation II and Generation IV welding fumes are shown in Table 8. Measured Cr(VI) concentrations in the Generation II and IV welding fumes were reduced by two orders of magnitude compared to E308-16 tested at similar heat inputs. These concentrations represent an average value of all fume particle types and sizes as they were measured from bulk fume filters. The SMAW consumables developed during this work contained no measureable amounts of chromium in the flux coatings or core wires. Therefore, any Cr(VI) in the welding fume must have originated from the base plate because Type 304L contains approximately 18 wt-% Cr. It was not clear from the results obtained during XRD studies what phase(s) could have contained the Cr(VI). The very low concentrations of Cr(VI) as measured with colorimetric techniques (Table 8) indicate the compounds that give rise to its presence would be difficult to identify with diffraction because they would be present in such low concentrations. However, there were ample amounts of oxygen, potassium, and sodium within the bulk fume. Therefore, it is possible that Cr(VI) may have been detected as an oxide or chromate compound. Note that the Cr(VI) concentration in bulk fume scaled with heat input into the base metal as shown in Fig. 12 supporting the idea that complete elimination of chromate during arc welding is likely unavoidable because some vaporization of Cr from the molten weld pool will occur.

Consumable Applicability

The current study showed successful welding of Type 304L base metal during weldability evaluation of the consumables. The Generation III and IV consumables would likely have further success and application in welding other 300-series austenitic alloys. Some of the most widely used alloys in this series include Type 304, 316, 321, and 347, which are based on the 18Cr and 8-10Ni metallurgical system (Ref. 37). Weld fusion zones on these base metals would remain fully austenitic according to an analysis with the Schaeffler Diagram and assuming reasonable dilution levels by the consumables (Ref. 25). Susceptibility to solidification, ductility dip, and weld metal liquation cracking is expected to be similar to the current results based on this approximation alone. However, variations in minor alloying concentrations (such as C, Si, Ti, and Nb) in the other grades of base metal may alter cracking behavior to some extent. Heat-affected zone liquation cracking susceptibility would also be dominated by changes in base metal. In addition, the various stainless grades are used in a broad range of corrosive and high-temperature environments, which necessitates additional weld corrosion testing to determine performance in those environments. Further studies are required to substantiate applicability in a broader sense.

Summary and Conclusions

This study was performed to develop and evaluate a Cr-free welding consumable for the purpose of reducing Cr(VI) in the welding fume produced during joining of austenitic stainless steels. Various tests were performed to evaluate the weldability of a Ni-Cu-based consumable during joining of Type 304L austenitic stainless steel. These tests assessed the mechanical performance, corrosion characteristics, weld cracking susceptibility, and fume generation characteristics in comparison to data published elsewhere for conventional stainless steel welding consumables. Based on these tests, the following conclusions were made:

1. The final target composition for a bare wire consumable for GTAW (and potentially GMAW) was Ni-7.5Cu-1Ru-0.5Al-0.5Ti-0.02C. The final target composition for a SMAW core wire was Ni-7.5Cu-1Ru-0.5Al-4Ti-0.02C. Note that this core wire produced a weld deposit with a composition very close to that of the bare wire due to significant Ti loss in the arc.

2. Weld microstructures of GTAW and SMAW deposits consisted of a columnar austenitic grain structure with the presence of Ti(C,N) particles at solidification grain boundaries and cell and dendrite boundaries.

3. Welds deposited on Type 304L stainless steel using Generations II, III, and IV electrodes exhibited good mechanical properties. Tensile strengths of weld deposits exceeded minimum values required for E308-16 weld deposits. Elongation values of Generation III and IV deposits exceeded minimum values required for E308-16 weld deposits.

4. Electrochemical corrosion tests revealed that weld deposits met corrosion design criteria to avoid galvanic and localized corrosion in chloride environments.

5. Transvarestraint testing revealed that Generation II and III weld deposits had solidification cracking temperature range (SCTR) values of approximately 110°C. This is significantly higher than E308L weld metal (30°–40°C) but similar to other Ni-base weld deposits that exhibit moderate solidification cracking susceptibility.

6. Hot ductility testing revealed that the Generation II and III-BW deposits had low liquation cracking indexes as determined by the cracking susceptibility range (CSR) calculations. The CSR values were 33° and 54°C for Generation II and III weld deposits, respectively.

7. Generation III GTA weld deposits had better overall elevated temperature ductility than Generation II SMA weld deposits. Both deposits exhibited a ductility dip in the range of 800° to 1100°C.

8. Strain-to-fracture testing revealed that cracking threshold strains of Generation II (~2%) and III (~3%) weld metals were significantly lower than stainless steel alloys such as Type 304L, although threshold strain levels were comparable to other Ni-base filler metals.

9. Fume generation rates of the Generation II and IV consumables were higher than E308-16 at similar heat inputs but were lower than stainless steel flux cored welding consumables.

10. Cr(VI) bearing compounds were not detected when XRD was used to analyze the chemistry of bulk fume produced from the SMAW process.

11. Cr(VI) in the Generation II and IV welding fumes was reduced by two orders of magnitude compared to E308-16 tested at similar heat inputs. Complete elimination of Cr(VI) may be unavoidable because there will always be some vaporization of Cr from the molten surface during arc welding when there is some dilution of the Ni-Cu consumable by the stainless steel.

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Calorimetric Measurement of Droplet Temperature in GMAW

Droplet temperature reaches a minimum at the transition from globular to spray transfer

BY E. J. SODERSTROM, K. M. SCOTT, AND P. F. MENDEZ

ABSTRACT

Average temperature was calculated from calorimetric measurements in free-flight gas metal arc welding (GMAW) for ER70S-6 (carbon steel), ER316L (stainless steel), and ER4030 (aluminum) electrodes. Measurements were conducted using a constant-pressure water calorimeter to capture the droplets and a flow-through copper cathode/calorimeter to carry the arc. Thermocouples were used to monitor the temperature change of the water flowing through the cathode as well as in the constant pressure calorimeter. Results show a local minimum in temperature during the transition from globular to spray transfer modes.

Introduction

Droplet temperatures during free-flight gas metal arc welding (GMAW) have been studied by several researchers. However, there is an incomplete understanding as to how droplet temperature is affected by process parameters. Understanding the response of droplet temperature with different transfer modes is necessary to understand fume formation rates and alloy recovery.

