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On the cover: Two Motoman SSA2000 robots weld individual segments for snow plows.
Manufacturers Must Rethink, Retool, Rebuild

While it’s clear to everyone that U.S. manufacturing isn’t the powerhouse it once was, we tend to forget how large a segment of our economy it remains and how important it is. To give you an idea of how large and how important, take a look at these statistics posted on the Web site of the International Trade Administration, an agency of the U.S. Department of Commerce.

- The United States is the world’s largest manufacturing economy, employing nearly 12 million people in the production of $1.6 trillion in manufactured products.
- U.S. manufacturers produce 18% of the world’s manufactured goods.
- U.S. manufactured products accounted for 86% of all U.S. exports of goods in the first quarter of 2010.
- The manufacturing sector accounts for 11% of U.S. gross domestic product.
- Manufacturing accounts for 9% of total U.S. employment.

While the general public might have the impression American companies don’t manufacture very much any more, it’s clear from those figures that the perception doesn’t actually reflect the truth. What is true, however, is that U.S. manufacturers are struggling in an era of ever-increasing global competition and high costs. This has been the situation for a long time, but the pressures are even greater during a period when the entire economy remains in a downturn.

So what’s to be done?

The Manufacture America program, a segment of the International Trade Administration, is organizing a series of regional conferences “designed to help American manufacturers rethink, retool, and rebuild their operations through exploring new products, markets, processes, and sources of finance.” The conferences are scheduled to be held in Morgantown, W.Va., Pittsburgh, Pa., Detroit, Mich., and Chicagoland, Ill., starting in the fall. You can visit http://trade.gov/manufactureamerica to get the details; you can also send questions to ManufactureAmerica@trade.gov.

According to Manufacture America, the purpose of the conferences is to allow manufacturers to
- Learn how they can retool and rebuild through entering new market segments, industries, or supply chains, as well as modernizing processes to become more sustainable and efficient while lowering costs
- Hear success stories from manufacturers who have successfully retooled
- Learn about export opportunities and how to export
- Learn about resources and funding, including technical assistance and financing
- Discuss issues they face with federal, state, and local governments
- Network with representatives from other companies.

I’ve never been fond of the term proactive. It’s used so often and has become such a buzzword that it doesn’t seem to have the punch it should have. However, it fits in this case. Proactive means to create or control a situation by causing something to happen rather than responding to it after it has happened. Now, I’m not so naive as to think attending a conference will solve all the problems of today’s manufacturers, but it certainly could be a start. These conferences are one idea; I’m sure there are lots of other good ideas out there as well. I do know that we need to proactively rethink, retool, and rebuild so that the public’s perception doesn’t become the reality.

Mary Ruth Johnsen
Editor, Welding Journal and Inspection Trends
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R&D Funding Bill Finally Passes House

Unsuccessful in two attempts due to spending concerns, the America Competes Reauthorization Act was approved by the U.S. House of Representatives on the third try. The bill would authorize approximately $85 billion for research, education, and innovation programs over the next five years at the National Science Foundation, Department of Energy, and National Institute of Standards and Technology. The bill is a comprehensive overhaul of the 2007 legislation aimed at a ten-year budget-doubling for these agencies.

This legislation faces an uncertain future in the Senate.

Bill Introduced to Provide Technical School Subsidies

Legislation has been introduced in the House that would establish and fund competitive grants to states to subsidize the education of unemployed persons at local technical schools. Subsidies would be limited to $2000 per student per academic year for a maximum of two years. This bill (HR 5594) defines the term “technical school” as any “postsecondary vocational institution that provides career and technical education.”

Skills Legislation Broadly Supported

The America Works Act (S. 3529) has been introduced in the U.S. Senate. This legislation would seek to better align federally funded education and training to the needs of employers by incentivizing existing federal job-training programs to implement an industry-recognized credential system. This bill has received bipartisan support.

Government Intellectual Property Plan Released

Recognizing that “enforcement of intellectual property rights is a critical and efficient tool we can use, as a government, to strengthen the economy, support jobs, and promote exports,” the White House recently unveiled its first Joint Strategic Plan to combat intellectual property theft from U.S. companies by foreign competitors and governments. Among the action steps are a particular focus on China and on the unique problems posed by foreign-based Web sites and other entities that provide access to counterfeit or pirated products.

The report is available at the following link: www.whitehouse.gov/omb/assets/intellectualproperty/intellectualproperty_strategic_plan.pdf.

White House Officially Ends Agency and Commission Appointment of Lobbyists

President Barack Obama has directed all federal agencies to cease making appointments of federally registered lobbyists to agency advisory committees and other boards and commissions. In doing so, the president cited the need to reduce the “undue influence of special interests that exert this disproportionate influence by relying on lobbyists who have special access that is not available to all citizens.” Persons currently serving on advisory boards are unaffected.

This action follows on an Executive Order from earlier this year restricting the hiring of registered lobbyists by the federal government to work in positions related to their prior lobbying activities.

OSHA Proposes Revised Rules for Injuries on Walking-Working Surfaces

The U.S. Occupational Safety and Health Administration (OSHA) has announced in a notice of proposed rulemaking to require additional worker protection from tripping, slipping, and falling hazards on walking and working surfaces. The notice describes revisions to the Walking-Working Surfaces and Personal Protective Equipment standards. OSHA estimates that there are 20 workplace fatalities and more than 3500 serious injuries annually in this area.

The Federal Register notice is available at http://s.dol.gov/3J.

Pension Legislation Signed into Law

Legislation has been signed into law to allow more time for employers to make up losses to their pension plans suffered when the stock market plummeted beginning in late 2008. Most pension plans, on average, lost 30% of their value during the market downturn at the end of 2008 and the beginning of 2009. The Preserve Benefits and Jobs Act will give companies additional time beyond the prior seven-year time limit to make up those losses and it is hoped free up essential cash for companies to expand and create jobs.

Proposed Rule Would Allow Metric-Only Labeling for Some Products

The National Institute of Standards and Technology (NIST) is urging the amendment of federal labeling laws to allow the voluntary use of only metric units on some consumer products. NIST argues that adoption of metric labeling will lead to greater agreement between state and federal labeling laws and simplify domestic and international commerce.

Other Developments Affecting Small Businesses

- Efforts to pass so-called “extenders” legislation (HR 4213) continue to stall. This legislation would, among other things, extend the research and development tax credit, which expired at the end of 2009. Offsetting tax increases included in the legislation are the primary focus of the continuing negotiations in Congress.
- House and Senate conferees on financial reform legislation have tentatively agreed to exempt publicly traded companies with market capitalization of less than $75 million from having to comply with reporting requirements of the Sarbanes-Oxley Act.
- Legislation (HR 5297) has passed the House. Designed to increase lending to small businesses, this bill would authorize a fund of up to $30 billion that would be available to community banks that could then leverage these amounts to as much as $300 billion in small business loans.

Contact the AWS Washington Government Affairs Office at 1747 Pennsylvania Ave. NW, Washington, DC 20006; e-mail hwebster@wc-b.com, FAX (202) 835-0243.
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Mary Andringa Appointed to Presidential Council

Mary Vermeer Andringa, president and CEO, Vermeer Corp., Pella, Iowa, was appointed July 7 by President Barack Obama to serve as a member of the President’s Export Council. In this capacity, she will join a panel of business leaders from around the country who will offer advice on how to promote U.S. exports, jobs, and growth. Andringa also serves as vice chairman of the board, National Association of Manufacturers; a director for Herman Miller, Inc.; a member of the Board of Councilors for the China-U.S. Center for Sustainable Development; a trustee for Fuller Theological Seminary; and trustee emeritus on the Central College Board. Andringa was selected to serve on the council as a private-sector representative of business and industry, agriculture, and labor.

Miller Launches 5th Annual Welding Project Contest

Miller Electric Mfg. Co. launched its 5th annual Welding Project Contest: The Welding Showdown. Contestants will submit a project in one of three categories — easy, moderate, or difficult. Judges will select two finalists from each category based on the project’s creativity, presentation quality, and craftsmanship. Entries are due by August 10.

Each finalist wins an ArcStation™ 30SX welding workbench, Arc Armor™ welding protection package, and all-expense-paid trip to the company’s headquarters in Appleton, Wis. Also, finalists will receive a tour of Miller’s headquarters and compete head to head to build a project, selected by the company, within a set time period. Miller will supply all materials and tools for the Welding Showdown as well.

The grand prize winner in each category wins their choice of a Millermatic® 211 Auto-Set™ with MVP™ gas metal arc welding machine with a Spoolmate™ 100 spool gun, a Diversion™ 180 gas tungsten arc welding package, or a Spectrum® 375 XTREME™ plasma cutting device.

For information on contest rules and entering, visit www.millerwelds.com/showdown.

Robotic Industries Assoc. Starts Educator Sponsorships

A new Educator Sponsorship program, an initiative by the Robotic Industries Association (RIA) Membership Committee, has been launched to assist robotics faculty and students pursuing careers in robotics. It allows any RIA member to sponsor a teaching and training institution for an Educator Membership in the association. Eligible institutions include vocational and technical institutes as well as two- and four-year colleges offering a curriculum and path leading to high-tech, well-paying jobs in robotics or related automation technologies.

ABB Inc. is the first member to utilize the program by sponsoring Fox Valley Technical College, Appleton, Wis., and Vincennes University, Vincennes, Ind.

A company sponsorship is $350 per school and provides benefits including company recognition on the Robotics Online Web site, participation in student research or development projects, and opportunities to present new technology and/or products in the classroom or provide seminars and recruitment days at the institution. To learn more about sponsorship of an RIA Educator Member or how to be a sponsored institution, visit www.robotics.org/EduSponsor.

TRUMPF Debuts Its Interactive LaserLab

TRUMPF’s LaserLab, currently on display at the Connecticut Science Center in downtown Hartford, enables children and adults to learn about lasers, including how the technology impacts everyday life. The hands-on exhibit, courtesy of TRUMPF, Inc., Farmington, Conn., is making its North American debut at the center through Sept. 4. Developed by the company’s mechanical engineering students from the Stuttgart University of Cooperative Education in Germany, it features a foosball table where visitors can put their newly-acquired understanding of lasers to use, and a station that lets a single person or team guide a laser beam through a labyrinth.
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AWS Enhances Web Site for Welding Jobs

The American Welding Society (AWS) has recently made improvements to its Jobs In Welding Web site. Located at www.jobsinwelding.com, the redesigned career portal includes additional capabilities for companies posting and individuals looking for jobs.

Through relationships with numerous job boards and distributors, it offers direct access to more than 88% of the welding jobs posted on the Internet. Users may search various openings for welders, Certified Welding Inspectors, engineers, technicians, and managers/supervisors.

The Web site contains the following highlights:
- The home page displays featured welding jobs along with the companies looking to fill these and city/state locations.
- The job seeker section connects individuals to new career opportunities allowing them to post an anonymous résumé, view jobs, and make personal job alerts. This area has résumé tips, certification information, and a school locator.
- The employer area enables association with qualified applicants. Résumés, job postings, and products/pricing options may be viewed here.

“We are excited about the increased exposure this site offers to both employers and job seekers,” said Monica Pfarr, corporate director, Solutions Opportunity Squad, AWS Foundation Inc. “Thanks to OKI Bering for their generous donation to the AWS Foundation. Their leadership made this jobs Web site redesign possible.”

Visit the Web site to create or access job seeker and employer accounts. Current or previous customers of AWS Job Find have had their accounts transitioned to the new job board and passwords reset. In addition, for those who have posted their résumés, they have been transitioned to the updated site and are currently listed as private; however, if users now want to have their résumé visible, they will need to access their account to make it public.

Individuals with questions may call (860) 437-5700 or send an e-mail to support@jobtarget.com.

Motoman Robotics to Get New North American Headquarters

Motoman Robotics expects to move by June 2011 into new headquarters combining the current West Carrollton, Ohio, headquarters plus a manufacturing plant and warehouse in Troy, Ohio. Pictured are three of the company’s SSA2000 robots welding individual segments for snow plows.

The Motoman Robotics division of Yaskawa America, Inc., recently executed an option agreement to secure property at the Austin Rd. interchange just south of Dayton, Ohio, for its 300,000-sq-ft office and production facility.

The company’s new North American headquarters will combine the current West Carrollton, Ohio, headquarters along with a manufacturing plant and warehouse in Troy, Ohio. The facility will house approximately 250–275 employees, and there’s capabilities for future growth as it can be expanded by 200,000 sq ft.

The facility will be located approximately five miles south of Motoman Robotics’ current headquarters. The building design for the facility is underway. Construction is contingent upon completion and approval of financing arrangements, as well as finalization of state of Ohio incentives. Subject to resolution of these contingencies, construction was expected to begin in July with a move-in date of June 2011.

Helium Leak Testing Marks 50 Years in Business

Helium Leak Testing, Inc., Northridge, Calif., is celebrating its 50th anniversary this year. It has new management with President Jeff Markel and Test Manager David Johnson, but Founder and CEO Al Markel, 92, is still active in the business.

The company started serving as a support lab for the nuclear industry’s development and safety. Al Markel previously worked for General Electric Co. during the development of the Hanford Nuclear Power Plants using a mass spectrometer helium leak detector (MSHLD), a tool used to assure no leakage of radioactive gases from the Manhattan and Fermi development projects.

Additionally, it has worked with various companies in leak
testing fuel storage tanks, valves, actuators, and space suits. Many components of the shuttle program passed through its testing facility. The company also supported end products, specifically for military use, requiring hermetically sealed electronic circuitry and mass spectrometer helium leak detector testing.

Helium Leak Testing has contributed to the development of equipment, procedures, and universal use of the MSHLD. In the 1960s, this leak testing process had limited use only in the nuclear field, yet today is known in many industries including automotive, medical, refrigeration, and petroleum. The company’s Web site is at heliumleaktesting.com.

For info go to www.aws.org/ad-index
Pilz Protects Robotic Welding System at Idaho National Laboratories

A robotic material handling, welding, and inspection system has been developed at Idaho National Laboratories as a prototype for the next generation of industrial automation systems. Developed by the lab with resources from the Dept. of Energy, it was built to “design, develop, and demonstrate a system that will enable operations to remotely control two robots that use specialized tools to perform welding functions and nondestructive examination equipment.”

The added layer of accuracy and safety to the welding cell allows for a high-level quality to the weld points themselves, increasing resistance to stress corrosion and cracking. The system moves material in and out of the cell automatically by a robotic gantry system and transfer card. Including the Pilz PSS control monitoring system allows safe operation by constantly monitoring the status of various moving components from the welding and inspection robotics to the surrounding safety access controls.

Weld Repairs Finished on National Research Universal Reactor

According to the Atomic Energy of Canada Ltd. (AECL), all of the National Research Universal reactor weld repairs at Chalk River Laboratories, Chalk River, Ont., Canada, are complete. The repair team completed the finishing weld and a series of nondestructive examinations of the final repair site. A review of these results confirmed that all requirements for the final repair have been met. This completes the repair phase of the reactor that began December 12, 2009.

Information on the transition from the repair program to

The Atomic Energy of Canada Limited’s repair team conducted test welds (as shown above) on the National Research Universal reactor mockup, but when performing welds on the actual vessel, welding specialists relied on visuals displayed on computer monitors to guide the tools and perform the work. (Photo courtesy of AECL.)
preparing the reactor for restart can be seen in a video posted on www.NRUCanada.ca. Activities related to restarting the reactor after an extended shutdown period are defined in “Protocol for the NRU Restart Licensing Activities” available at the same site.