Droplet temperature measurements have been made using different methods, including thermocouples, optical pyrometry, and calorimetry (Ref. 1). Previous researchers have reported droplet temperatures ranging from the boiling point of the metal in question to several hundred degrees above the melting temperature (Refs. 2–7). Lu and Kou (Ref. 6) utilized a setup that implemented a gas tungsten arc welding (GTAW) torch to melt welding wire to simulate globular transfer and used a water-cooled copper cathode during spray transfer. In each case, the droplets were collected in a calorimeter surrounded by a radiation baffle. Ozawa et al. (Ref. 8) used a calorimeter setup similar to Lu's for droplet heat content measurements. The arc was established between a consumable anode and nonconsumable cathode using a variety of materials. Fu, Ushio, and Matsuda (Ref. 9) tested heat content of steel and aluminum alloys and analyzed the contributions of ohmic heating and heat input from the arc using a setup similar to Lu and Kou but with a carbon cathode. Attempts to acquire the droplets and measure heat content have also been made by Kiyohara, Yamamoto, and Harada (Ref. 10); Ando and Nishiguchi (Ref. 11); Acinger, Sipek, and Smars (Ref. 2); Erohin and Rykalin (Ref. 12); Watkins (Ref. 13); Pokhodnya and Suptel (Refs. 4, 14); Heiro and North (Ref. 15); Ueguri et al. (Ref. 16); and Tong et al. (Ref. 17).

In addition to measuring droplet temperatures, this setup also has the ability to separate heat generated by the arc from that contained within the droplets. The latest data from setups with similar capabilities are from the late 1980s, and the intervals of welding current used in surveying the process were coarse and insufficient to resolve the local minimum in droplet temperature reported in this work. Therefore, it is necessary to revisit the problem using an experimental matrix with slight variations of welding current. The scope of this project is limited to direct current electrode positive (DCEP) welding conditions with 1.1-mm (0.045-in.) ER70S-6 (carbon steel), ER4043 (aluminum), and ER316L (stainless steel) electrodes shielded with argon. Programmable waveforms and/or pulsing were not utilized in the study to minimize the number of experimental degrees of freedom. Although the switch to pulsing or a complex waveform is only a matter of changing the machine settings, the fundamental changes in droplet temperature are expected to be more complex than in direct current and outside the scope of this initial work. The following section describes the experimental setup in detail. The procedure implemented is found in Appendix C.

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KEYWORDS

Gas Metal Arc Welding (GMAW)
Droplet Temperature
Globular Transfer
Spray Transfer
Stainless Steel
Aluminum

Experimental Setup

The experimental setup can be divided into six critical subassemblies. The welding equipment, calorimeter, copper heat shield, water-cooled copper cathode, high-speed imaging, and current/voltage data acquisition work simultaneously to provide feedback about the process.

Welding Equipment

The power source used in this research was a Miller PipePro 450RFC machine operated in constant voltage mode. Coupled to the power source was a Miller PipePro Single Feeder that communicated directly with the power supply for precise process control. The welding torch was a Miller Type GW-60A. An adapter was manufactured to allow for the use of the Miller Type GA-17C contact tip. An Omega gas proportioning rotameter Model FL-2GP-40ST-40ST was used for monitoring the flow rate of the shielding gas, received from the factory calibrated with a precision of ± 2%.

Calorimeter

Instrumental to the experimental setup was a constant-pressure calorimeter shielded from arc influence by a copper

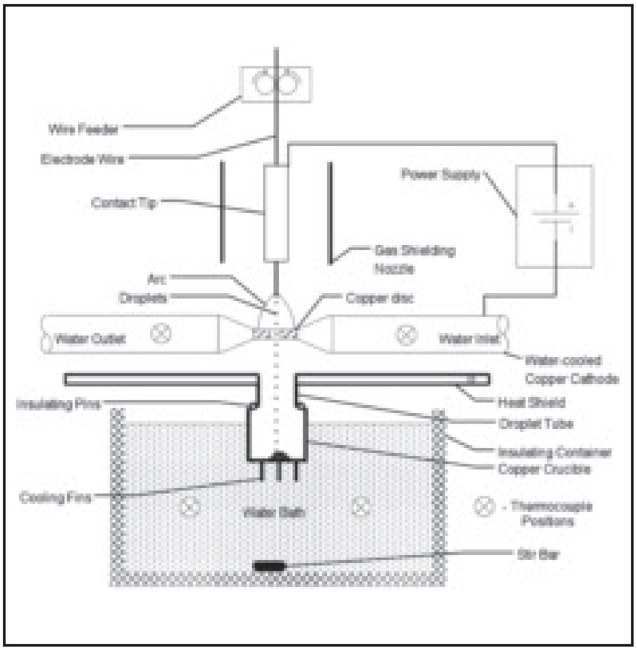

Fig. 1 — The experimental system. Droplets fall through the cathode and are captured in a copper crucible. The temperature change of the water bath is monitored with thermocouples. Not to scale (Ref. 18).

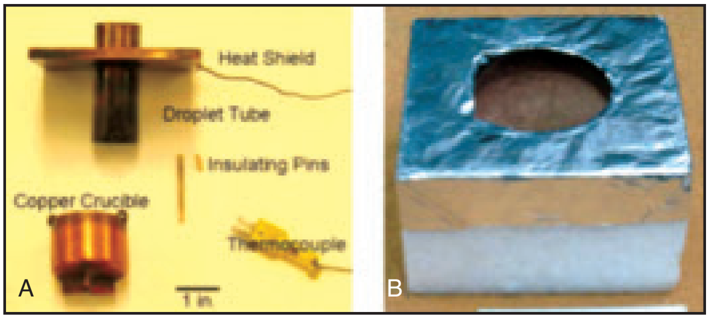

Fig. 2 — A — Components that facilitate capturing the droplets; B — constant-pressure calorimeter made from Styrofoam™ (Ref. 18).

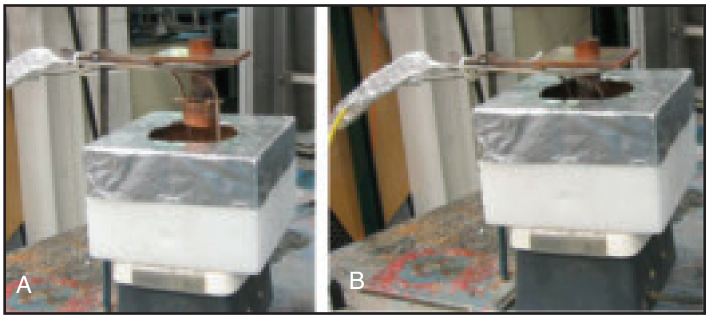

Fig. 3 — A —The assembled calorimeter. The crucible is elevated above the water bath to allow for the photograph; B — the crucible is submerged in the water bath during testing (Ref. 18).

plate along with a water-cooled copper cathode, shown in Fig. 1 (Ref. 18). Due to the harsh nature of the welding environment, many design issues had to be evaluated for feasibility. The first step in the design process was to identify the functionality of each component. After the design and fabrication of the experimental apparatus, a series of tests was performed to validate the system and verify all the components worked properly.

The function of the calorimeter was for the measurement of droplet heat content. Figure 1 shows the main components of the calorimeter system. It is composed of a water bath within an insulating container, a copper crucible to catch the droplets, a supporting system to hold the crucible, a stir bar to circulate the water, and thermocouples to measure the temperature or the water bath.

Figure 2 shows the two main components of the calorimeter, the "hot" components that experience elevated temperature during testing and the insulating container that holds the water bath. When assembled with the insulating pins, which are hollow alumina tubes, the copper crucible is thermally isolated from the droplet tube and heat shield. All of these parts fit together along with the thermocouples, magnetic stir bar, water, and stir plate to form the calorimeter, shown completely assembled in Fig. 3.

The process of acquiring temperature data proved to be difficult due to arc interference that affected data acquisition. Electrical noise greatly influenced the voltage output of the DAQ board. The problem could be solved by using low-noise thermocouples, Omega Model GKQSS-18U-18, as well as oversampling the data. This eliminated excess electrical noise to produce temperature profiles with negligible arc interference.

Copper Heat Shield

The calorimeter may be influenced by the plasma flame that is expelled through the disk of the calorimeter as well as additional radiation from the arc due to the proximity to the copper cathode. To account for this, a heat shield with an embedded K-type thermocouple was integrated between the calorimeter and cathode, as shown in Figs. 1 and 2. The shield can capture some of the radiative heating of the arc. The thermocouple does not account for temperature gradients within the heat shield during the duration of testing.

Water-Cooled Copper Cathode

The water-cooled copper cathode serves several purposes in the system. The first is to sustain the welding arc between itself and the consumable electrode, as shown by the circuit in Fig. 1. The second purpose is to allow passage of the detached droplets into the copper crucible. The third purpose is to monitor the temperature rise in the cooling water to determine the amount of heat that is supplied by the arc to the cathode.

The copper cathode assembly is shown in Fig. 4. Process water from the building's closed-loop system was used as the coolant. Ahead of the water inlet is a 0.2 to 2 gal/min flow meter indicating the flow rate of the process water. The volumetric flow rate is one of the terms needed to calculate the power being supplied to the cathode. The second value is the change in water temperature, which is monitored by the thermocouples placed in the flow-through ports.

Several cathode designs were tested to establish which would perform best for the duration of the study. Figure 5 shows a schematic representation of each. Version 1 is simply a section of 19.05 mm (0.75 in.) copper tubing with a through-hole drilled through the tube body. A smaller section of copper tube was brazed in place to provide a water-tight seal and a passage for the droplets. This design proved to be quite fragile and not sustainable; the arc wandered down the droplet passage and eventually extinguished. Variation 2 is similar to 1 but with a Mullite insulator pressed in place to keep the arc from wandering. This iteration also proved to be unstable, as the insulator melted in conjunction with establishment of the arc. Version 3 implemented a 25.4-mm- (1-in.-) diameter copper disk with a 0.925-mm (0.375-in.) through-hole that was brazed into 19.05-mm (0.75-in.) tubing that had been compressed. After compression, the di-

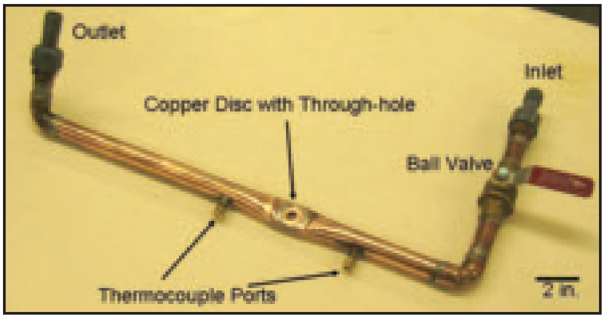

Fig. 4 — The water-cooled copper cathode. This piece of equipment acts to monitor water temperature before and after the arc and to allow droplets to travel unobstructed into the crucible (Ref. 18).

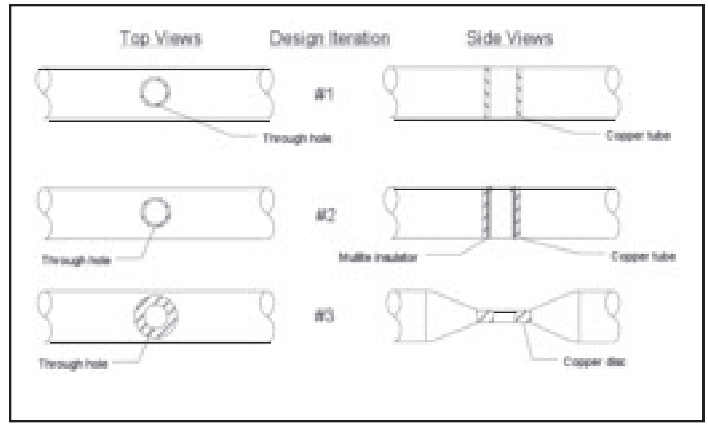

Fig. 5 — Copper cathode design iterations. Version 3 led to the most desirable arc characteristics (Ref. 18).

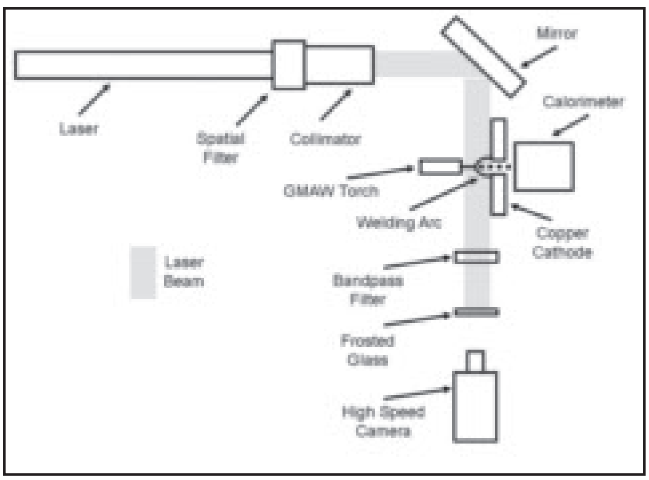

Fig. 6 — A schematic of the laser imaging system used in the research. The welding gun, calorimeter, and cathode have been rotated for the sake of the schematic. Actual welding position was vertical (Ref. 18).

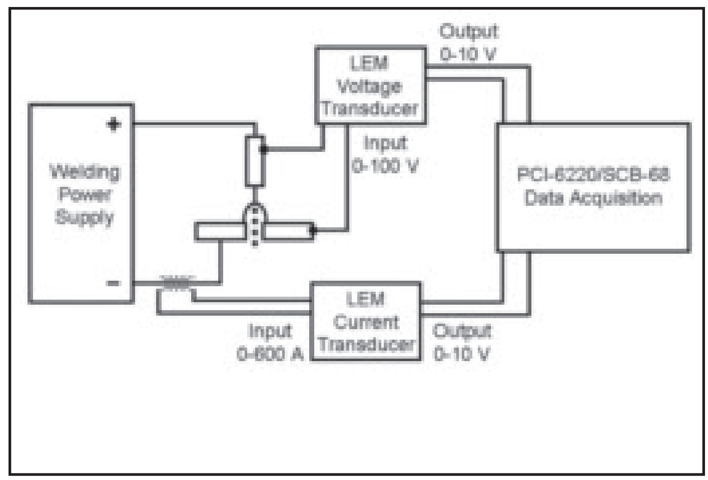

Fig. 7 — Diagram of the current/voltage data acquisition setup (Ref. 18).

mensions of the cathode at the copper disk were 31.75 mm wide × 6.35 mm thick (1.25 in. × 0.25 in.). The flat surface of the disk allowed the arc to be established and maintained consistently resulting in an arc that is typical of standard bead-on-plate GMA welds. Although undocumented, arc stability on the copper cathode will be demonstrated in subsequent publications. The consistent results led to the implementation of this version for the remaining tests.