Additionally, the Technical Standards and Safety Authority completed its inspections and assessments of the weld repairs and vessel’s fitness-for-service. Based on the nondestructive examinations, as well as the visual inspections of the repair regions and successful leak check, AECL concluded the vessel can now be returned to service. The company recently appeared before the Canadian Nuclear Safety Commission in a public hearing and received approval to proceed with restarting the reactor; for more details, go to www.nuclearsafety.gc.ca.

It was estimated the reactor would resume isotope production by the end of July. Part of the return-to-service project’s plan includes reactivating the reactor’s auxiliary operating systems. As of press time, 26 of the 35 systems are now in service.

Moonbuggy Race Teaches Ohio State Students Real-World Engineering Skills

Team members from The Ohio State University’s (OSU) College of Engineering recently participated in the NASA Great Moonbuggy® Race. To support the practical application of engineering knowledge and promote personal growth in a team environment, the ITW Welding Companies (Miller, Hobart Brothers, and Smith Equipment) provided them with a $10,000 cash gift this year. Additionally, Hobart Welders, Smith Equipment, and Miller donated welding products and safety gear to help the team fabricate, from scratch, a Moonbuggy chassis, suspension, and other key components from 4130 chrome-moly tubing.
The libraries at TWI (formerly The Welding Institute) and the World Metal Index (WMI) of Sheffield Libraries, Archives, and Information Services hold more than 60 years' worth of information on metals and consumables, in the form of trade literature brochures, standards, and publications, providing a large repository of data for the metallurgist and welding engineer. However, these data were difficult to search efficiently. To remedy that situation, the two organizations teamed with Granta Design and the National Metals Technology Centre (NAMTEC), Rotherham, UK, in July 2008 to launch the MI-21 database of ferrous and nonferrous metals, and welding, brazing, soldering, thermal spraying, and surfacing consumables.

With the aid of Principal Software Architect Craig Seymour and colleagues at Granta Design, a software house in Cambridge, UK, that specializes in materials information, the group applied for partial funding from the European Community; this was granted in 2002 and data input from the written word began in 2004.

The database offers a unique combination of information to its users. While the latest standards and products are included, searches can also find old standard grades and products used to build structures, ranging from bridges to nuclear power stations, that are now in need of repair and maintenance. Some of the most fascinating projects for which the information has been used include the rebuilding of historically important aircraft and steam engines. There is also extensive coverage of U.S. metals (nearly 5000 standard grades and proprietary products from more than 50 manufacturers) and consumables (more than 6000, including most AWS grades and a wide range of proprietary products from more than 40 manufacturers), plus thousands of products from the rest of the world. Comparable products/grades, where known, are listed on datasheets — Fig. 1.

The aim of the database is to save industry time and money in finding accurate data and sourcing products, offering a single source to trace products and grades as companies merge, separate, close down, and change their product range. MI-21 has a Version History function that allows users to view when the data were entered and what changes (composition, mechanical properties, etc.) have been made to it over time, another bonus for the repair and maintenance engineer.

At present, the database contains, in addition to details of suppliers and source documentation, more than 50,000 datasheets in a roughly 50:50 ratio of metals to consumables. Due to the size of the original databanks, TWI and WMI have both prioritized inputting the most popular products and standard grades, and are continuing to add items, particularly in response to inquiries and the publication of new standards.

The datasheets cover trade products and standard grades, and can be searched by the following:

- Trade name
- Standard grade/classification
- Chemical composition
- Mechanical and physical properties
- Form (plate, sheet, etc.; solid filler metal, wire/flux combination, etc.)
- Workability (metals only)
- Country of origin

**Fig. 1** — Datasheets provide information on comparable products and grades.

**Fig. 2** — Datasheet layouts. **A** — Whenever possible, the datasheets link to their source document, supplier, and comparable standard grades; **B** — datasheets of standard grades link both to the source standard and to products conforming to that grade.
A reporting function allows products/grades to be compared by individual elements or other properties, either as a table or as an X-Y chart — Fig. 3. These data can be saved to a file or e-mailed.

MI-21’s flexible and detailed searching facility will save hours hunting through trade catalogs and standards, or searching the Internet. The following are some examples of the types of queries the database is designed to answer:

• What is the chemical composition of 9SMn28?
• Who supplies Smootharc 317L-17?
• Is there a current “equivalent” to the obsolete Messer SFK5?
• What is the tensile strength of ASTM A182 F51?
• Is there a U.S.-made alternative to Valco 4370 Kb?
• Which materials are covered by BS EN 10088?
• Is there an electrode suitable for welding AISI 316Cb steel and where can I buy it?
• Which basic electrodes can be used to weld bridges made of weathering steel?

The MI-21 online subscription also includes access, via the Support Service (telephone, e-mail), to all the nondigitized materials records WMI and TWI holds. These total more than 500,000 products/grades, 10% of which have now been entered into the database. Advice on searching the database is also provided.

For more information, visit www.mi-21.com or contact MI-21 World Metal Index at wmi@sheffield.gov.uk.

**For Info go to www.aws.org/ad-index**
Q: I am a design engineer working for a welding fabrication company about to become involved with building welded aluminum structures. I have not designed welded aluminum structures for many years, so I am interested in learning of recent changes to the structural design requirements for aluminum welds. The aluminum structures we will build are required to conform to the requirements of the American Welding Society (AWS) D1.2, Structural Welding Code — Aluminum. The code directs the user to an Aluminum Association publication for design requirements. Any information relating to this subject will be greatly appreciated.

A: Your inquiry is very timely as there have been some significant changes to the design criteria for aluminum structures, and some of them pertain to welded connections and welded members. Yes, AWS D1.2, Structural Welding Code — Aluminum (clause 2.1, Structural Design), refers to the Aluminum Design Manual (ADM), published by the Aluminum Association, for design requirements for aluminum weldments. The ADM is revised every five years and provides information for designing aluminum structural applications, including welded connections and welded members. The 2010 ADM edition has recently become available, and it has been substantially revised from the previous edition published in 2005 — Fig. 1.

The main part of the ADM is the Specification for Aluminum Structures, which has been completely reorganized for the first time since the specification was first published in 1967. The specification’s table of contents has been changed to match that of the American Institute for Steel Construction’s (AISC) Specification for Structural Steel Buildings. For example, in both documents Chapter J is titled “Design of Connections,” and Section 1.2 addresses welds. The ADM also covers groove welds, fillet welds, plug and slot welds, and stud welds, providing design strengths for each.

Virtually all building codes in the United States require that aluminum construction comply with the Specification for Aluminum Structures, which covers the following items:

- Methods for determining the strength of aluminum structural members and connections that are welded, bolted, riveted, or screwed.
- 25 wrought alloys and 10 cast alloys.
- Aluminum extrusions, sheet, plate, forgings, rod, bar, and castings.
- Design of aluminum structures exposed to fire and elevated temperatures.
  - Design for fatigue (cyclic loading).
  - Evaluating existing aluminum structures.
  - Testing aluminum structural components.

The 2010 edition of the Specification for Aluminum Structures is also the first version of this specification to address both allowable strength design (ASD) and load and resistance factor design (LRFD), and is similar in this regard to the 2005 AISC specification. The ADM also includes information on these following topics:

- A commentary that provides background information on research and testing used to develop the specification and a bibliography for the provisions in the specification.
- A design guide that contains useful information on aluminum composite material (ACM), codes and standards used for aluminum in structural applications (such as highway structures, rail cars, pressure vessels, ships, and pipe), adhesively bonded joints, extrusion design, preventing corrosion, and sustainability.
- Material properties, including typical mechanical and physical properties.
- Dimensions and section properties (such as area, moment of inertia, and section modulus) for commonly used aluminum shapes, including channels, I-beams, angles, Ts, Zs, round and rectangular tube, roofing and siding, and pipe.
- Design aid tables, including allowable stress tables for 24 alloy tempers (welded and unwelded), recommended minimum bend radii for sheet and plate, maximum allowable spans for roofing and siding, allowable shear and tension for aluminum fasteners, and allowable stresses for welded connections. All data were determined in accordance with the requirements of the specification.

There have been some significant changes made to the recently published 2010 edition of the Aluminum Association’s Aluminum Design Manual. This new document can help you to conform to the requirements of your manufacturing code and assist you in the development of appropriately designed welded connections for your aluminum structure. I encourage you to acquire a copy of the current version of this publication.

The latest edition of the Aluminum Design Manual can be ordered from the Aluminum Association online at www.aluminum.org under Bookstore, or by calling (301) 645-0756.

Acknowledgment

I would like to thank Randy Kissell of the TGB Partnership, an aluminum design specialist and an active member of the Aluminum Design Manual Committee, for his help in compiling this article.

Fig. 1 — The recently published 2010 edition of the Aluminum Association’s Aluminum Design Manual contains some significant changes.

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Q: We manufacture appliances that require the brazing of copper tubing in a variety of configurations. Most of our products have tubing circuits that distribute fluid from one large-diameter tube to several smaller distribution tubes. We hand braze using oxyacetylene torches and have up to 15 people brazing on any given day. The joints are all copper to copper and we use 5% silver filler metal rods. Since we are brazing copper to copper we are not using a flux. The price of copper has made us review our designs to look for ways to save on material cost.

On several of our designs, we switched one of our copper distributor tubes to a copper-coated, low-carbon-steel tube. These designs, then, have both copper tubes and a coated steel tube as part of the assembly. The leak rate at the copper distributor/coated steel tube joint is ten times as great as the copper-to-copper joints. What could account for this large leak rate?

A: At first glance, your change to a copper-coated steel tube seems like a good idea. The braze joints are all copper-to-copper surfaces so the use of a 5% silver filler metal (balance of copper and phosphorus) looks acceptable. The addition of phosphorus acts as a wetting agent on the copper oxide. This type of filler metal is the universal standard for copper-to-copper tube joints. The steel would normally require the use of flux but since it is copper-coated, it may be that flux is not required. While it may be possible to make this material substitution work in this application, there are several warning flags that should be considered.

The first thing to consider is the difference in thermal conductivities between copper and low-carbon steel. One of the attractive things about hand brazing copper tube joints is that copper is an excellent conductor of heat. You can instruct a hand brazer on these joints relatively easily because the copper spreads the heat throughout the joint with little fear of overheating. If you keep the torch moving, you can learn to braze quickly.

Copper's thermal conductivity is 2712 BTU-in./h ft² °F (391 W/m K). Comparatively, the thermal conductivity of 1020 steel is 357 BTU-in./h ft² °F (51 W/m K).

The steel will heat up very rapidly and will not disperse the heat readily, making it prone to overheating. If the torch is focused on the steel tube it may excessively oxidize, creating a location in the joint where the alloy will not bond. The phosphorus in the filler metal is capable of absorbing the oxygen found in copper oxides on the tube surface but will be unable to handle heavy scale.

Related to the subject of overheating the steel tube is the copper coating. You did not indicate the nature of the coating. Typically these coatings are a thin flashing, intended for oxidation resistance, not brazing. The greater the overheating, the more likely it is that the copper flashing will be damaged or scavenged off the surface of the steel. If this occurs, the braze alloy will be required to bond to the steel surface below the coating. This bonding may occur but most likely it will not. It would probably be oxidized to the point where the filler metal would not wet the surface. Unfortunately, even if it did achieve a good metallurgical bond, the joints would be suspect mechanically as phosphorus forms a brittle compound with iron. The joints may test acceptable after brazing but fail later in service, particularly if any vibration is encountered.

The key will be to develop a heating technique that allows you to heat the steel component without overheating it. The heat should not be applied directly to the steel tube. It should be allowed to heat indirectly from the heating of the copper tubes around it. It may be a challenge as you have quite a few brazers. Getting hand brazers to all do the same thing is difficult. You may also want to look at the intensity of your torch flame. A softer flame may be easier to control. In all cases, it should be a reducing flame to minimize oxidation.

If you are able to work out the proper heating of these joints, whereby the steel is not overheated and the copper coating is not disturbed, you will then need to deal with the different coefficients of thermal expansion (CTE). The CTE of copper is 9.4 in./in. °F (17 mm/mm°C). The CTE for 1020 steel is 6.5 in./in. °F (11.7 mm/mm °C). I am not sure of your joint design but in typical applications, the distributor tubes are inserted into the main tube, usually in some type of end formed configuration. The joint clearances will want to grow during heating. The gap at the coated steel-copper interface will be greater than at the copper-to-copper interfaces as the steel has a lower CTE.

Care must be taken to ensure proper full of the filler metal at these locations.

These types of joints usually have a great deal of residual stress after the end-forming operation. The relaxation of these stresses may also contribute to larger than desirable joint clearances.

If proper control of joint clearances is not possible, it may be possible to switch to a more joint clearance-filling filler metal. The BCuP classification has many filler metals to choose from. One with a lower amount of phosphorus would have better ability to bridge joint clearances. There is usually a trade off in a slightly higher brazing temperature but with good heat control this can be successful. The key to making this substitution of a copper-coated steel tube successful is to properly manage the heating. Overheating will lead to excessive oxidation, damage to the copper coating, and excessive joint clearances.

Considering the procedure changes and risks involved with brazing copper to steel tubing, it may be cost-effective to bite the bullet, pay the higher price, and use the reliable all-copper-tubing process that is proven to work well for your applications.

This column is written alternately by TIM P. HIRTHE and ALEXANDER E. SHAPIRO. Both are members of the C3 Committee on Brazing and Soldering and several of its subcommittees, ASH Subcommittee on Filler Metals and Fluxes for Brazing, and the Brazing and Soldering Manufacturers Committee (BSMC). They are coauthors of the 5th edition of AWS Brazing Handbook.

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

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Selecting SAW Consumables for Low-Alloy Steels

Detailed are the key factors to help you choose the most appropriate welding wire and flux for your low-alloy steel application

BY KEITH PACKARD

Due to its precise chemical and mechanical properties, low-alloy steel has become an increasingly common material in industries ranging from heavy equipment manufacturing and shipbuilding to cross-country pipe construction. Compared to conventional mild or carbon steels, low-alloy steels — through the addition of specific alloys (nickel, chromium, and molybdenum, for example) — can increase temperature strength, hardness, and corrosion resistance, among other benefits. The addition of alloys such as silicon or manganese further differentiate low-alloy steel from other materials by adding greater deoxidizing capabilities.

Like any other material, however, low-alloy steels have their own unique welding requirements, especially when they are joined using the submerged arc welding (SAW) process, a common choice among many industries that need to weld thicker materials and require faster travel speeds and/or high deposition rates. Not surprisingly, selecting the right filler metal and flux for these applications is critical to achieving the advantages sought by using the submerged arc process in the first place. Following are some of the key details you should know to help you achieve good results on your low-alloy submerged arc welding applications.

Why Submerged Arc Welding?

Low-alloy steels typically range in strength from 80 to 120 ksi with some grades available as strong as 140 ksi. These materials vary from HY80, 90, and 100 steels used for bridges and off-highway vehicles to high-strength, low-alloy (HSLA) steels used in structural steel erection and ASTM A514 (or T1) quenched and tempered steels often found in boiler and pressure vessel fabrication. Low-alloy steels are also commonly used in thicker sections for many heavy-duty applications, making them good materials to weld with the submerged arc process.