Imaging System

This setup is very similar to the laser shadowgraph system used by Allemand et al. (Ref. 19), which has seen wide use by many researchers and is shown in Fig. 6.

The high-speed camera used in this research was an X-PRI model manufactured by AOS Technologies AG. Recordings were made at either 1000 or 2000 frames per second, depending on the metal transfer mode. The lens used for imaging was a variable zoom (0.5 to 3×) unit.

Current and Voltage Data Acquisition

The current was measured with a LEM HTA 600-S current transducer, which has a current range of 0–600 A. An LEM LV25-P voltage transducer was used for voltage sampling; it is capable of sampling between 0 and 100 V. Both sensors were connected to a signal processing device. Figure 7 shows a representation of this setup.

Synchronization

Synchronization of the high-speed video with the high-speed current and voltage signals was accomplished using various techniques. Because the data card used in this research does not have analog output abilities, the signal had to first be routed through a digital relay. An AC voltage generator was then used to activate the mechanical relay that triggered the camera. The camera was triggered upon activation of the current and voltage acquisition system.

To synchronize the independent systems, an LED that operates off of the current/voltage system was placed in the line of sight of the camera. Programmed to activate every 100 ms for 10 ms, the LED allows for adjustment of the video to align with the current/voltage output. When the adjustment is complete, the video lags the current and voltage signals by approximately 1 ms. The video will always lag the current and voltage because of the delay in the mechanical relay used to activate the camera.

Figure 8 shows two images captured 10 ms apart. The vertical bar on the voltage readout indicates where the frame of the video aligns with the voltage signal. The videos were compiled by a MATLAB code written specifically for this project.

Results and Discussion

Droplet Heat Fraction

An advantage to using the current setup is the ability to separate the heat

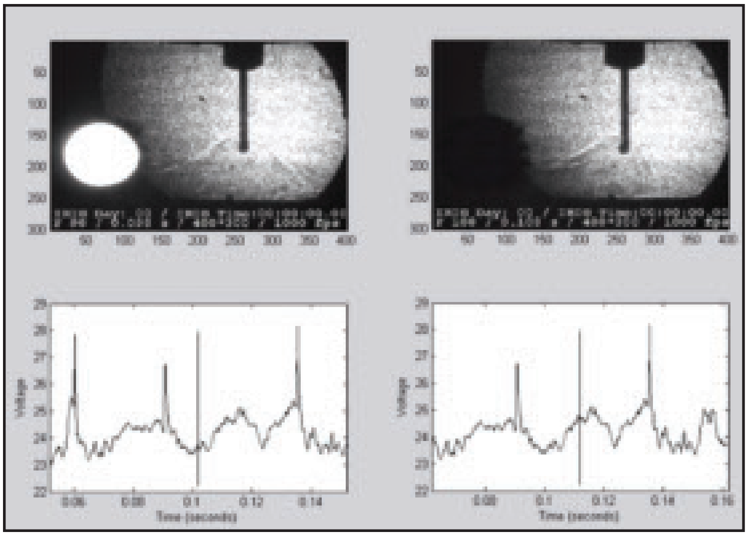

Fig. 8 — Images captured 10 ms apart using the synchronization system. This figure demonstrates the delay between the video and voltage signal. Although it was proven that the peaks correspond to droplet detachment (Ref. 18), the signal does not precisely correlate to the video. ER4043, 107 A.

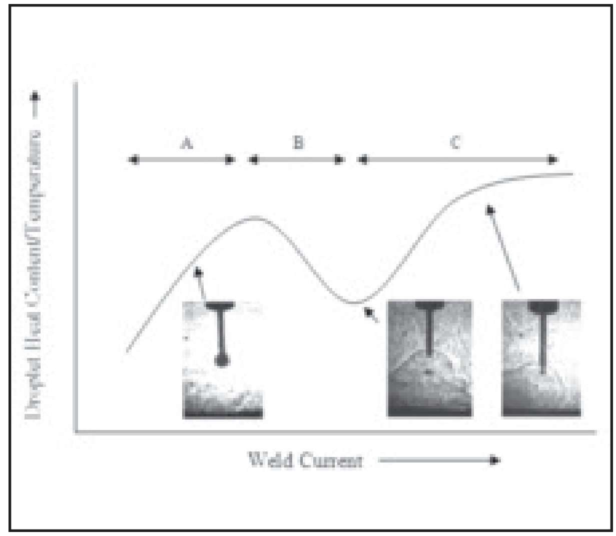

Fig. 9 — Generic trend seen in each case, with three distinct regions representing the following: A — Globular transfer; B — the transition region; C — spray transfer. The photographs are of 1.1-mm (0.045-in.) ER4043 electrodes shielded with argon.

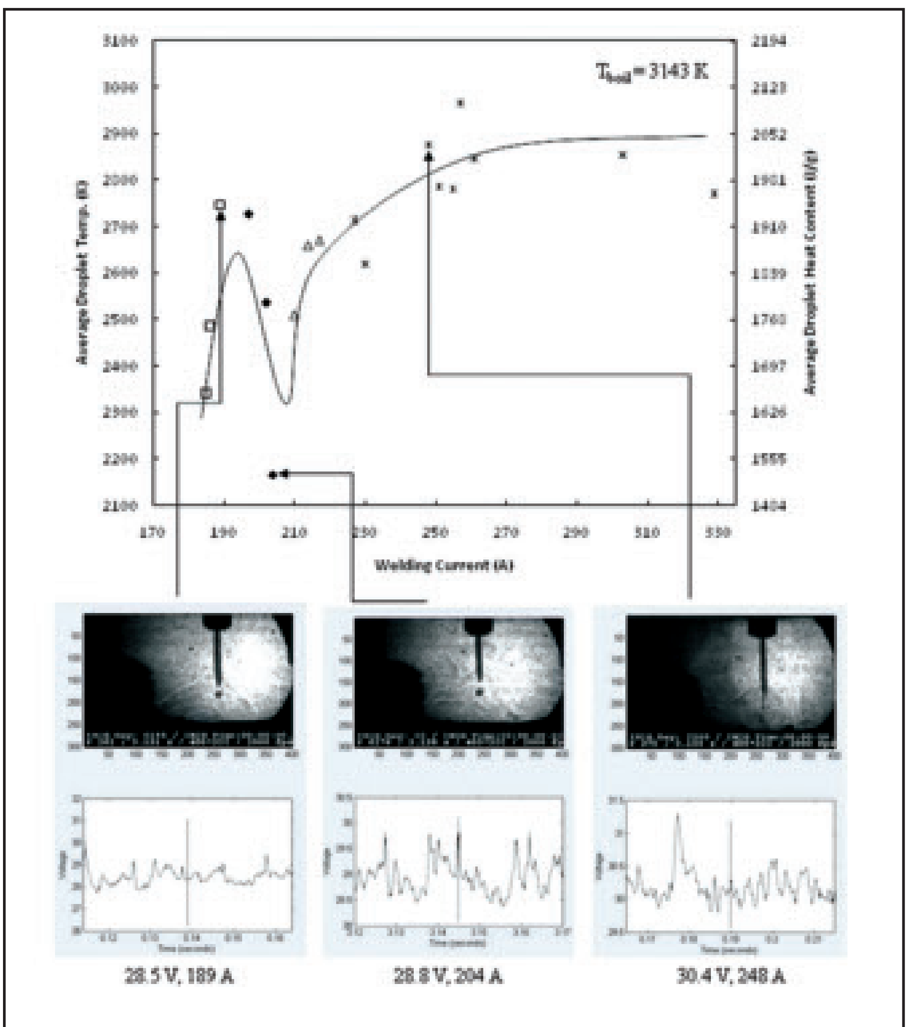

Fig. 10 — Average droplet temperature and average droplet heat content for ER70S-6 (mild steel) 1.1-mm (0.045-in.) electrodes shielded with argon. Data used for calculating average droplet temperature and heat content in regions A, B, and C are indicated by square, diamond, and triangle markers, respectively.

content of the droplets from that of the arc. Results from previous researchers show efficiencies anywhere from 68 to 88% (Refs. 7, 20–22), depending on the welding conditions. These results were found using a variety of methods, none of which isolates the arc from the droplets. The methodology for computing the heat fraction of the droplets is straightforward. The process is not completely efficient due to radiation and evaporative losses; therefore, for the nonpulsed conditions used, the total heat into the weld is given by the following:

$$q_w = IV\eta \quad (1)$$

where q_w is the total energy input to the weld and η is the process efficiency. The main emphasis of this study is to determine the heat content of the droplets in globular and spray transfer modes, given by Equation 2:

$$q_d = f_d q_w \quad (2)$$

where q_d is the heat contained within the droplets and f_d the droplet heat fraction. Both welding current and voltage were measured using transducers; therefore, the total power delivered to the system was calculated using Equation 1. Because the arc is separated from the calorimeter by the heat shield and copper cathode, any subsequent increase in the temperature of the water bath is considered to come from the droplets. Therefore, f_d is expressed by rearranging Equation 2, leaving

$$f_d = \frac{q_d}{q_w} \quad (3)$$

Combining Equations 1 and 2 leaves the

total heat of the droplets in terms of the welding current, voltage, process efficiency, and droplet heat fraction as follows:

$$q_d = f_d \eta IV \quad (4)$$

Droplet Heat Content and Temperature

The behavior of both the average droplet heat content and average droplet temperature as a function of welding current followed the same generic trend for each of the alloys, shown in Fig. 9, with three distinct regions: A, corresponding to globular transfer mode; B, corresponding to the transition; and C, the region correlating to projected/streaming spray transfer. Droplet energy increased until the process reached a threshold, or the transition from globular to spray transfer. Although unstable, process operation within the transition region can help reduce fume formation and therefore alloy losses, two aspects that are highly desirable in industry when workplace cleanliness is of concern. Also, the advent of new, highly alloyed materials make reducing alloy losses necessary. This region can also be tailored using pulsing to make it more desirable for an industrial setting.

In the transition phase, droplet size decreased and the energy balance of the system changed. A detailed, theoretical study of this phenomenon is in progress. Intuitively, however, it is reasonable to expect that for a given droplet size, surface temperature increases with heat input which increases with current (Ref. 23). The sudden reduction of droplet size hinders development of the thermal gradient and therefore decreases average droplet temperature.

Heat content and droplet temperature are monotonically related through the specific heat capacity of the metal, and are calculated via a simple heat balance between the melting and superheating of the droplet and the calorimeter, as shown in Equation 5:

$$\int_{T_l}^{T_d} C_{pl} dT + \Delta H_f + \int_{T_f}^{T_s} C_{ps} dT = \int_{T_w}^{T_f} C_{pw} dT + \int_{T_w}^{T_f} C_{pc} dT \quad (5)$$

where T_d is the maximum temperature of the molten droplet, T_l is the liquidus temperature of the droplet, C_{ps} is the specific heat capacity of the solid metal, ΔH_f is the latent heat of fusion of the metal, T_s is the solidus temperature of the metal, T_f is the final temperature of the water in the calorimeter, C_{pl} is the specific heat capacity of the molten metal, T_w is the initial temperature in the water bath, C_{pw} is the specific heat of water, and C_{pw} is the specific heat of the copper crucible. In this first implementation of the calorimeter, average C_p values were used, resulting in the linear Equation 6. This equation can be easily solved, unlike Equation 5, which is nonlinear. More information about the values used in the calculation can be found in Appendix B.

$$C_{pl}(T_d - T_l) + \Delta H_f + C_{ps}(T_s - T_f) = C_{pw}(T_f - T_w) + C_{pc}(T_f - T_w) \quad (6)$$

In Equation 6, the only unknown is T_d, the temperature of the droplet after leaving the arc column. The approximation that C_p does not change significantly with temperature was made to simplify the calculations in this study. The authors acknowledge the influence of temperature on the heat capacity of materials, and are currently working on incorporating this variability into the calculations.

The average droplet temperature for each alloy is shown in Figs. 10–12. In these graphs, the points represent the experimental data, while the continuous lines represent a manual interpretation. Not all the data were of the same quality, in particular the case of the steel electrode for which the design of the cathode was still at an iteration stage, resulting in a relatively large scatter in Fig. 10.

An interesting observation should be noted. In the case of the steel electrode, the maximum recorded average droplet temperature is below the boiling temperature of the liquid. However, previous research has indicated temperatures at the surface of the droplet to be at the boiling point (Ref. 24). This suggests that the bulk temperature of the droplet is well below the boiling point of steel, and that vapor-