The majority of low-alloy steels that companies submerged arc weld range from ½ in. thick or more (some applications can be greater than 4 in.), and often require multiple passes. Generally, they also require very long, straight, and repeatable welds, and it is not uncommon for the ma-
Joint design indicates it is the best procedure to that of the low-alloy steel base material. Welding wire strength to the low-alloy steel wires are generally 80-ksi tensile strength. However, you need to match the flux, providing exceptionally high deposition rates.

Choosing a Filler Metal

Selecting low-alloy filler metals for SAW is much the same as selecting one for other semi-automatic or automated applications, with the addition of adding an appropriate flux. Before selecting your flux, however, you need to match the chemical and mechanical composition of the SAW wire to that of your particular low-alloy steel. Low-alloy submerged arc wires are generally 80-ksi tensile strength or higher, and like low-alloy steel base metal, they contain alloying elements such as chromium, nickel, silicon, manganese, and molybdenum.

As a general rule, the low-alloy submerged arc wire you select should match not only the chemistry of the base metal, but also its strength as closely as possible. It should be a near match in terms of elongation and toughness (Charpy V-notch) properties, too. As with other applications, overmatch the submerged arc welding wire strength to the low-alloy steel base material isn’t typically recommended, as it can lead to cracking. You should only overmatch when a specific joint design indicates it is the best procedure. Similarly, undermatching the strength of the submerged arc welding wire to that of the low-alloy steel base material is generally done only when the joint design indicates it can still provide the appropriate strength weld and/or when the specific type of steel being used will be postweld heat treated in a way that allows for a lower-strength weld.

Submerged arc welding wires are available in both solid and composite (metal-cored) versions, with the latter becoming increasingly popular due to its ability to be alloyed more readily. Composite wires often have shorter lead times for manufacturing and delivery for that reason as well, making them viable options if you need to maintain larger inventory for high volume of parts production. They also tend to have higher melt-off and deposition rates, and faster travel speeds, making them a good choice to help improve productivity. Both types of wires are classified under AWS A5.23, Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding.

Similar to other welding wires, low-alloy submerged arc wires have specific classifications to signify their mechanical and chemical properties, but they have the added distinction of including a flux designation. For example, a low-alloy submerged arc composite wire with the AWS classification of F8A8-ECMI-M1 indicates the following:

- “F” signifies SAW flux.
- “8” indicates the wire provides a minimum of 80 ksi tensile strength.
- “A” designates the condition of heat treatment, which here is “as welded.”
- “P” would signify “postweld heat treated (PWHT).”
- “8” indicates the temperature in Fahrenheit at which the impact of the weld metal meets or exceeds 20 ft-lb. In this example, it is -80°F.
- “EC” indicates this wire is a composite electrode.
- “M1” refers to the chemical composition of the wire. In this example, the wire is comprised of manganese (0.60–1.60%), nickel (1.25–2.00%), and molybdenum (0.35%).
- The second reference to “M1” indicates the chemical composition of the weld metal obtained with the flux and the electrode combined.

Based on this information, when selecting the filler metal you need first to match the tensile strength indicated in the wire’s classification with that of your base material, then consider the chemical compositions of both the wire and the low-alloy steel that you plan to weld. At the same time, you want to determine the type of flux that is compatible with the wire and that can provide the weld properties you need.

Getting to Know Your Flux

When submerged arc welding any type of material, selecting the right flux for a low-alloy steel application is key. As a rule, fluxes for these applications are classified into three main categories: neutral, active, and alloyed. (Note: There are also other types of flux specially designed for applications such as pipe welding.) Each flux, in combination with a given submerged arc wire, provides distinct properties and is designed to work best on a given type of application.

For instance, neutral flux typically will not change the chemistry of the weld during the welding process and is not affected by fluctuations in the welding parameters (increases in voltage will not increase the consumption of a neutral flux). Because of this feature, neutral flux works well if you are welding on heavy, thick sections of low-alloy steel that require multiple welding passes; the ingredients in the flux should not compound to alter the chemistry of the final weld.

Unlike neutral flux, active flux depends on the weld parameters, specifically changes in voltage, to produce a weld. In short, increases in voltage cause an increase in the consumption of the flux. Additionally, because of the silicon and manganese contained in this type of flux, active flux generally welds quite well through contaminants like rust and mill scale, and it tends to offer faster travel speeds than other types. If you have an application requiring a single pass on a thinner section of materials, active flux would be a good choice. It often has a more easily removed slag than other types of flux, as well.

Finally, alloyed flux, as its name implies, works in combination with the submerged arc wire to add specific alloys into the weld. It can be a more cost-effective alternative to other types of flux, as it often allows you to purchase a lower-cost welding wire that still provides the desired weld properties. Alloyed flux works well if you have applications containing stainless steels, low-alloy chrome-moly steels, or if you wish to gain greater strength when welding higher-strength, low-alloy steel.

Bringing It All Together

While compatible with many different types of submerged arc wires, each flux provides different properties when combined with a particular wire. Specifically, the combination of wire and flux you choose can affect the deposition rate you achieve, bead profile, travel speeds, and slag release. Your selection of wire and flux will chiefly depend on your particular application and the desired mechanical properties, along with the welding system you are using. Joint design also contributes to the choice, as different fluxes release from specific joints more readily than others.

Typically, filler metal manufacturers can advise as to the best combinations for your welding system and application so that you can achieve the desired results. Welding distributors are also a good resource to help make the selection. If, however, you are choosing your own low-alloy submerged arc welding wire and flux combination, keep in mind that you will need to do testing to ensure that you are obtaining the correct properties for your application.

Whichever way you proceed, the goal is still the same: to gain the productivity improvements brought forth by the submerged arc process through the combination of the most appropriate welding wire and flux for your low-alloy steel application.
Adaptive Control Techniques Advance Automatic Welding

Smarter welding control technology simulates human decision-making skills

BY PAUL SAGUES

Manual welding continues to play a significant role in welding applications for several reasons. Humans tend to be more adaptable to variations in the welding process. Skilled human welders can learn what parameters to adjust and by how much in order to keep the welding process under control.

A skilled and experienced welder can examine a part to be welded noticing the variations in the part and in a split second come up with the adjustments necessary to make a good weld. An example is a welder noticing a wider groove because of mild bowing where he or she will immediately increase the oscillation, decrease heat, and adjust the electrode extension to keep the voltage at an appropriate level. Welding, in essence, is a multivariable control problem that makes it difficult to automate.

Conventional Automation Solutions

Fully automatic welding today is employed in only a limited number of mostly high-volume applications because these systems cannot adapt to variations as humans can. Commercially available automated welding systems use simple control techniques that focus on linear system models with a small subset of the larger set of process parameters, thereby limiting the number of applications that can be automated. There is a compelling need for automation in high-volume applications and those involving welding underwater, in tight spaces, hazardous, or remote locations.

In the real world, this requirement by the welding control system to evaluate a number of parameters and build a strategy based upon multiple deviations from the desired values leads to an explosion in complexity of the problem. Because the control system cannot evaluate what can easily be millions of possible responses, there is a tendency to take a simplistic approach. In turn, this control system simplification leads to processes that are not robust. A machine that is welding parts correctly may suddenly begin making bad parts. No manner of fiddling with control system parameters will get the machine making good parts again. The machine is deemed to be temperamental.

The Holy Grail of Welding

Adaptive welding systems have been called the Holy Grail of the industry. The approaches to adaptive welding employed today have primarily focused on dynamic joint tracking.

Significant advances have been made in adaptive welding by integration of a larger set of the process variables (such as weld power, wire feed, torch position, and torch motion) into the machine control system, combined with the measurements of the actual joint to produce a high-quality weld, while allowing for a greater degree of variability in joint configuration and other process parameters.

One way to illustrate these advances is to use the three basic steps shown in Fig. 1.

Step 1: Observation and Recording of the Parts to Be Welded

An automated welding system starts with a careful observation of the entire part to be welded before the arc is struck. The system will notice deviations (just as the human welder would have) such as the bowing of the part, asymmetry in the groove walls, or one side of the groove higher than the other.

The system performs a comprehensive inventory of the joint to be welded. Observations include measurements such as the uniformity of the groove and comparing the mean value to specified process value. The system also keeps an inventory of previous welding passes and draws from the previous experience using it as a knowledge base. For example, the welding system can identify previous tie-in points as well as decide the next steps in the process. Additional parameters such as temperature of the metal are also observed and recorded to aid the decision-making recipe discussed below.

Step 2: Recipe for Decision Making

The automated welding system then prioritizes the effects of the various process variables. The prioritization is itself a multistep process involving decision-making. The decision recipe is created by the welding process engineer for a given type of weld. One example is the case of a plate butt joint weld with beveled edges where the first step is to scan the entire weld path and measure the maximum, minimum, and standard deviation of the differences in height between the two plates on either side of the weld. A score is given to the measured statistics. The recipe then looks at the variation in weld

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joint gap, in the case of the same plate weld. What is the variation from nominal along the length of the weld? A score is given to this set of statistics.

Other parameters that might have been derived from the scan information are gone through step by step in the decision recipe, each receiving a score that represents its importance. One of the problems facing early attempts at automated welding was the explosion of possible strategies to deal with variations in welding parameters. This scoring of the scanned values manages this explosive problem. The scoring system enables some automated welding systems to emulate the expert human welder by providing a mechanism to focus on the most important parameter and then subsequently go down the list of priorities.

Step 3: Integrating the Rest of the System

The power supply, torch motion, and wire feeder need to be coupled to the welding control system. Some currently available automated welding systems can precisely control the heat by independently controlling these three parameters, especially when the piece to be welded has asymmetrical or nonuniform heat capacity. With such a joint configuration, it is often preferred to make the oscillation motion itself nonuniform, dwelling on the high-heat capacity side of the groove, while perhaps increasing power supply power. Power is often lowered during the transit across the groove to the other side where power is then increased to a lower level than on the high-heat capacity side. Synchronizing wire feed rate with torch motion can produce a better weld. Sometimes decreasing wire feed rate during the longer dwell on the high-head capacity side of the groove results in a better weld than not changing wire feed rate.

Coordinating Critical Elements

The trend to put more intelligence in all the disparate parts of a welding machine does not necessarily ensure that they will work well together, unless they can be coordinated and synchronized. For example, if the welding power supply controls the wire feeder and the power level to the torch, can the weld control system quickly command a change in power and wire feed speed? The answer is generally negative if the weld power supply is intent upon doing overall weld control. At the same time, however, the welding power supply is ill-suited to run the part of the machine that moves the torch. If that is a robot controller, then we ask if the robot controller is capable of more general control of the welding process.

Welding Automation Solutions

Today, manufacturers are implementing adaptive automation solutions for welding spent nuclear fuel canisters as well as some pipe applications. All of these applications require high-quality welds, plus reliable and high-productivity solutions. And manufacturers are constantly innovating to produce next-generation systems, too.

For example, Moog, Inc., has developed and successfully implemented automation solutions for several applications, including pipeline welding and welding nuclear spent fuel canisters.

These nuclear canister welding solutions are operational at a dozen power plants that have implemented remote welding as one way to minimize workers’ exposure to radiation. The machines represent a key step toward fully automated adaptive welding systems.

The spent fuel from commercial nuclear power plants is placed into dry storage inside steel canisters. Generally, two lids (i.e., an inner and an outer cover) are welded to close the canister.
A gas tungsten arc welding (GTAW) process is employed, with more recent systems using an AC-heated wire to improve deposition rate. Along with a five-axis manipulator (Fig. 2) that holds the torch, the welding system controls a servo-driven wire feeder and a wire manipulator that steer the wire into the pool.

Unlike a conventional industrial robot, the five-axis manipulator canister welding machine is designed to provide both torch travel and oscillation along a path that can be mathematically specified from measured part features. This part-geometry-aware system is significantly different from industrial robots that employ a teach-playback strategy with no sensing of the part’s geometry.

The automated welding system includes all motion control as well as weld power supply control, enabling the adjustment of the heat applied and the wire feed to the precise location in the weld groove. For example, the inner wall of the canister weld groove generally has a higher heat capacity than the outer, thinner wall. To obtain the same penetration with minimal part distortion, the welding system delivers less heat to the outside of the groove. In addition, the canister welding system can adjust, in real time, the width of oscillation to track variations in the weld groove due to compromised fit-up. To date, the Moog canister welding system has welded hundreds of spent fuel containers.

**Conclusions**

There is a shortage of skilled human welders and a need to accommodate hazardous environmental conditions as well as ergonomic concerns for workers. Economic advantages for using automation are powerful when implemented correctly, as this delivers high-quality parts via a repeatable, safe, error-free process. Yes, machines can weld faster and for longer periods of time than humans. If, however, the machine introduces defects to the weld or is not robust in the long run, then the gains are illusory. But as manufacturers increasingly build a track record with fully automated welding systems, it demonstrates the ability to weld faster and do so with fewer defects on production parts offering results that previously could only be emulated by humans. And that, in turn, brings the industry’s existing solutions closer to adaptive welding.

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The purpose of high-deposition SAW equipment such as ESAB’s Tandem-Twin system is to increase the metal deposition rate and cut arc time.

BY TOBIAS FINNDIN

Optimizing Welding and Cutting for Wind Tower Production

Wind towers are produced in a complex environment where rigorous demands on quality and strength need to be carefully balanced against tough productivity levels in order to reach even modest revenue margins. This article examines the production of one of the three parts of a wind turbine — the wind tower — and examines how welding and cutting steps can be optimized and made more effective in order to contribute to the overall profitability of the production. Although the article focuses on a wind tower operation, similar steps can be applied in many other welding operations.

Production Challenges

To fully understand the challenges in the production of wind towers, we must first cover how a wind tower is made. A wind turbine consists of three main parts: the foundation at ground level, the nacelle with generator and blades at top, and the tower that guides all forces to the ground and sustains the weight on top. A modern onshore wind tower varies between 295 and 460 ft in height and in most cases is slightly conical in shape. Most towers are steel constructions with a typical diameter of 14.8 ft and a weight of 250 tons. The plate thickness varies from 16 to 60 mm throughout the tower wall for an onshore tower; in offshore towers, the wall thickness can reach 100 mm or even 140 mm in a monopole foundation. As on-shore wind towers are transported by road to the erection site, the towers are made in segments of between 88 and 98 ft that are screwed together on site to create the tower. The segments are constructed from 8–10 circular “cans” that are usually 9.8 to 11.5 ft long. These cans are made from rolled steel plates.

Steps in Wind Tower Segment Production

With only minor variations, most wind tower segments are produced in the same way across the globe.

Demands. The basic demand on a wind tower is to be able to support the weight of the nacelle on top and the forces that are transferred in the strongest winds. Depending on the climate, the material may also need to withstand cold temperatures and tough conditions, especially in offshore environments. Specific demands, including the type of steel to be used, are usually set by local regulatory bodies.

Major Production Challenges. The major portion of the production of the wind tower cans (time-wise and in terms of value-adding steps) consists of the welding and cutting involved. When striving to improve productivity in wind tower production, the welding and cutting are good areas to focus on.

Cutting

The plates that are to be rolled and welded into the circular, slightly conical shapes must be cut from rectangular plates into a more curved form. All the plate edges must be prepared for welding in order to achieve the needed quality results. For thick plates, this has traditionally required a number of cutting and grinding operations. Production can now be done in one smooth cutting run by utilizing a high-accuracy cutting method such as

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as a triple-torch head with the capacity to cut at three accurate angles all the way around the plate in a single cutting run — Fig. 1. This is done using oxyfuel cutting, a slower method than plasma arc cutting but one that offers the needed accuracy.