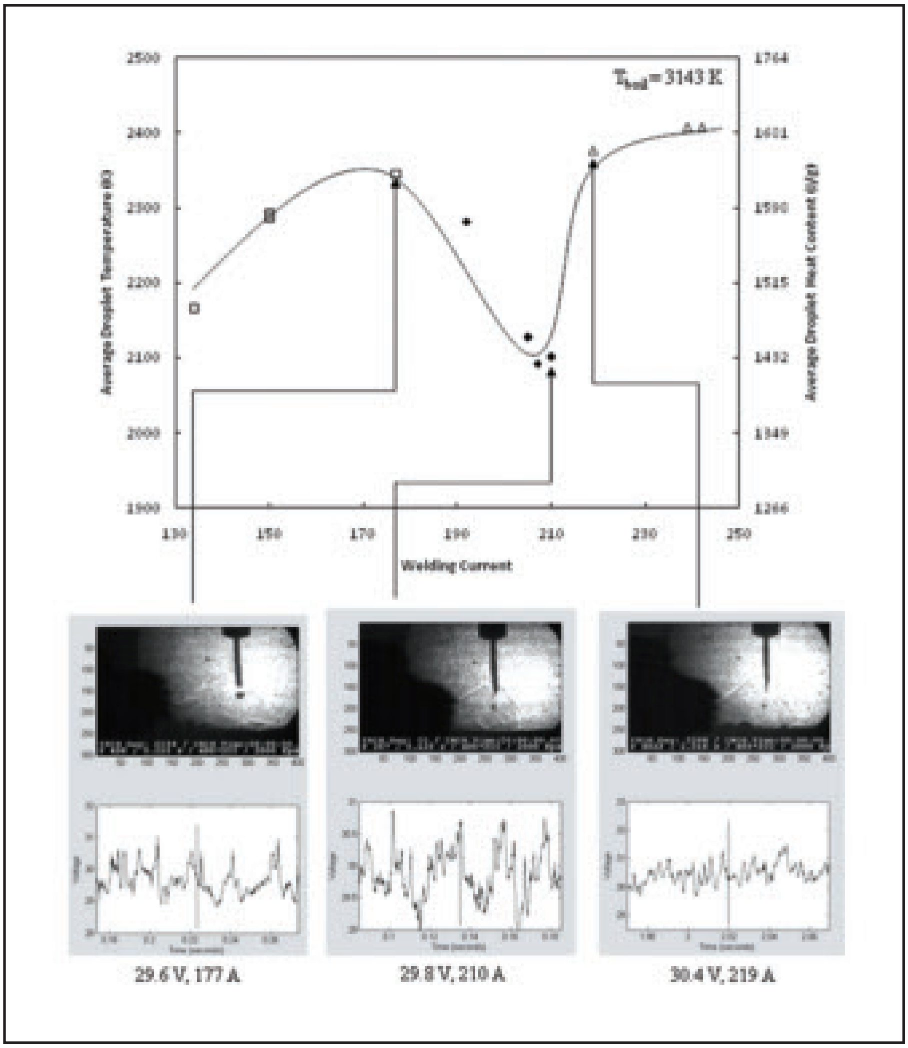

Fig. 11 — Average droplet temperature and average droplet heat content for 1.1-mm (0.045-in.) ER316L (316 stainless steel) electrodes shielded with argon. Data used for calculating average droplet temperature and heat content in regions A, B, and C are indicated by square, diamond, and triangle markers, respectively.

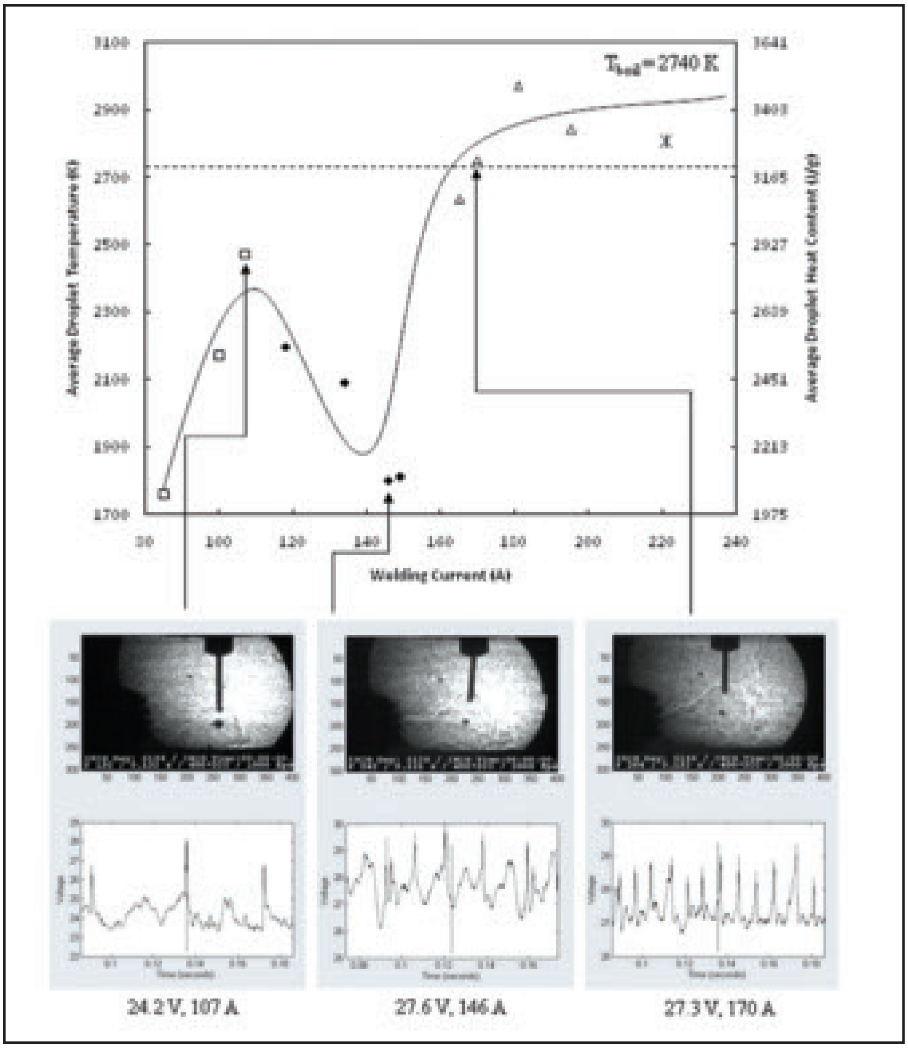

Fig. 12 — Average droplet temperature and average droplet heat content for 1.1-mm (0.045-in.) ER4043 (aluminum) electrodes shielded with argon. Data used for calculating average droplet temperature and heat content in regions A, B, and C are indicated by square, diamond, and triangle markers, respectively.