**Welding**

The welding involved in the wind tower production is dependent on the code used that sets the toughness levels. Based on these inputs, the needed bead shape, tensile strength, and more can be determined for each production.

With the demands set, the welding joint geometry and welding process can be selected. In the majority of cases, submerged arc welding (SAW) is the preferred choice. Submerged arc welding offers the highest rate of deposited weld metal compared with other suitable welding methods. In SAW, the welding takes place submerged beneath a layer of flux, a powder consumable that protects the weld pool as well as influences the chemical composition and mechanical properties of the weld.

With the process and joint types identified, the details of the joint geometry can be determined. To achieve high productivity, one must be able to weld the joints in the shortest time possible. The actual welding time can be adjusted by varying primarily two factors: deposition rate and total joint volume.

**Joint Volume.** The joint volume can be varied by using different joint types; however, double-V-groove weld joints (or single-V-groove weld joints) are the most common. In thicker plates, often in offshore monopoles, other weld joint shapes can be found, such as a ground U-groove. By changing the joint opening angle, the joint volume can be changed; however, a more narrow joint opening (smaller angle) places tougher demands on the welding, especially on the consumables. The most common joint angle is 60-deg included. Use of a flux with easy slag release allows the reduction of the included angle of the weld joint from the typical 60 to 50 deg. This increases productivity due to the reduced weld joint volume.

**Deposition Rate and Welding Speed.** Although the smallest possible joint volume and joint opening angle might appear to be the most appealing, the choice of SAW must be taken into account. By choosing a variant (Fig. 2) with higher deposition rate, the overall welding time can be shorter even when the welding process demands a slightly larger joint opening than a lower deposition rate alternative. By increasing the number of welding wires and optimizing the wire diameters, the deposition rate can be dramatically changed.

**Heat Input and Strength.** When calibrating the welding process and joint shape for optimized welding, one must also consider the strength requirements. With an increased deposition rate, the heat input will also become higher, heating up the object to be welded. Too much heat and the mechanical properties will not match the requirements. If the workpiece gets too hot, the process must be adapted or the workpiece must be allowed to cool down between runs — both adjustments again increasing the total operation time in production. If the welding travel speed is increased, the heat input per millimeter is lowered.

**Welding Travel Speed.** With increased deposition rate and increased heat input, the solution is to increase the travel speed. Especially when welding the longer circumferential joints, an increased travel speed can allow the workpiece to cool down before one whole rotation has been made and a new layer is to be welded. When welding with high deposition rates, 66–88 lb/h, a travel speed of 39.4–47.2 in./min is often ideal. Submerged arc welding is stable at these speeds, but it is a challenge for any welder to weld this manually. For quality results, an automated system is needed with an automatic joint-tracking system to make sure the welding takes place at the ideal spot. Although the aim is perfectly round welding cans, wind tower segments often have small deviations from the ideal shape.

![Fig. 1 — Cutting with a triple torch for an x-joint preparation.](image)

This can cause the cans to slide horizontally when rotated. As the welding equipment is often held stable by use of a welding crane, any movement of the workpiece must be measured by the joint-tracking equipment and the welding automatically adjusted.

For example, let’s look at a tower with a total joint length of 1570 ft. With a (mean) joint angle opening of 60 deg, the total welding volume is 2.2 ft³ (with a mean plate thickness of 1 in.), corresponding to 1080 lb of weld metal to be used. Using a single-wire process with a deposition rate of 17.6 lb/h, the total welding time is 1080/17.6 = 61 h. If the joint opening is reduced to 55 deg, the new total welding volume is 1.98 ft³, which welded with the same process reduces the total welding time to 972/17.6 = 55 h, a change of 9%.

![Fig. 2 — Comparison of SAW variants.](image)
Setup
- Load workpiece at roller beds
- Adjust workpiece alignment
- Attach start and stop plates (longitudinal joint only)
- Check and replenish welding consumables when needed
- Move welding head to joint and start position
- Adjust electrode extension
- Set joint-tracking systems (when needed)
- Check/set parameters
- Get into welding position
- Welding:
  - Start welding
  - Monitor and adjust parameters
  - Ensure slag release and visual inspection
- Postwelding
  - Release left-over slag from workpiece
  - Remove welding equipment
  - Cut welding wires
  - Document welding details/object data
  - Off-load/move workpiece

Fig. 3 — The typical work cycle at a welding station in wind tower production.

If the welding process is changed from single wire to tandem wire, with a deposition rate of 44 lb/h, the welding time will be further reduced to $972/44 = 22$ h, or 59% of the starting time. With a process with an even higher deposition rate of 185 kg/h, such as the new tandem-twin submerged arc welding technology, the total time will be 12 h (see lead photo).

Arc Factor

Optimizing the welding process and joint volume is only part of the way toward high productivity. The entire workstation duty cycles need to be improved in order to reap the benefits of higher deposition — Fig. 3. There are many components that make up the so-called “arc factor,” the percentage of time in a duty cycle that is actually spent welding. The higher the arc factor, the greater the effects of a high-deposition welding process and the higher the value-adding time of production.

When looking at the station work cycle, it is clear the arc factor will always be low, but a number of welding-related components of the factor can easily be adjusted to lower the time needed.

Loading and Positioning. Through the use of self-aligning or manually adjusted roller beds (Fig. 4), the loading and positioning of the workpiece can be made more quickly. By integrating all station controls for positioning and welding in the same control unit, additional time can be saved and the work environment is improved.

Bulk Size Welding Consumables. The changeover time for setting up a new 200-lb wire coil can be between 20 and 40 minutes depending on setup and experience. By using larger wire packages on turntables, these costly changeover times are reduced in frequency as well as time. A 2200-lb package will often last an entire shift or more.

A continuous supply of welding flux is equally important, and various systems exist to ensure a constant supply of flux while also keeping it dry and in good condition. To get the most out of the flux con-

Fig. 4 — Roller beds such as the one shown here facilitate loading and positioning of the workpieces.
Production Steps in Wind Tower Production

- The plates are cut to the right shapes in order to form the conical segment part and to prepare the edges for welding.
- The plates are rolled into a circular shape (cans) then tack welded.
- The cans are welded longitudinally in order to become a (mechanically performing) homogenous piece.
- When needed, the cans are rerolled to become entirely circular.
- Segment end pieces are fitted with a flange, which is tack welded and then fully welded circumferentially.
- The circular cans are joined together to form a longer (cigar-shaped) piece, circumferentially.
- When all segment cans have been attached and welded together, the segment is ready for blasting and painting. The bottom segment will also have a door frame attached.

Joint Tracking, Checking, and Monitoring.

With a good joint-tracking system, the setup time is very short, and the assistance and monitoring easy and integrated in the welding control system. This way the operator can control the entire welding process from one system with fast set-up. Through the integration of a log system, the welding data can be logged in real time from several welding stations at a time, and the data can be stored for future control and reference purposes — Fig. 6.

With the integration of a logging system and a control system where the parameters for all joint variables can be stored for easy access, the setup and post-welding time can be reduced further.

The combination of effective consumable packages and systems, integrated control, and log and joint-tracking systems all help increase the arc factor. In combination with a high-deposition process, this leads to a highly productive flow and resultant high profitability.

Further Improvements

By increasing the arc factor and flow throughput, a factory can reduce the number of workstations needed or simply harvest the profit from an increased volume. However, to be fully optimized, the factory floor space must be used in the best way. It is desirable to minimize the space required by the welding equipment. One new technology to achieve this is the telescopic boom. Using a telescopic boom frees up costly space behind the welding station that with traditional, fixed-length booms must be free and unused.

Conclusion

By optimizing the weld geometry and joint volume matched to a high-deposition submerged arc welding process, productivity in wind tower production can be increased dramatically. Only looking to the welding details is not enough to become fully profitable, however. The “arc factor” must also be increased by using the right equipment and consumable solutions. By reducing the setup and preparation time at the welding stations through the use of fully integrated equipment and control systems, while also utilizing advanced joint-tracking and logging systems, the arc factor can reach the levels that allow high productivity and production with high profitability.

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Automation: Opportunities for Increased Efficiency and Savings

Fig. 1 — The QCT1 conductor tube alignment fixture allows users to initially verify and consistently repeat the bend and alignment of conductor tubes before installing into robotics torches. Also, if a crash occurs in a robotics cell that bends the conductor tube out of alignment, this tool is used to manually align and bend it back to the original configuration.

BY DIANE STEADHAM

In welding automation, manufacturers have to make decisions daily on equipment selection and choices. Selections are based on what equipment is necessary for each process, while choices can be up to the discretion of the individual welder. Choices are often the most difficult to measure a return on investment. The ultimate selection will be based on each facility's approach and viewpoint toward production, preventative and routine maintenance, and related costs.

The selection of consumables is one of the most discussed issues in automation. While the least expensive and smallest piece of the automation system, these small parts can add up as they can require frequent and/or regular replacement — again depending upon the production facility's production philosophy.

In addition, the same viewpoint is frequently shared as it relates to accessories. The fact is, there are a variety of selections and options available, but by truly understanding the consumables and accessories added benefits and expectations, any professional will be able to select the right

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Several factors should be considered in selecting the welding automation consumables and accessories that will work best for a given application.

The advantages for two viewpoints are addressed — the utilization of high-quality, premium material, higher-priced consumables vs. mass-produced, possibly “generic” low-cost consumables (a reproduced/copy of recognized brand parts) as well as the pros and cons of cost justification related to the addition of accessories.

**Consumable Choice with Contact Tips, Nozzles**

There are a variety of materials for consumables that industry continues to explore. Each selection available provides unique opportunities for added value in production processes. Focusing on contact tips and nozzles, the three preferred types of alloys for contact tips are as follows: copper-silver, chrome zirconium, and standard copper.

**Alloys to Consider**

The copper-silver alloy has properties such as low-service temperature, electrical resistance and electrical conductivity that greatly reduce erosion, arc instability, and poor arc starting characteristics. Therefore, these tips promote good arc start as well as longevity.

Chrome zirconium, which is used in high-heat applications, is a harder material than pure copper, increasing the wear resistance properties and allowing for longer life in an operating application, particularly involving excessive heat. Although standard copper doesn’t produce as hard of a finish as chrome zirconium, it has been around for years and is the material of choice for gas metal arc welding (GMAW) applications. Due to its high electrical conductivity and availability, it exhibits the best electrical conductivity compared to all copper grades.

When considering nozzle material, standard copper alloy or nickel-plated copper alloy, and occasionally brass, are just a few choices to select from. The standard copper alloy, which is fairly easily machined, is widely used for piping gas, liquefied petroleum gas, natural gas, water heaters, and kitchen ranges.

Nickel-plated copper alloy, which is suitable for any type of industry production, helps decrease the amount of spatter buildup that can interrupt production by creating arcs and building up to the point where production must stop to manually clean the nozzle. By reducing downtime and required machine maintenance due to using the correct nozzle material, manufacturers are able to increase production volume and lower labor costs.

**Recognizing Many Styles**

Contact tip and nozzle style is another consideration for many professional welders. Within consumables, there are different styles that offer various qualities for reachability and enhanced efficiency. For instance, for access into hard-to-reach spaces that would otherwise be inaccessible, the straight bore or bottleneck front-end nozzles are recommended. Or, when selecting contact tips, one could choose a standard thread or cam-lock/quick-lock version.

There will be a variety of difference in costs depending on the material and style selected. The welder’s needs, as well as the consumable’s function in the facility, will help determine not only the best selection, but the ultimate cost. Each alternative is unique in its own way, but selection depends on the application and desired result. Ultimately, the decision comes down to which option best fits your situation.

**What’s Your Perspective?**

In the end, it comes down to expectations. What do you expect to get in production quality, part life, and downtime improvements for the cost?

**Pay Attention to Quality**

At first glance, many welding professionals only consider the price when purchasing consumables, not bearing in mind the quality, part life, and production benefits. Although initial investment is lower with consumables, the advantages for long-term manufacturing in choosing a quality preventative product are hard to deny. It doesn’t take long after starting to increase your production, reducing downtime, and creating high-quality parts with less touch-up required for the return on investment to justify the overall higher consumables cost.

**Deciding How to Control Consumable Usage**

To some professionals, the cost is the bottom line — they may simply want the least expensive alternative. In these plants, they are likely looking at it from a preventative maintenance standpoint. Not considering the parts life, they change out the consumables on a strict schedule; for example, every four hours or every shift.

On the other hand, others may have different anticipations for managing consumables.
Fig. 3 — An example of fixed automation manufacturing, where wheels were moved in and lifted up to the torches for welding, consumables required consistent maintenance and replacement because of the welding equipment’s need for repeatability and accuracy.

sumables. These plants may literally empower their weld cell operators to know when to change out consumables. Thus, these operators tend to choose parts that promote less spatter for longer part life. These higher-quality consumables often improve the quality of the production, the longevity of the machinery, as well as the overall downtime by impacting the run of connected machinery.

The best advice is to balance the considerations. Luckily, today’s automation parts have been developed to give less downtime, higher quality parts with less repair.

Accessory Selection

Accessory choices are often the more difficult decision for end users and one of the most hotly debated topics in welding. Why should you buy them? How do you know which accessories are needed? And are they really worth it?

Whether you are just starting an automation line or expanding an existing enterprise, every aspect of the business must be weighed for a cost justification, including accessories. Truly understanding how these optional pieces enhance the life, quality, and volume of a production line will help any welder see the added value in accessories.

Extending Parts Life

Peripherals, often called accessories, are not required but can be advantageous. Examples of common accessories in automation include antispatter mist applicators, wire trimmers, nozzle cleaning stations, tool center point (TCP) check tool kit, and conductor tube alignment fixtures.

Many of these accessories contribute to reducing maintenance on the welding equipment and extend the life of a variety of welding torches, conductor tubes, and consumables. By reducing the wear on equipment, reducing the frequency of consumable replacement, and enhancing cleaning abilities, these accessories are able to prolong parts life.

One cost-effective accessory is a conductor tube alignment fixture — Fig. 1. When a crash occurs in a robotics cell, a conductor tube is often bent. The alignment fixture was engineered to enable the manual adjustment of the TCP before and/or after a collision. It allows reestablishing the TCP on a variety of conductor tube bend angles and lengths. By being able to reuse the conductor tube after a collision rather than replacing the piece entirely, the alignment fixture quickly saves time and money.

Increasing Production Volume

Spatter buildup can interrupt production by creating arcs and building up to the point where production must stop to hand-clean or replace consumables on the conductor tubes. The antispatter mist alternative is an oily substance that coats either the inside or outside of the nozzle to prevent spatter buildup, reducing downtime.

Similarly, wire trimmers snip or trim off the end of the welding wire to allow a clean arc start and assist in achieving repeat tool center point (TCP). They also create a smooth end for easy use with nozzle reaming and cleaning stations to further clean
out spatter inside the nozzle — Fig. 2.

By reducing downtime and required routine equipment maintenance due to accessory usage, manufacturers are able to increase production, efficiency, and volume. For example, Fig. 3 shows a wheel manufacturer in which fixed automation fabrication was utilized. The wheels were moved in and lifted up to the torches for welding, then set down and moved on by a conveyor belt. Thus, the torches stay stationary, and the part moves in and out. However, due to the repeatability and accuracy required of the welding equipment, consistent maintenance and replacement was required.

In this case, a change in the style of the torch nozzle and an introduction of anti-spatter mist allowed the manufacturer to more than exceed their production goals in a short period of time. Parts efficiency was so improved that rather than have a scheduled maintenance for a preventative change out, it was up to the weld cell operator to determine the frequency of parts replacement. In addition, they had such success with the new conductor tube nozzle and mist combination that production only had to be interrupted to clean twice a day — Fig. 4.

Improving Production Quality

Since automation and robotics were engineered to create consistent and the best possible parts, industry is continually increasing production quality and accuracy. Every option and accessory gives your business the opportunity to improve the system for quality welds, repeatability, and consistency.

For instance, the Tweco TCP Check Tool Kit allows quickly checking the tool center point. This will ensure torch alignment in the exact same place every time a new weld cycle is started; users can avoid or decrease manual touch-ups and lost production time.

At first glance many welding professionals only consider the price when purchasing accessories, not bearing in mind the quality, part life, and production benefits. Although initial investment is higher with accessories, the advantages for long-term manufacturing are impossible to deny. It doesn’t take long after starting to increase your production, reducing downtime, and creating high-quality parts with less touch-up required for the return on investment to justify the accessory cost.

Go Forth and Automate

So how do you begin a search for the right consumables and accessories? A good starting point is usually talking to a professional within the industry who is aware of the application process. Distributors and manufacturers are also great places to begin.

Determining the type of welding automation consumables and accessories needed comes down to a matter of options, so exploring all that is available will help you find the best product for any situation.

Although consumables may be known for their low cost, it is important to look at the whole picture and determine whether or not the parts chosen would be best for short-term or long-haul use. While consumables require the least initial investment, the need for continual replacement can create higher cost overall than the machinery over its lifespan.

It really comes down to expectation. What is your expectation out of your business? What is your expectation out of your consumables and accessories? How much are the weld cell operators empowered to make these decisions? Remember, it’s all about choices, and you have the ability to change or tweak and add or subtract them to get the best value for your business.
Implementing Robots into a Submerged Arc Welding Operation

A setup is described that led to reduced lead times for welding a restrained joint ductile iron pipe and provided consistent torch-to-pipe angles

BY CHARLES E. BOYER

The American Cast Iron Pipe Co. (ACIPCO), Birmingham, Ala., a manufacturer of ductile iron pipe and fittings for the waterworks and power industries, recently enlisted Wolf Robotics, LLC, Fort Collins, Colo., a metalworking robot equipment provider, to develop a workable robotic solution after identifying an existing submerged arc welding (SAW) process for automation. ACIPCO manufactures ductile iron pipe in standard 20-ft lengths ranging in diameter from 4 through 64 in. It utilizes joints of various types designed for ease of installation and dependability in a variety of conditions.

Several challenges existed to accomplish the conversion from operating manually to using robotics. In addition, a calculated return on investment (ROI) target was established. By working together, the companies faced these tasks head-on.

Deciding to Automate an Iron Pipe’s Welding Production

In 2007, the ACIPCO Continuous Improvement Automation Team, headed by Process Control Engineer Mike Murphy, evaluated every manufacturing job for potential automation. Automating the Flex-Ring® welding production operation was one of the many areas identified with a desirable ROI. About a year later, in March 2008, four employees attended a submerged arc welding seminar at Wolf Robotics. They went on to develop a workable design approved by management.
Assignment Details Explained

The project involved a large-diameter, Flex-Ring restrained joint ductile iron pipe that’s easily assembled and provides positive restraint against endwise separation due to thrust — Fig. 1.

A weld bead is applied in two consecutive passes and together, with a rubber-backed ring containing ductile iron segments, provides the necessary restraint. As the plain end of the pipe is fully assembled into the bell, the ductile iron segments automatically close on the pipe behind the weld bead, providing the flexible restraint with approximately 1 in. of free axial movement — Fig. 2. This liberal deflection decreases the number of necessary fittings and accommodates settlement as well.

How the Process Previously Worked

Originally, this Flex-Ring weld bead was applied using the SAW process in several welding stations, with overtime frequently required to meet the user demand. Welders were required to closely monitor the welding torch to maintain a...
constant electrode extension distance as the pipe rotated. Also, these pipes had to be hauled to several different locations for processing prior to shipping.

Robots Enhance Compensation, Throughput

The Wolf Robotics system involved one cell incorporating two side-by-side robots and a SAW pipe sensing head assembly mounted to the robot arms using spring-loaded steel rollers to follow the curvature of the pipe’s surface. Positional feedback provided back to the robots results in smooth and accurate compensation, plus keeps the torch-to-pipe angle consistent. This helps maintain a constant, accurate welding wire electrode extension length during the entire 720 deg of rotation for welding (see lead photo).

In addition, the cell control provides an easy-to-use welding machine interface for adjusting weld parameters such as wire feed speed, voltage, torch angle, and wire electrode extension.

Significant improvements in throughput have resulted along with eliminating a considerable amount of forklift handling for moving these pipes.

Process to Salvage Flux

Another area of savings was recycling the used flux. The company previously had discarded tons of flux annually. As the pipe is now being welded prior to any coating, the flux can be recycled.

A system captures the spent flux and conveys it outside the cell — Fig. 3. The flux is screened, and good flux is returned to its recirculation system, while the hardened flux is separated and discarded. The used flux is then crushed, screened, mixed with about 20% new flux, and returned for a fraction of the cost of new flux.

Worthwhile End Results

“The SAW pipe sensing head assembly has been much more robust than I anticipated,” said Murphy. “After startup and almost a year of production, we still have the original end effector equipment.”

Typical startup issues were quickly resolved by having an engineer onsite for the first seven weeks of startup and training. A number of user interface features provided on the cell controller touch screen, including the ability to look at the data on the last 20 pipes, view cycle times, and assign weld evaluation to each record, were also beneficial.

“Overall, the system has exceeded our expectations,” added Murphy. Factors such as reduced lead times and safety/ergonomic improvements have contributed to project approval.

The American Cast Iron Pipe Co. has already seen a large portion of the estimated labor savings. It expects that number to increase this year when additional equipment is installed, which will result in the estimated and actual ROIs being close to the original projections.

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The Use of Crushed Slag as Submerged Arc Welding Flux

Information is provided to give you a better understanding of the differences between virgin flux and crushed slag

BY DEANNA MURLIN

Slag processing companies offer services that crush or grind the slag generated during welding for use as a welding flux. This crushed slag may be sized and mixed with virgin flux prior to use as a welding flux. Manufacturers who utilize these services should be aware of the differences that exist between crushed slag and the corresponding virgin flux and how those differences affect weld performance. (For definitions related to flux and slag, see the boxed item.)

Ingredients for use in welding fluxes are carefully chosen to provide specific benefits to the submerged arc welding (SAW) process, including cleansing the weld metal, providing appropriate weld metal composition (carbon, manganese, silicon, oxygen, nitrogen, etc.), protecting the weld pool from atmospheric contamination, stabilizing the arc, allowing for ease of slag removal from the weld metal, and providing the appropriate slag viscosity and freezing range for intended applications — Figs. 1, 2. When virgin flux is melted by a welding arc, it does not fully reach an equilibrium state. Although the specific elements contained in the slag may be similar, the chemical form of these elements in the generated slag will be significantly different from that of the virgin flux.

The Form of the Elements

One of the most important functions of welding flux is cleansing the weld metal
and removing the oxides and sulfides that would otherwise be dissolved in weld metal, or would be present in the form of inclusions. Fluxing agents must be in the correct chemical form to achieve the intended reactions in the weld metal. After these reactions occur, the slag will have different chemical forms than the original virgin flux.

For example, manganese and manganese oxide in virgin flux often transform into manganese silicates in the slag. All of these compounds will appear as Mn when analyzed by the most commonly used chemical analysis method, X-ray fluorescence. However, each of these forms of Mn will provide different levels of cleaning and alloying to the weld metal. In addition, each has different melting characteristics that will influence the operability of the flux.

**Impurities in Slag**

In the welding process, melted flux mixes with molten weld metal to form chemical compounds that pull impurities out of the weld and into the slag. When slag is crushed for subsequent reuse, the compounds needed to cleanse the weld are already bonded to impurities and unable to perform this function. Crushed slag is usually in these harmful impurities, like sulfur, carbon, and silicon, since the virgin flux removes these from the weld metal and adds them to the slag. Contaminants such as copper come from the welding wire, contact tips, or even ground cables. There is no practical way to separate these small pieces of copper from the slag. When present in crushed slag used for welding, they may cause weld cracking.

**Operability and Appearance**

Virgin flux and its crushed slag generally have significantly different melting points. This is due to changes that occur in the form of the oxides, silicides, fluorides, metals, etc. Further, materials that are included in virgin flux to stabilize and shield the arc during welding are no longer available in the same chemical form as originally intended after melting. Change in the compounds upon melting will often detrimentally affect the welding performance of crushed slag, such as slag removal and operability, potentially resulting in lower travel speeds and productivity.

**Physical Properties of the Slag**

Blending crushed slag with virgin flux is a common practice of flux processors. Crushed slag is approximately 20% denser than the virgin flux it was generated from. This promotes segregation of any blends of crushed slag with virgin flux. It can also significantly increase the consumption of welding flux and increase the slag to metal ratio.

**Flux Density and Consumption**

Grinding of slag produces a large amount of fine particles that affect flux particle distribution and density. Differences in flux density can negatively impact weld bead wetting, arc stability, slag removal, and weld appearance. As mentioned previously, crushed slag is denser than virgin flux and will segregate from virgin flux in crushed slag blends. Table 1 shows the increase in density and flux consumption when welding with crushed slag blends with increasing percentages of crushed slag.

### Table 1 — Flux Density and Consumption Test Results

<table>
<thead>
<tr>
<th>Amount of Crush Slag in Blend</th>
<th>Flux Density (g/mL)</th>
<th>Increase in Flux Consumption(1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>1.45</td>
<td>—</td>
</tr>
<tr>
<td>40%</td>
<td>1.44</td>
<td>4.7%</td>
</tr>
<tr>
<td>50%</td>
<td>1.53</td>
<td>9.3%</td>
</tr>
<tr>
<td>60%</td>
<td>1.54</td>
<td>15.1%</td>
</tr>
<tr>
<td>100%</td>
<td>1.72</td>
<td>17.4%</td>
</tr>
</tbody>
</table>

(1) When compared to 100% virgin flux.

### Table 2 — Mechanical Properties of Virgin Flux and Crushed Slag

<table>
<thead>
<tr>
<th>Flux or Crushed Slag Welded with EL12 Electrode</th>
<th>Tensile Strength</th>
<th>Yield Strength</th>
<th>%Mn</th>
<th>%Si</th>
<th>Charpy V-Notch ft-lbf@°F</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flux 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Virgin Flux</td>
<td>74</td>
<td>63</td>
<td>1.30</td>
<td>0.52</td>
<td>466@-20°</td>
<td>-9.5%</td>
</tr>
<tr>
<td>Crushed Slag</td>
<td>67</td>
<td>59</td>
<td>0.93</td>
<td>0.29</td>
<td>68@-20°</td>
<td></td>
</tr>
<tr>
<td>Flux 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Virgin Flux</td>
<td>77</td>
<td>68</td>
<td>1.30</td>
<td>0.50</td>
<td>67@0°</td>
<td>-11.7%</td>
</tr>
<tr>
<td>Crushed Slag</td>
<td>68</td>
<td>60</td>
<td>0.93</td>
<td>0.21</td>
<td>27@0°</td>
<td></td>
</tr>
<tr>
<td>Flux 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Virgin Flux</td>
<td>78</td>
<td>69</td>
<td>1.20</td>
<td>0.53</td>
<td>44@0°</td>
<td>-10.3%</td>
</tr>
<tr>
<td>Crushed Slag</td>
<td>70</td>
<td>59</td>
<td>0.88</td>
<td>0.27</td>
<td>62@0°</td>
<td></td>
</tr>
</tbody>
</table>
Closed-Loop Crushed Slag

Slag generated by a fabricator from a specific brand of virgin flux and crushed for subsequent reuse by the same fabricator is referred to as closed-loop crushed slag. It is important to note that the differences between virgin flux and crushed slag are no different for closed-loop crushed slag.

Chemical Analysis and Mechanical Properties of the Weld Metal

The different cleansing and alloying that crushed slag imparts vs. virgin flux can affect the mechanical properties of the weld metal. Several examples using agglomerated virgin fluxes and the crushed slag generated from these fluxes are shown in Table 2. The most consistent difference is the significant decrease in tensile and yield strengths when using crushed slag as a welding flux. This is a result of the substantial decrease in the percentage of Mn and Si in the weld deposit. The Charpy impact toughness varies and may be higher, lower, or the same when welding with the crushed slag. This is largely dependent upon the change in the alloy level, impurities in the weld metal, and number and size of the inclusions.

AWS Classification for Crushed Slag

AWS A5.23/A5.23M: 2007, Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding, and AWS A5.17/A5.17M-97(R2007), Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding, have requirements regarding the classification and packaging of crushed slag, or blends of crushed slag with virgin flux. The trade designations or trademarks of crushed slag or blends of crushed slag with virgin flux must clearly differentiate it from the original virgin flux used in its manufacture. Slag processing companies are required to verify if the blend of crushed slag with virgin flux is in full conformance with the classification requirements of the AWS A5.23 and A5.17 specifications. AWS A5.17 and A5.23 also require that “crushed slag or a blend of crushed slag with virgin flux shall have a unique trade designation that clearly differentiates it from the original virgin flux used in its manufacture.”

Conclusion

Using crushed slag blends in the submerged arc welding process is ultimately the decision of each individual manufacturer. Flux processing companies promote crushed slag blends as a way to reduce the cost of welding consumables. Before switching from virgin flux, consider how it might affect welding performance.†
What’s New in ASME Section IX?

Discussed are several issues including waveform-controlled power supplies, testing of small brazed parts, and a host of new materials

BY WALTER J. SPERKO

The 2010 edition changes to the ASME Boiler and Pressure Vessel Code, Section IX — Welding and Brazing Qualifications, become mandatory Jan. 1, 2011. Presented here is a discussion of the significant changes from the previous edition. Editorial and other minor changes are readily identified in the Summary of Changes beginning on page (c) of the Addenda. The opinions expressed in this article are those of the author and not the official opinions of the BPV Standards Committee IX.

Waveform-Shape Technology

Let us rejoice, for the changes to Section IX for the 2010 edition are mild compared to last year’s changes. There are no new P-numbers and no big changes to the P-number table.

Most of us in the welding industry are aware that equipment manufacturers have moved from motor-generator welding power supplies to solid-state power supplies over the last 30 years. This trend, like advancements with computers, has made power supplies smaller, more efficient, and more versatile. The latest innovation is “waveform shape control technology” that allows the power source to respond very rapidly to conditions at the arc. With proper programming of the power source computer, welding, particularly gas metal arc welding (GMAW), is easier to learn to use and is more productive than when using previous generations of power supplies.