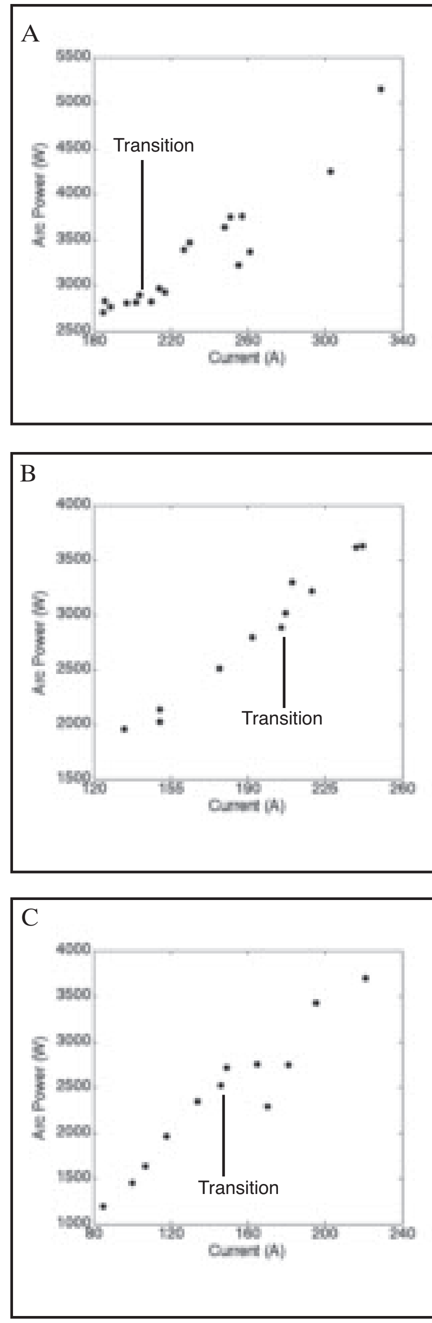

Fig. 13 — Cathodic heat input for the following: A — ER70S-6; B — ER316L; C — ER4043 1.1-mm (0.045-in.) electrodes shielded with argon.

ization may not be a dominant heat transfer mechanism. The same cannot be said for the aluminum droplets, however. The maximum recorded droplet temperature in this case was above the boiling point, indicating vaporization is a dominant heat transfer mechanism. In making these considerations, it is important to keep in mind that temperature gradients within the droplet can cause surface temperatures to be much higher than bulk temperatures.

Arc Power

The minimum seen in the droplet heat content was only seen in the droplets, and did not translate to the arc. Figure 13 shows a linear trend between arc power and welding current, as expected.

The apparent minimum arc power seen in the ER4043 data set, as well as the scatter seen in the ER70S-6 data set do not correspond to a minimum droplet temperature or any significant change with the process. They are likely related to experimental error.

Heat Distribution

Table 1 shows how heat is distributed between the electrode and cathode during welding on a copper cathode. For the constant voltage conditions used, average power input is calculated by multiplying the average welding current by the average voltage. Average droplet, cathodic, heat shield, and other heat fractions are calculated by dividing average droplet heat content, energy delivered to the cathode or heat shield and energy not directly measured by the total average power input. Average droplet heat content is calculated from Equation 6, from which average droplet temperature can be directly calculated. The calculation of process efficiency considers only the average droplet heat content and heat delivered to the cathode divided by average total power. Because radiation from the arc as well as from the plume extending below the cathode were not taken into account in the captured fraction calculation, the overall captured energy was lower than typical reported efficiency values.

The copper heat shield was not used consistently during the testing of the ER70S-6 electrodes and was therefore omitted from the table. In both ER316L and ER4043, the fraction of heat contained within the heat shield was quite low, between 5 and 11%. This suggests one of two things: either welding times were not long enough to allow the plate to come to thermal equilibrium, or it is simply not capturing significant quantities of heat from the plasma flame. Changes can be made to the experimental procedure to determine the best way to capture more of the radiant heat.

Conclusion

- An experimental platform was constructed that has the ability to characterize several different aspects of the GMAW process. Metal transfer modes were analyzed with a high-speed laser imaging system that is synchronized to the current and voltage signal. The results show direct correlation between droplet detachment events and sharp peaks in the voltage outputs of the process. Energy measurements of both the detached droplets and welding arc were made on three separate calorimeter systems.

- Three different electrode materials, ER70S-6 steel, ER316L stainless steel, and ER4043 aluminum were tested for average droplet heat content and temperature during different metal transfer modes. The same trend was seen for all three alloys; a significant reduction in droplet heat content and average droplet temperature occurs at the transition from globular to spray transfer. Average droplet temperature increased slightly during globular transfer, was minimum at the transition between globular and spray transfer, and any subsequent increase in welding current in the spray transfer mode increased the heat content of the droplets.

Table 1 — Summary of Heat Distribution on ER70S-6, ER316L, and ER4043 Electrodes for the Three Transfer Modes Observed[(a)]

		ER70S-6		
	Unit	A	B	C
Avg Power Input	W	5444	5835	5926
Avg Droplet	%	23	23	28
Avg Cathode	%	51	49	49
Avg Heat Shield	%	N/A	N/A	N/A
Losses Not Captured	%	26	28	22
Avg Droplet Temp.	K	2524	2476	2612
Avg Droplet Heat Content	J/g	1789	1753	1846
Captured Fraction	%	74	72	78
		ER316L		
	Unit	A	B	C
Avg Power Input	W	4370	5947	7141
Avg Droplet	%	24	24	26
Avg Cathode	%	43	45	42
Avg Heat Shield	%	7	6	6
Losses Not Captured	%	27	25	25
Avg Droplet Temp	K	2273	2151	2397
Avg Droplet Content	J/g	1578	1474	1677
Captured Fraction	%	67	69	68
		ER4043		
	Unit	A	B	C
Avg Power Input	W	2368	3625	4959
Avg Droplet	%	19	15	21
Avg Cathode	%	55	55	51
Avg Heat Shield	%	5	11	5
Losses Not Captured	%	21	19	23
Avg Droplet Temp.	K	2133	1975	2800
Avg Droplet Heat Content	J/g	2495	2305	3281
Captured Fraction	%	74	70	72

(a) Average values are tabulated by using points that lie closest to the transition, i.e., data collected at relatively high or low welding currents are neglected. The overall captured fraction is comparable to low values of efficiencies reported in literature. This suggests the setup does not lose much energy that would have been transferred to a substrate in typical bead-on-plate welding.

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Appendix A

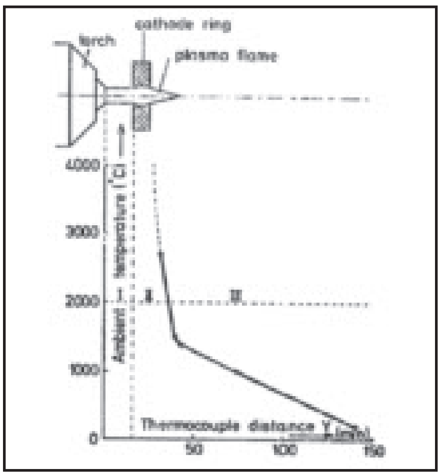


Fig. 14 — Ambient temperature readings using a thermocouple at different distances from a cathode ring. At approximately 140 mm (5.5 in.), the plasma flame shows little effect. From Jelmorini (Ref. 5).

In research conducted by Jelmorini (Ref. 5), it was shown that excess energy input from the plasma to the calorimeter may be problematic. To avoid excess heating, it was determined that the calorimeter should be ~140 mm (5.5 in.) below the exit of the cathode (Ref. 5). Figure 14 shows the results obtained by Jelmorini. In addition to the offset distance recommended by Jelmorini, this study used a copper heat shield to further reduce arc influence on the droplets and calorimeter.

Appendix B

See Table 2.

Appendix C

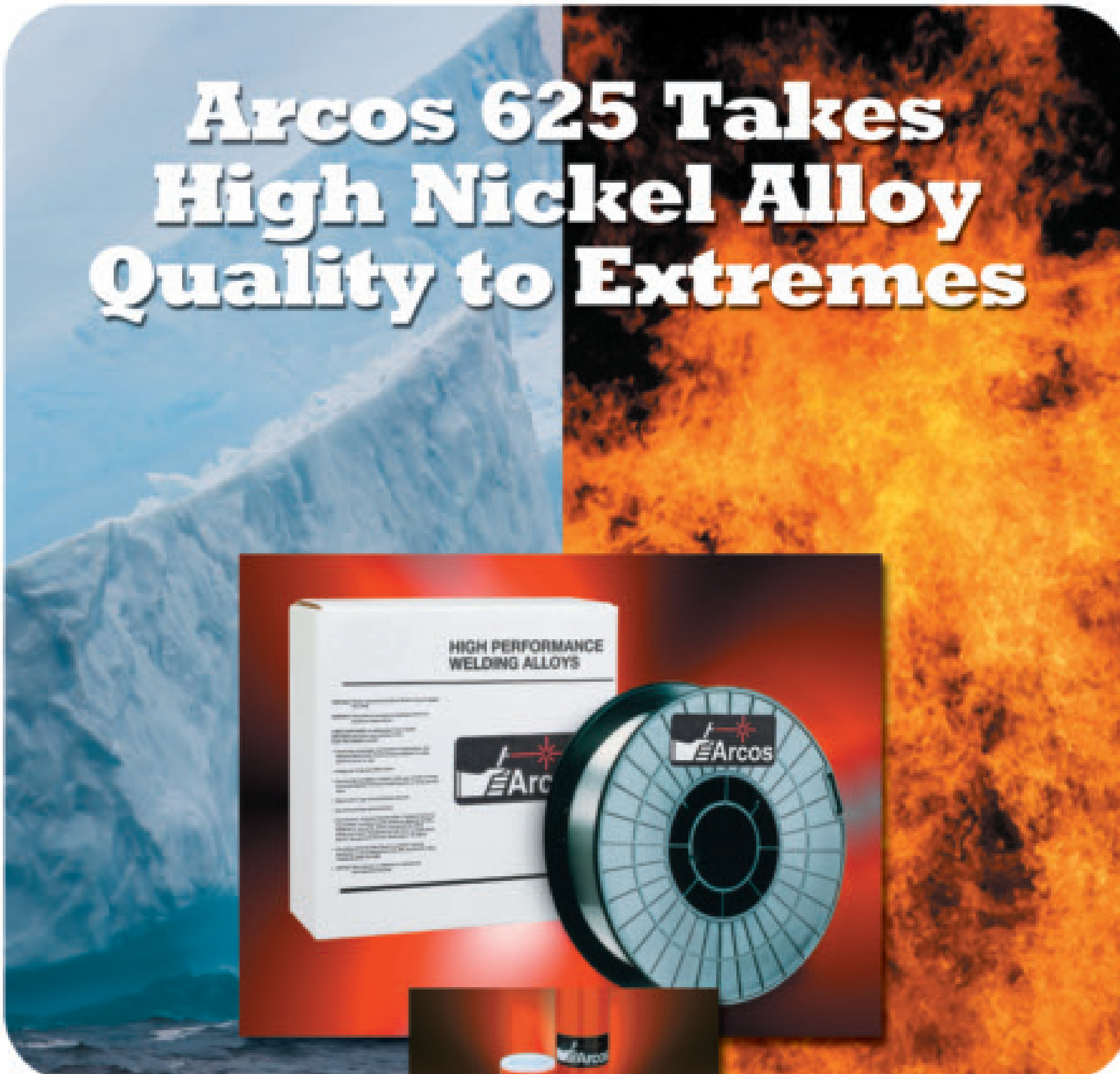
Procedure

- The power supply was turned on and shielding gas was purged through the system to ensure proper flow rate.
- Wire adjustment can be checked with a simple test of hand feeding the wire through the cable with little resistance.
- If new welding parameters are to be used, the proper adjustments (wire feed speed, voltage) need to be made prior to taking actual heat measurements. Adjustments are made to keep the contact tip to work distance and electrode extension constant at 25.4 mm (1 in.) and 12.7 mm (0.5 in.), respectively.
- Align the torch with the copper cathode by feeding enough wire through the contact tip such that it sticks through the hole in the cathode. Adjustments are made via X-Y-Z adjustment knobs.
- Clean the copper cathode using a die grinder equipped with a 76-mm-(3-in.-) diameter Scotch-Brite™ SL surface-conditioning disc.
- Set the process water flow rate to 3 L/min (0.79 gal/min) using the flow meter and ball valve on the copper cathode.
- Assemble the calorimeter. Prior to assembly, the Styrofoam and empty copper crucible are weighed individually to calculate any mass loss or gains during the experiment.
- The two thermocouples that monitor the temperature of the water bath are clamped into position with metal binder clips such that they are directly adjacent, but not touching, the copper crucible.
- Pour approximately 500 mL of water directly into the center cavity of the Styrofoam. Record the exact amount of water that is poured into the Styrofoam for later calculations. A magnetic stir bar is placed into the Styrofoam container, which is subsequently placed on the magnetic stirrer.
- Turn the magnetic stirrer to 400 rev/min.
- The calorimeter is now ready for the experiment. Raise the calorimeter to immerse the crucible in the water bath.
- The data acquired during experiments are divided into three separate categories: current and voltage, temperature, and video. All three are controlled by a program written in LabView.
- When all of the subassemblies are prepared for an experiment, the welding process can be enabled. The arc is started by using a flattened piece of copper tubing, positioned in such a way to create a short circuit between the wire and cathode.
- Once the process stabilizes, the manual trigger on the voltage/current acquisition can be pressed. This operation will simultaneously begin the voltage/current analysis as well as the high-speed video recording.
- Record the final weight of the Styrofoam container and copper crucible.
- Three different computer files are generated: the current/voltage signal, the temperature signal, and the movie file. These files are analyzed along with the weight and time measurements to determine average droplet detachment frequencies, heat contents, current, and voltage.

Table 2 — Thermophysical Properties of Materials Used in This Study (Ref. 24)

Material Property	Symbol	Unit	ER70S-6	ER316L	ER4043	Copper	Water
Liquid heat capacity	C_{pl}	J/gK	0.711	0.83	1.19		4.186
Solid heat capacity	C_{ps}	J/gK	0.685	0.6	1	0.385	
Heat of fusion	ΔH_f	J/g	250	260	425		
Liquidus temperature	T_l	K	1538	1402	614		
Solidus temperature	T_s	K	1538	1402[(a)]	614[(a)]		

(a) Although these alloys undergo a range of solidification, for the sake of the calculations, it was assumed that the solidus and liquidus temperatures are the same.



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