Waveform shape-controlled power supplies sense the volts and amps at sampling frequencies as high as 10 kHz. This allows the power source designer to do things that were impossible before, such as suppress the high-current surge that occurs in GMAW-S as the molten droplet of metal on the end of the wire touches the weld pool at the beginning of a short circuit to virtually eliminate spatter. This ability to rapidly control the volts and amps also allows the programmer to control the transfer of metal across the arc very closely in spray pulse welding, precisely controlling the droplet shape, the bead shape, penetration, wetting, and arc energy.

One down side of this technology is that ordinary volt (V) and amp (A) meters, even RMS meters, do not measure the arc energy (i.e., V x A) accurately and, even worse, the deviation from true energy when using ordinary meters can deviate 30% or more. This is why waveform-controlled power sources can also be used without the waveform.

Waveform-controlled welding: A welding process modification of the voltage and/or current wave shape to control characteristics such as droplet shape, penetration, wetting, bead shape, or transfer mode(s).

Instantaneous power or energy: As used for waveform-controlled welding, instantaneous power or energy is measured at rapid intervals using the product of current and voltage measurements made at rapid intervals that capture brief changes in the welding waveform.

Most waveform-controlled power sources can also be used without the waveform shape controls active. If this is permitted by the WPS, then the voltage must be specified in the WPS when waveform control is inactive.

It should be noted that waveform control does not automatically imply that the transfer mode is pulsed transfer, even though the power may be pulsing. Waveform-controlled power sources that have programs suitable for welding open root joints made from one side will be operating in the short-circuiting transfer mode. In doubt, ask the power source manufacturer what the transfer mode is for your particular setup.

On to the more challenging aspect of this technology — measuring heat input. With waveform control of the power source, ordinary volt and amp meters are useless for determining arc energy. The only way to measure the arc energy is to
measure the volts and amps instanta-
neously then integrate those measure-
ments over time.

One can use a specialized hand-held meter such as the Fluke® 345 Power Quality Clamp Meter that samples volts and amps at high frequency and provides the required integration to give the power readings. For some older pulsing power supplies, using this type of meter may be the only route available.

Fortunately, for most of us, computer-controlled power supplies are capable of measuring and recording the volts and amps at the same frequency that the computers control those volts and amps. The computers can perform the necessary calculations of instantaneous arc energy over time to provide a display of either accumulated joules (J) used during the arc-on time or instantaneous energy — J/s, i.e., watts (W). The formulas for heat input using instantaneous energy or power measurements are as follows:

For instantaneous energy measurements:

\[
\text{Heat input} = \frac{\text{Energy (J)}}{\text{Weld Bead Length (in. to mm)}}
\]

For instantaneous power measurements in J/s or W:

\[
\text{Heat input} = \frac{\text{Power (J/s or W)}}{\text{Weld Bead Length (in. to mm)}} \times \text{arc time (s)}
\]

Other work where the control of heat input is required is for the application of corrosion-resistant weld metal overlay and temper bead welding. The heat input variables refer back to QW-409.1 for the appropriate formula when using waveform-controlled power sources. When waveform-controlled power sources are operating in the nonwaveform-controlled mode, the ordinary heat input formula is applicable:

\[
\text{Heat input} = \frac{\text{Volts} \times \text{Amps} \times 60}{\text{Travel Speed (in./min to mm/min)}}
\]

Appropriate instruction needs to be provided to the welder on how to apply the meter readings to determine the required travel speed for the power that he or she will be using. Section IX does not require any separate testing of the welder when using waveform-controlled power sources, but they are sufficiently different that a welder qualified for using an ordinary power source should get training on how to use the waveform-controlled power source, and practice using it, before going into production. Similarly, if a welder has learned to weld using a waveform-controlled power source, he or she should practice using a nonwaveform-controlled power source if it will be used in production. The last section of Appendix H further addresses these concerns, but it provides no requirements for welder qualifications.

What if you have a waveform-controlled power source but it does not show the joules, power, or watts in the display? Contact the manufacturer — an upgrade may be available. For many units, this will be a software upgrade. For those who have older waveform-controlled power sources that cannot be upgraded, the only route to measure power is to purchase add-on meters that are expected to be on the market soon.

Forms QW-482 and QW-483 for the WPS and Procedure Qualification Record (PQR), respectively, have been revised to show a new column for “Power or Energy” and also “wire feed speed.” Remember that these forms are not mandatory. You may develop and use your own forms as long as every essential, nonessential, and, when the construction code requires that the WPS be qualified with impact testing, the supplementary essential variables are addressed.

Now for the tricky part. What if you have WPSs qualified with nonwaveform-controlled power sources and you need to write WPSs for use with waveform-controlled power sources? How about the reverse of that scenario? The Committee prepared Appendix H to provide guidance on these matters. In brief, when qualifying a new WPS that will specify using a waveform-controlled power source, the instantaneous power or energy must be used to calculate the heat input qualified using the appropriate instantaneous power formula.

When a waveform-controlled power source is used in a nonwaveform mode, either the instantaneous power or energy or the traditional formula using V and A shall be used to calculate the heat input. Once the heat input is determined and recorded on the PQR, the WPS must specify the heat input limits. When the WPS specifies waveform-controlled welding, the instantaneous power or energy per unit length of weld bead must be specified. When the WPS specifies nonwaveform-controlled welding using a waveform-controlled power source, either the instantaneous power or energy per unit length of weld bead or the more traditional volts, amps, and travel speed limits must be specified. When the WPS specifies a conventional power source, the WPS must specify the more traditional volts, amps, and travel speed limits.

One obvious conclusion is that WPSs that have been qualified using traditional nonwaveform-controlled power supplies may be revised to specify power or energy per unit length of weld bead when specifying use of a waveform-controlled power source without requalification. For waveform-controlled power supplies that cannot be upgraded to show power or energy, the use of an external instantaneous power meter is necessary to accurately measure arc power or energy. For PQRs where the test coupon was welded using waveform-controlled power supplies without knowing the instantaneous power or energy (i.e., those that you qualified before you knew about the need to measure instantaneous power), it may be possible to establish the true heat input if sufficient data were recorded on the PQR showing the power source settings and the energy or power is established by welding a bead on plate using an instantaneous power meter.

Alternatively, if the exact power source settings had been recorded and those settings are what are specified on the WPS, it would not be necessary to establish the instantaneous power or energy. Unfortunately, this approach would be manufacturer-, model-, and program-specific to be valid, so requalification of the WPS may be necessary. If this is your situation, keep in mind that the test coupon you weld for impact tested qualifications only has to be big enough to extract the required impact test specimens, and that tension and bend testing normally does not have to be repeated (see QW-401.3).

Any time heat input limits are specified, the directions to the welder should be given in a form that is easy for the welder to work with. Using the power or energy route, the WPS can specify that the power or energy/in. of weld may not exceed some value. The welder deposits a weld bead of some length, measures that length, then divides it into the power or energy x s shown on the power or energy meter. That is, if the maximum heat input qualified is 39 kJ/in. and the welder deposits a weld bead 10 in. long, the welder is within the heat input limit of 390 kJ if the energy meter shows less than 390 kJ to make that weld bead. For the more traditional measurement, a convenient way to give the welder guidance is with a table. Again, assuming the same qualified maximum heat input, one might specify a voltage range of 28 to 30, then using 30 V, prepare the following table:

<table>
<thead>
<tr>
<th>Amps</th>
<th>Volts (max)</th>
<th>Minimum Travel Speed (in./min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>70–85</td>
<td>26</td>
<td>3.4</td>
</tr>
<tr>
<td>86–100</td>
<td>26</td>
<td>4.0</td>
</tr>
<tr>
<td>100–115</td>
<td>26</td>
<td>4.6</td>
</tr>
<tr>
<td>116–140</td>
<td>26</td>
<td>5.6</td>
</tr>
<tr>
<td>141–160</td>
<td>27</td>
<td>6.4</td>
</tr>
<tr>
<td>161–180</td>
<td>27</td>
<td>7.2</td>
</tr>
<tr>
<td>181–210</td>
<td>28</td>
<td>8.5</td>
</tr>
<tr>
<td>211–250</td>
<td>30</td>
<td>10.0</td>
</tr>
</tbody>
</table>
This way the welder only has to determine the travel speed. The WPSs should not simply specify the “heat input shall not exceed 39 kJ/in.” unless the welder has been carefully taught how to calculate the required travel speed for any given set of volts and amps.

On to simpler changes. Table QW-451 has a new footnote limiting the thickness of base metal and weld metal qualified to 2T or 2t, respectively, for electrogas welding. There was no limit the way the table was written before.

Several supplementary essential variables such as QW-403.6, QW-406.3, QW-407.4, QW-409.1, and QW-410.9 state that they do not apply when the weld is heat treated above the upper transformation temperature or an austenitic material is given a solution heat treatment because the effects of base material thickness, interpass temperature, and heat input are wiped away by these heat treatments. Solution heat treating a duplex stainless steel has the same effect, and these addenda revised the above variables to make them not applicable when either an austenitic or a duplex stainless steel is solution heat treated. Duplex stainless steel is P-10H.

**Welder Qualification (QW-300) Changes**

Welders and welding operator test coupons and production welds will be allowed to be ultrasonically examined as of the 2010 edition of Section IX. Generally, where the term “radiography” or its derivatives have been used in Section IX in the past, the phrase “or ultrasonic examination” has been added or “volumetric NDE” is used. QW-191.2 on the ultrasonic examination method has been added, and, paralleling the requirements for radiography, refers to ASME BPV Section V for technique. The acceptance criteria are similar to those for radiography. It also specifies that technicians performing ultrasonic examinations have to be qualified in accordance with the manufacturer or contractor’s written practice, which has to meet ASNT SNT-TC-1A, or they may be qualified by ASNT Central Certification or CP-189.

The limits of QW-304 for welders and QW-305 for welding operators regarding using radiography instead of visual examination plus bend testing apply when the test coupon will be ultrasonically examined, except that ultrasonic examination may be used to examine test coupons that were welded using GMAW in the short-circuiting transfer mode. While incomplete fusion defects, the rogue flaw characteristic of GMAW-S, can be difficult to find using radiography, that is not the case when using ultrasonic examination.

The big limit on using ultrasonic examination on performance qualification tests, however, is that the coupon or production weld must be ½ in. thick or thicker.

Forms QW-484A and QW-484B have been revised to add a check box choice of RT or UT when volumetric NDE is performed.

One subtle change that was not directly associated with addition of ultrasonic examination of performance test coupons, but resulted from discussion during the meeting, is that QW-191.2 was revised. That paragraph said that when a welder qualified on a production weld, the acceptance criteria were those specified in the Code Section applicable to the component that was being built. No more. When a welder or operator is qualified on a production weld, the acceptance criteria are the same as for a test coupon.

The sketches in QW-462.4 and QW-462.5 were revised to eliminate hidden lines where cuts were to be made for examination of metallographic cross sections. The sketches now show only cut lines.

Last year, I mentioned inquiry IX-07-11, which asked if a person making adjustments of the volts, amps, wire feed speed, or other settings at the direction of a qualified welder or welding operator had to also be a qualified welder or welding operator. The reply was, “No.” The following definitions were revised (shown in italics) to address this issue:

- **welding operator**: one who operates or directs the operation of machine or automatic welding equipment.
- **welding, machine**: welding with equipment that has controls that are manually adjusted by the welding operator or adjusted under the welding operator’s direction in response to visual observation of the welding, with the torch, gun, or electrode holder held by a mechanical device.

It’s reassuring to know that if a welding operator hollers, “Joe, gimme five more amps!” that Joe does not have to be qualified to run the machine.

Finally, Table QW-452.5, which covers qualification of welders by fillet weld test, has been revised to allow use of test coupons ¾ in. (5 mm) thick or greater. Previously, the first line of the table required test coupons to be ¾ to ⅜ in. (5 to 10 mm) thick. This change was the result of an intent interpretation that asked if the committee really meant to limit the test coupon thickness — and we couldn’t find a good reason for the limit — so we made it more open and flexible. The second line of the table covers test coupons less than ¾ in. thick, and is unchanged.

**Base Metals and Filler Metals**

As a result of last year’s removal of S-numbers, some materials were reevaluated and deleted from QW/QB-422. This was due to inadequate chemical composition limits in the specifications. Deleted are A-148, structural castings; A-521, die forgings; and A-688, high-strength forgings. Tensile strengths listed for some materials previously were removed and replaced with “* * *” because the material specification did not have a specified minimum tensile strength. A sentence was also added to QW-420 saying that, for materials listed in QW/QB-422, only those that have a specified minimum tensile strength may be used for groove weld procedure qualification test coupons.

Many new materials were added to QW/QB-422, including several European materials. SA/EN 10028-1, Grades P355GH of C-Mn-Si plate similar to SA-516 Grade 70 was added as P-1, Group 2, and Grade P275NM, similar to SA-516 Grade 60 was added as P-1, Group 1. SA/EN 10222-2, Grades P-280GH, P305GH, 13CrMo4-5, 13CrMo9-10, and X10CrMoVNb9-1 were assigned to P-1, Group 1, P-1, Group 2, P-4, Group 1, P-5A, Group 1, and P-15E, Group 1, respectively. SA/EN 10216-2 Grades P235GH, P265GH, 16M03, 13CrMo4-5, 13CrMo9-10, and X10CrMoVNb9-1 were assigned to P-1, Group 1, P-1, Group 1, P-3, Group 1, P-4, Group 1, P-5A, Group 1, and P-15E, Group 1, respectively. SA/EN-10088-2 Grade S235JR plate and SA/EN 10217 Grade P235TR2 ERW tube were added as P-1, Group 1, and SA/EN 10088-2, X6CrNiMoTi 17-12-2 was added as P-8, Group 1, SA/EN-10028-4, Grades X7N9 and X8Ni9 (quenched and tempered 9% nickel steel) was added as P-11A, Group 1; and SA/EN-10028-2, Grade 13CrMoSi5-5+ QT was added as P-4, Group 1.

I encourage readers outside the United States to bring materials manufactured to local specifications for pressure applications to ASME for incorporation into the Boiler Code. See ASME Section II Part D, Mandatory Appendix 5, for more details about the information that is required for materials to be adopted.

ASTM A-199 seamless alloy tube, Grades T11, T22, T21, T5, and T9 were added with P-numbers of 4, 5A, 5A, 5B, and 5B, respectively. These grades were also added as A-234 fittings. A-691, fusion welded pipe, was added as Grade 91 with a P-number of P-15E, Group 1. It should be noted that the ASTM specification for this material requires it to be normalized and tempered after welding. UNS S34865 was added as a super-
austenitic stainless steel, P-8, Group 4 for various product forms. SA-213, 310HCbN tube was added as P-8, Group 1. Finally, SA-299, Grade A, was added as P-1, Group 2, and Grade B was added as P-1, Group 3.

A new classification of titanium, Ti3Al-2.5V-0.1Ru, was added for various specifications, and a matching filler metal, ERTi-28, was added to the F-number table.

**Brazing (QB) Changes**

If you ever have to braze a small part like a valve seat to a large part like a casting, QB-451.3 has been revised to make qualifying the BPS simpler and more meaningful. This table requires that two tension tests and two peel tests be performed, and it sets limits on the thickness qualified based on two times the thickness of the test coupon. Tension testing becomes difficult to do and is of questionable value for brazing where one part is large and the other small, so a footnote was added that allows one to validate the properties of the joint by making tension and peel test specimens using any convenient thickness of test coupon, then to supplement that PQR with an additional test piece following QB-451.5 workmanship coupons. While QB-451.5 thickness ranges qualified are identical to those of QB-451.3, only sectioning of the specimens is required.

Footnote 1 of QB-452.1 on performance qualification was clarified to make it clear that when one cannot do a peel test, section testing is permitted.

**Inquiries**

Occasionally I am asked, “Can one welder weld one side of a 6G pipe test coupon using GTAW followed by SMAW and another welder weld the other side and both welders be considered to be qualified for all positions?” After all, both welders weld some overhead, some uphill, and some horizontal. That question is answered by the following:

**Question 1:** If radiographic examination per OW-302.2 is done for qualification of two welders on a single pipe coupon welded in the 6G position, must each welder complete the entire circumference of the pipe coupon in order to remove the required bend specimens in accordance with QW-463.2(d) or QW-463.2(e)?

**Reply 1:** Yes. The rationale for this reply is that different skills are required on a 6G coupon welding up one side vs. welding up the other side — kind of like welding one side right-handed and the other side left-handed. So each welder needs to weld the entire circumference.

**Question 2:** If mechanical testing per OW-302.1 is done for qualification of two welders on a single pipe coupon welded in the 6G position, must each welder com-

While the final decision about the moniker “QP” is not decided, the new part will cover joining of high-density polyethylene (HDPE), which is already permitted by Code Cases.

If that’s not enough to excite you, soon the ASME Boiler and Pressure Vessel Code will stop publishing addenda. As of 2013, the Code, all 20,000 pages of it, will be republished biennially without addenda. Mechanisms for advising users of errata and errors will be developed so that anyone who buys the Code book will be notified of such matters, and we should expect to see more use of Code Cases to provide interim rules between editions so that new technology can be implemented in a timely manner without getting hung up by publication cycles. ASME has advised that the price of Code books will be adjusted to be “revenue neutral.” Exactly what that means remains to be seen.

Readers are advised that all ASME Code Committee meetings are open to the public. The meeting schedule is posted at www.sperkoengineering.com and www.asme.org.

For info go to www.aws.org/ad-index
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Mark Burke - Indalco Alloys - Mississauga, Ontario, Canada

Aluminum Welding Metallurgy
Bruce Anderson - MAXAL Wire Company - Traverse City, MI

Metal Preparation for Aluminum Welding
Kevin Summers - Miller Electric - Appleton, WI

Filler Alloy Selection Primary Characteristics
Tony Anderson - Miller Electric - Appleton, WI

Gas Metal Arc Welding of Aluminum Alloys
Mark Burke - Indalco - Mississauga, Ontario, Canada

The Fundamentals of GTAW Welding of Aluminum & Some New Innovations
Kirk Webb - Miller Electric - Appleton, WI

Aluminum Weld Discontinuities: Causes and Cures
Tony Anderson - Miller Electric - Appleton, WI

Design and Performance of Aluminum Welds
Bruce Anderson - MAXAL Wire Company - Traverse City, MI

Applications of the AWS D1.2 Structural Welding Code – Aluminum
Tony Anderson - Miller Electric - Appleton, WI

Robotic Applications
Kevin Summers - Miller Electric - Appleton, WI

New Aluminum Filler Alloy Development – Alloy 4143
Bruce Anderson - MAXAL Wire Company - Traverse City, MI

Friction Stir Welding – Challenges for Aerospace Aluminum
John A. Baumann - The Boeing Company - St. Louis, MO

Thermal Cutting Methods for Aluminum
Jay Ginder - ESAB Welding & Cutting Products - Florence, SC

Practical Challenges in High Tech. Welded Aluminum Structural Fabrication
Steve Pollard - Machinists Inc. - Seattle, WA

Advances and Improvements in Friction Stir Welding and Friction Stir Processing
John F. Hinrichs & Christopher B. Smith - Friction Stir Link - Brookfield, WI

Explosion Bonding with Aluminum
Don Butler - High Energy Metals - Sequim, WA

For the latest conference and exhibitor information or to register for the conference, visit our website at www.aws.org/conferences or call 800-443-9353, ext. 462
COMING EVENTS

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

♦ Trends in Welding Conf. Aug. 2–5, Cherry Valley Lodge, Newark, Ohio. Cosponsored by American Welding Society and Edison Welding Institute. Contact George Ritter (614) 688-5199; gritter@ewi.org.


♦ ICWJM 2010. Third Int'l Conf. on Welding and Joining of Materials, and Int'l Welding Show Peru. Aug. 9–11, Lima, Peru. To feature weldability of advanced alloys, modeling processes, distortion, advanced NDE of welds, welder training, special welding and joining processes, technology transfer, etc. Sponsored by the AWS Peru Section, organized by Soldexa S.A. and Pontifical Catholic University of Peru in collaboration with the University of Chicago. Visit www.pucp.edu.pe/icwjm/index.html.


♦ AWS/AA 13th Annual Conf. on Welding Aluminum. Sept. 21, 22, Doubletree Guest Suites Seattle Airport/Southcenter, Seattle, Wash. A distinguished panel of aluminum-industry experts will survey the state of the art in aluminum welding technology and practice. For information or to register, call (800) 443-9353, ext. 264; or visit www.aws.org/conferences/aluminum.


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Canadian Welding Association Conf. Sept. 26–28, Blue Mountain, Collingwood, Ont., Canada. Call (800) 844-6790, or visit www.cwa-ac.org.


Canadian Manufacturing Week 2010. Oct. 5–7, Toronto Congress Centre, Toronto, Ont., Canada. Sponsored by Society of Manufacturing Engineers. Call (888) 322-7333; canadasales@sme.org.


FABTECH. Nov. 2–4, Georgia World Congress Center, Atlanta, Ga. This show is the largest event in North America dedicated to showcasing the full spectrum of metal forming, fabricating, tube and pipe, welding equipment, and technology. Contact American Welding Society, (800/305) 443-9353, ext. 204; or visit www.aws.org.


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♦ JOM-16, 16th Int’l Conf. on the Joining of Materials and ICEW-7, 7th Int’l Conf. on Education in Welding.  May 10–13, 2011. LO-skolen Conference and Hotel, Helsingør, Denmark. Contact JOM Institute, Gilleleje, Denmark. Phone +45 48 35 54 58; jom_aws@post.dk.


Educational Opportunities


Basics of Nonferrous Surface Preparation.  Online course, six hours includes exam. Offered on the 15th of every month during 2010 by The Society for Protective Coatings. Members $145, nonmembers $245. Register online at www.sspc.org/training.


Brazing Fundamentals Training Seminars. Oct. 5–7, Embassy Suites, Greenville, S.C. Covers furnace, torch, induction, etc., as well as all filler metal types (Ni, Cu, Ag, Al, etc.). Contact Kay & Associates (860) 651-5595, or visit www.kaybrazing.com.


Preparation and Exam for AWS Certified Welding Inspector/Educator. Two-week-long courses beginning Aug. 9, Sept. 20, Nov. 1, Nov. 29 in Troy, Ohio. Call Hobart Institute of Welding Technology (800) 332-9448; hiwt@welding.org; or visit www.welding.org.

Preparation and Exam for AWS Certified Welding Supervisor. One-week-long course begins Oct. 18 in Troy, Ohio. Call Hobart Institute of Welding Technology (800) 332-9448; hiwt@welding.org; or visit www.welding.org.


ASM Int’l Courses. Numerous classes on welding, corrosion, failure analysis, metallurgy, heat treating, etc., presented in Materials Park, Ohio, online, webinars, on-site, videos and DVDs. Visit www.asminternational.org, search for “courses.”


— continued on page 81
AWS Certification Schedule
 Certification Seminars, Code Clinics and Examinations

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

<table>
<thead>
<tr>
<th>Certified Welding Inspector (CWI)</th>
<th>Location</th>
<th>Seminar Dates</th>
<th>Exam Date</th>
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<tr>
<td>Denver, CO</td>
<td>Aug. 1-6</td>
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<td>Philadelphia, PA</td>
<td>Aug. 1-6</td>
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<td>Chicago, IL</td>
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<td>Charlotte, NC</td>
<td>Aug. 15-20</td>
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<td>San Antonio, TX</td>
<td>Aug. 15-20</td>
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<td>Bakersfield, CA</td>
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<td>Rochester, NY</td>
<td>Aug. 22-27</td>
<td>Aug. 28</td>
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<td>Portland, ME</td>
<td>Aug. 22-27</td>
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<td>Salt Lake City, UT</td>
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<tr>
<td>Corpus Christi, TX</td>
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<td>Pittsburgh, PA</td>
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<td>Anchorage, AK</td>
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<td>Nashville, TN</td>
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<td>Tulsa, OK</td>
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<td>Dec. 4</td>
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<td>Syracuse, NY</td>
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<td>Corpus Christi, TX</td>
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<td>Dec. 18</td>
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<tr>
<th>9-Year Recertification Seminar for CWI/SCWI</th>
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<tr>
<td>Orlando, FL</td>
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<td>Denver, CO</td>
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<td>Miami, FL</td>
<td>Nov. 29-Dec. 4</td>
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For current CWIs and SCWIs needing to meet education requirements without taking the exam. If needed, recertification exam can be taken at any site listed under Certified Welding Inspector.

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<thead>
<tr>
<th>Certified Welding Sales Representative (CWSR)</th>
<th>Location</th>
<th>Seminar Dates</th>
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<td>Miami, FL</td>
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<td>Atlanta, GA</td>
<td>Nov. 2-4</td>
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Certified Robotic Arc Welding (CRAW)

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<tr>
<td>ABB, Inc., Auburn Hills, MI</td>
<td>Aug. 2</td>
<td>(248) 391-8421</td>
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<tr>
<td>Genesis-Systems, Davenport, IA</td>
<td>Aug. 2</td>
<td>(563) 445-5688</td>
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<td>Sept. 13</td>
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<td>Wolf Robotics, Ft. Collins, CO</td>
<td>Sept. 13</td>
<td>(970) 225-7736</td>
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<td>Oct. 25</td>
<td>(563) 445-5688</td>
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<tr>
<td>Lincoln Electric, Cleveland, OH</td>
<td>Oct. 25</td>
<td>(216) 383-8542</td>
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<td>ABB, Inc., Auburn Hills, MI</td>
<td>Nov. 1</td>
<td>(248) 391-8421</td>
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International CWI Courses and Exams

Please visit http://www.aws.org/certification/inter_contact.html

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

To: Professors Engaged in Joining Research

Subject: Request for Proposals for AWS Fellowships for the 2010-2011 Academic Year

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

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

Please note, there are important changes in the schedule which you must follow in order to enable the awards to be made in a timely fashion. Proposals must be received at American Welding Society by September 15, 2010. New AWS Fellowships will be announced at the AWS Annual Meeting, November 2010.

THE AWARDS

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

The AWS Fellowship is awarded to the student for graduate research toward a Masters or Ph.D. Degree under a sponsoring professor at a North American University. The qualifications of the Graduate Student are key elements to be considered in the award. The academic credentials, plans and research history (if any) of the student should be provided.

The student must prepare the proposal for the AWS Fellowship. However, the proposal must be under the auspices of a professor and accompanied by one or more letters of recommendation from the sponsoring professor or others acquainted with the student's technical capabilities. Topics for the AWS Fellowship may span the full range of the joining industry. Should the student selected by AWS be unable to accept the Fellowship or continue with the research at any time during the period of the award, the award will be forfeited and no (further) funding provided by AWS. The bulk of AWS funding should be for student support. AWS reserves the right not to make awards in the event that its Committee finds all candidates unsatisfactory.

DETAILS

The Proposal should include:

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

In addition, the proposal must include:

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

The technical portion of the Proposal should be about ten typewritten pages; maximum pages for the Proposal should be twenty-five typewritten pages. Maximum file size should be 2 megabytes. It is recommended that the Proposal be typed in a minimum of 12-point font in Times, Times New Roman, or equivalent. Proposal should be sent electronically by September 15, 2010 to:

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

Yours sincerely,
Ray W. Shook
Executive Director
American Welding Society
Take Care when Using Degreasing Agents

Welders occasionally experience respiratory distress, immune reactions, or other toxic effects from exposures to chemicals incidental to the welding process. This type of exposure includes chemicals thought to be generated by photochemical decomposition products of degreasing agents and pollutants generated by pyrolysis or thermal degredation of paints or other surface coatings or contaminants. These exposures are not inherent to welding. Welders can, with few exceptions, avoid this exposure through changes to the manufacturing process and using proper ventilation and safety techniques.

Degreasing Agents

Degreasing agents can present a major health hazard in welding. Severe acute respiratory distress can result from such highly toxic chemicals as phosgene and dichloroacetyl chloride, which can arise from ultraviolet (UV) induced photochemical decomposition of degreasing agents such as trichloroethylene, perchloroethylene, and 1,1,1-trichloroethane. The gas metal arc (GMA) and gas tungsten arc (GTA) welding processes can produce high levels of UV radiation, so this type of hazard is greatest in shops where these processes are conducted. While, in the past, several incidents of severe respiratory distress were thought to have resulted from the chemical composition of degreasing agents, the actual presence of phosgene and/or dichloroacetyl chloride has been hard to substantiate.

Following are reports from two cases.

In 1991, an incident was reported in which a 50-year-old, highly experienced welder performed GTAW on a piece of stainless steel that had been degreased with trichloroethylene. The welding was done without local exhaust ventilation to avoid disturbing the gas shield. Almost immediately after starting to weld, he developed dyspnea. He rested, recovered, and returned to welding with no further symptoms until 12 hours later, when he developed severe respiratory distress and pulmonary edema. He was treated for these symptoms but was readmitted to the hospital ten days later with dyspnea (difficult or labored breathing) and respiratory failure. His exposure to trichloroethylene was confirmed by the presence of trichloroacetic acid (a metabolite of trichloroethylene) in his urine. It was speculated that the severe pulmonary reactions might have been due to inhalation of the photochemical decomposition products dichloroacetyl chloride and phosgene. However, no attempt was made to determine whether phosgene or dichloroacetyl chloride could form under welding conditions similar to what the affected welder experienced.

In a similar case involving 1,1,1-trichloroethane (methylenechloroform) exposure, researchers “extensively investigated the phosgene theory but with a frustrating outcome, illustrating the inherent problems of retrospective exposure assessment.”

In this case, a 62-year-old man used the GMAW process and an argon/CO₂ gas shield to weld mild steel covered with a drawing oil. Prior to welding, the pieces were degreased with 1,1,1-trichloroethane stabilized with dioxane. After welding for three days under these conditions, he developed fever, severe respiratory distress, and eventually died.

The incident was reconstructed at the work site, but no phosgene was detected, even in the presence of inordinately high levels of 1,1,1-trichloroethane (740 ppm). Phosgene could only be detected when the concentration of airborne 1,1,1-trichloroethane reached 1000 ppm during welding. The investigators concluded that, while the presence of phosgene could not be confirmed, the illness, diagnosed as toxic pulmonary edema, was related to welding in the presence of a chlorinated solvent.

Coated or Contaminated Surfaces

The following describes the experience of two welders in Sweden. These experienced welders developed fever, spirometric deterioration, and bronchial hyperreactivity after GMAW of steel painted with lacquers containing chlorinated polymers. The first welder, a 54-year-old man, experienced eye and throat irritation and shortness of breath shortly after his first experience welding steel coated with a new paint. Later that evening, he developed a high fever. The same symptoms occurred on six other occasions when he welded steel coated with the same paint. Repeated testing showed volume and flow decrementes that slowly returned to normal. The second man, a 49-year-old welder, developed fever and shortness of breath five to six hours after welding steel coated with a paint similar in composition to the paint welded by the first man. The second man felt tired for several weeks and experienced similar symptoms on four other occasions when he welded steel coated with the same paint, although the symptoms were milder and lasted for a shorter time.

Both welders were exposed to compounds generated by pyrolysis of paints that were epoxidized vegetable oils hardened by hexachloroendomethylene-tetrahydrophthalic acid anhydride. Limited tests showed that HCl, but not phosgene, is released from this paint during welding. The researchers concluded the two welders had toxic alveolitis and obstructive lung disease induced by HCl and other chlorinated compounds. They related the symptoms to reactive airways dysfunction syndrome (RADS), which is characterized by asthma and bronchial hyperreactivity and develops after one or more exposures to high concentrations of low-molecular weight respiratory tract irritants. The symptoms of RADS may be aggravated by nonspecific irritants. They speculated that HETacid anhydride may have been one of the components responsible for this syndrome.

What to Do

ANSI Z49.1, Safety in Welding, Cutting, and Allied Processes, provides the following advice for using cleaning compounds such as degreasers.

“5.5.4 Cleaning Compounds. When using cleaning compounds prior to welding, manufacturers’ instructions shall be followed.”

“5.5.4.1 Chlorinated Hydrocarbons. Degreasing or cleaning operations involving chlorinated hydrocarbons shall be so located that vapors from these operations will not reach or be drawn into the atmosphere surrounding molten weld metal or the arc.”

“In addition, these materials shall be kept out of atmospheres penetrated by the ultraviolet radiation of arc welding operations.”

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Excerpted from ANSI Z49.1:2005, Safety in Welding, Cutting, and Allied Processes, and Effects of Welding on Health IX.
AWS and GAWDA Form a New Management Link

Officers of the Gases and Welding Distributors Association (GAWDA) recently signed an agreement for AWS to manage the association's daily business affairs. In this arrangement, GAWDA remains an independent association dedicated to promoting the safe operation and economic vitality of distributors of industrial gases and related welding equipment and supplies.

Jenny McCall, GAWDA president, said, “AWS and GAWDA serve and are committed to the same industry, and we believe this partnership will establish an even stronger relationship with welding distributors, manufacturers, and end users.”

The Gases and Welding Distributors Association’s new mailing address is 550 NW LeJeune Rd., Miami, FL 33126. Natasha Alexis is GAWDA’s administrative manager, ext. 401.

Visit [www.gawda.org](http://www.gawda.org) to learn more about GAWDA’s services.

shown (from left) are GAWDA Treasurer David Walker, GAWDA President Jenny McCall, and Ray Shook, AWS executive director, at the agreement signing on June 23.

AWS Board Tours Society’s Future Headquarters Building

The AWS board members are shown during their recent tour of the Society’s future headquarters building (see inset). By the end of 2011, AWS plans to start moving its headquarters operations into the 122,482-sq-ft, five-story office building, located on a five-acre site in Doral, Fla., about seven miles from the present headquarters building in Miami. The purchase closed May 3.
Tech Topics

Two Official Interpretations: D1.3, Structural Welding Code — Sheet Steel

Subject: Low-hydrogen electrodes and welding sheet steel to structural steel


Code Provisions: Subclause 1.1.1, Table 1.1, Annex A

Inquiry 1: When using SMAW, are low-hydrogen electrodes required when welding sheet steel to structural Group II or higher steels?

Response 1: Yes. See AWS D1.3:2008 Table 1.2, Note 1, which states “Low-hydrogen electrodes shall be used when required by AWS D1.1.” There is an exception for arc spot, arc seam, and arc plug welds used to attach “decking” permitted by Annex A, Note 1.

Inquiry 2: When using FCAW, is E71T-GS (exempted in AWS D1.1 Table 3.1) acceptable when welding sheet steel to structural steel?

Response 2: No. See AWS D1.3:2008 Table 1.2, Note 4.

Subject: Low-hydrogen electrodes and arc spot welding


Code Provision: Clause 1.4, Table 1.2

AWS Log: D1.3-08-I10

Inquiry 1: When making arc spot welds for decking to AWS D1.1 Group II steels, does AWS D1.3 require the use of low-hydrogen electrodes?

Response 1: Yes. See Table 1.2, Note 1.

Inquiry 2: Upon successful completion of WPSs and PQRs, as identified in Clause 4 of AWS D1.3:2008, would E7010-P1 electrodes be an acceptable filler metal for arc spot welding ASTM A653 sheet steel to Group II structural steel?

Response 2: Yes. See AWS D1.3:2008, Table 1.2, Note a(1).

Standard Approved by ANSI


Revised Standards for Public Review

D1.4/D1.4M:20XX, Structural Welding Code — Reinforcing Steel. $43.50. 8/9/10.

D1.5M/D1.5:2010, Bridge Welding Code. $216. 7/19/10.

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. Draft copies may be obtained from R. O’Neill, ext. 451, roneill@aws.org.

Technical Committees Seek Your Expertise

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 Brian McGrath, bm McGrath@aws.org, ext. 311.

Surfaceing Industrial Mill Rolls


Welding Sales Representatives

Volunteers are invited to help set the qualification requirements in AWS B5.14, Specification for the Qualification of Welding Sales Representatives. Contact J. Gayler, gayler@aws.org, ext. 472.

Robotic and Automatic Welding


Thermal Spraying


Labeling and Safe Practices

SH4 Subcommittee on Labeling and Safe Practices to update F2.2, Lens Shade Selection; 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.

Magnesium Alloy Filler Metals

ASL Subcommittee on Magnesium Alloy Filler Metals. This subcommittee is responsible for updating AWS A5.19-92 (R2006), Specification for Magnesium Alloy Welding Electrodes and Rods. Contact R. Gupta, gupta@aws.org, ext. 301.
Distinguished Guests Visit Headquarters

Shown (from left) are District 5 Director Steve Mattson, Joan and Steve Charlip, and Gilly Bunion, chairman, South Florida Section. Steve Charlip, a 53-year AWS Member, and his wife, Joan, visited AWS headquarters June 24. He is a past chairman of the New York Section and has served as a South Florida Section board member, and as a welding consultant for Rockmount® Nassau.

Nominations Sought for M.I.T. Masubuchi Award

November 2, 2010, is the deadline for submitting nominations for the 2011 Prof. Koichi Masubuchi Award, sponsored by the Dept. of Ocean Engineering at Massachusetts Institute of Technology (M.I.T.). This award, including an honorarium of $5000, 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. The nomination package should include the candidate’s background, experience, publications, honors, and awards, plus at least three letters of recommendation from fellow researchers. The award was established to recognize Prof. Masubuchi for his numerous contributions to the advancement of the science and technology of welding, especially in the fields of fabricating marine and outer space structures.

Send your nominations to Prof. John DuPont at jnd1@lehigh.edu.

Welders Come to a Handicapped Hunter’s Rescue

Des Moines Area Community College welding instructors Keith Simpson (second from left) and Mike Rahn (kneeling at front) and student Mike Loffredo (right) welded this wheelchair-accessible shooting platform mounted to an all-terrain vehicle that will allow handicapped sportsman Jesse Mulder (seated in wheelchair) to do some hunting this fall. Ron Brown (orange hat), John Heck (at the wheel), and the others are working with the Central Iowa Outdoors Without Boundaries organization to assist handicapped hunters in enjoying the outdoors.

Nominations Sought for National Officers

AWS members who wish to nominate candidates for President, Vice President, and Director-at-Large on the AWS Board of Directors for the term starting Jan. 1, 2012, may:

1. Send their nominations by Sept. 22, 2010, to Gricelda Manalich, gricelda@aws.org, c/o Victor Y. Matthews, chairman, National Nominating Committee or

2. Present their nominations in person at the open session of the National Nominating Committee meeting scheduled for 2:00 to 3:00 PM, Tuesday, Nov. 2, 2010, at the Georgia World Congress Center, Atlanta, Ga., during the 2010 FABTECH show.

Nominations must be accompanied by biographical material on the candidate, including a written statement by the candidate as to his or her willingness and ability to serve if nominated and elected, letters of support, plus a 5-x 7-in. color portrait.

Note: Persons who present their nominations at the show must provide 20 copies of the biographical materials and written statement.
New AWS Supporters

New Sustaining Companies

**Centerline Machine, Inc.**
PO Box 285, Waucapec, WI 54981  
Representative: Bobbie Jo Shaw  
www.centerlinemachine.com  
Centerline Machine is a just-in-time custom machining and fabrication company. Its services can help you reduce downtime and increase profits by supplying all of your specialized machining needs.

**Denyo Co., Ltd.**
2-8-5 Nihonbashi-horidomecho  
Chuo-ku, Tokyo 103-8566, Japan  
Representative: Michael C. O’Donnell  
www.denyo.co.jp  
Denyo Co., known worldwide for its innovation and quality, has been a supplier of engine-driven generators, welding machines, air-compressors, and other construction-related equipment since 1948. Its products are sold exclusively in North America under the MQ Power brand by its long-standing partner, Multiquip, Inc.

**Eleet Cryogenics, Inc.**
11132 Industrial Pkwy. NW  
Bolivar, OH 44162  
Representative: Douglas Morton  
www.eleetcryogenics.com  
Eleet Cryogenics offers complete cryogenic bulk tank sales and rehab services including on-site installation and field services. It manufactures industrial and medical gas-control manifolds, parts, and vaporizers; and offers cryogenic delivery vehicle sales and rentals.

**Industrial Contractors, Inc.**
1001 Mt. Auburn Rd.  
Evansville, IN 47720  
Representative: Earl Young  
www.industrialcontractors.com  
Industrial Contractors is a self-performing general contractor engaged in engineering and construction within the power industry, industrial, and commercial markets involving all construction trades. Its in-house capabilities include manufacturing structural, breeching, piping, sheet metal, stacks, tanks, and prefabricated and modular products and assemblies.

Supporting Companies

**CMC South Carolina Steel**
PO Box 71  
Greenville, SC 29602

**Grupo IEMIC S.A. De C.V.**
Mier y Teran Nte No. 1501-C  
Col. Asuncion Gomez, Victoria  
Tamaulipas 87040, Mexico

**Promotora De Servicios En Ingenieria S.A. De C.V.**
Trabajadores Sociales No. 281  
Colonia Sifon, Mexico D.F. 09400  
Mexico

**Affiliate Companies**

**Alme’rag Construction & Industry**
22 Sabri Abo Alam St., Ismailia Sq.  
1st Fl., Heliopolis, Cairo, Egypt

**Code Welding & Mfg., Inc.**
3151-101 St. Ave. NE  
Blaine, MN 55449

**Eagle Precision Manufacturing**
816 Nina Way  
Warminster, PA 18974

**E&D Specialty Stands**
2881 Franklin St.  
North Collins, NV 14111

**Nexsol S.R.L.**
Los Brillantes 343 Urb Balconcillo  
La Victoria, Lima 13, Peru

**United Engineering Industries**
51/A, H-Sector, Industrial Area  
Govindpura, Bhopal Madhya  
PR 462023, India

**Educational Institutions**

**Atlanta Ironworkers Joint Apprenticeship Committee**
114 Selig Dr. SW  
Atlanta, GA 30336

**Ironworkers Local 40 & 361 JAC**
35-23 36th St.  
Astoria, NY 11106

**Lost River Career Cooperative**
600 Elm St., Ste. 1  
Paoli, IN 47454

**Mohave Community College**
1971 Jagerson Ave.  
Kingman, AZ 86409

**Orangeburg-Calhoun Technical College**
3250 St. Matthews Rd.  
Orangeburg, SC 29118

**Virtual Engineering Solutions PTE, Ltd.**
No. 1, Bukit Batok Crescent  
#09-05, WCEGA Plaza  
Singapore 658064, Singapore

AWS Member Counts

**Grades**

Sustaining................................. 514  
Supporting................................. 310  
Educational................................. 544  
Affiliate................................... 468  
Welding Distributor....................... 46  
**Total Corporate Members............... 1,882**  
Individual Members................... 53,435  
Student + Transitional Members.... 9,713  
**Total Members.......................... 63,148**

AWS Mission Statement

The mission of the American Welding Society is to advance the science, technology, and application of welding and allied processes, including joining, brazing, soldering, cutting, and thermal spraying.
Final Tally: Member-Get-A-Member Campaign

Listed are the final member-proposer data for the period June 1, 2009, through May 31, 2010. Congratulations to the top campaign winners: Bryan Chin, most new Individual Members; David Saunders, most new Student Members; and Satish Keskar, international sponsor winner. See page 65 in this Welding Journal or visit www.aws.org/mgm for the MGM rules and prize list.

Call the AWS Membership Dept. (800/305) 443-9353, ext. 480, for information on your member-proposer status.

Winner’s Circle
Sponsored 20+ new members
The superscript indicates the number of times the member has achieved Winner’s Circle status since June 1, 1999.
J. Compton, San Fernando Valley
E. Ezell, Mobile
J. Merzthal, Peru
G. Taylor, Pascagoula
B. Chin, Auburn-Ooppelika
E. Esders, Detroit
B. Mikeska, Houston
W. Shreve, Fox Valley
M. Karagoulis, Detroit
S. Mccull, NE Tennessee
T. Weaver, Johnstown-Altoona
G. Woomer, Johnstown-Altoona
T. Rowe, Tulsa
M. Rudden, Colorado
T. Sewell, International
J. Sims, Syracuse
S. Siviski, Maine
M. Stevenson, J.A.K.
T. Thomas, St. Louis

Student Member Sponsors
Sponsored 5 or more new Student Members
D. Saunders, Lakeshore
C. Rogers, San Antonio
G. Kirk, Pittsburgh
H. Hughes, Mahoning Valley
G. Gammill, NE Mississippi
D. Berger, New Orleans
J. Morash, Boston
S. Miner, San Francisco
C. Hardbarger, Mid-Ohio Valley
R. Durham, Cincinnati
D. Ketter, Willamette Valley
C. Lindquist, Central Michigan
D. Zabel, SE Nebraska
T. Palmer, Colorado
J. Carney, Western Michigan
T. Gerber, Allegheny
M. Anderson, Indiana
D. Kowalski, Pittsburgh
S. Kunz, Pittsburgh
D. Pickering, Central Arkansas
A. Stute, Madison-Beloit
R. Hutcheson, Long Beach/O.Cty.
M. Boggs, Stark Central
A. Duron, New Orleans
M. Hayes, Pequot Sound
S. Siviski, Maine
D. Aragon, Pequot Sound
A. Baughman, Stark Central
C. Ross, Pequot Sound
R. Wahrman, Triangle
N. Baughman, Stark Central
J. Ciaramitaro, N. Central Florida
T. Geisler, Pittsburgh
S. Burdge, Stark Central
R. Evans, Siouxland
E. Norman, Ozark
G. Marx, Tri-River
K. Rawlins, Columbia

President’s Club
Sponsored 3-8 new Individual Members
Keskar, India Int’l
E. Young, Tri-River
J. Hennessy, Fox Valley
J. Price, Detroit
L. Taylor, Pascagoula
D. Berger, New Orleans
J. Ciaramitaro, North Central Florida
J. Cooley, Birmingham
E. Ezell, Mobile
J. Hope, Puget Sound
G. Balderick, Rio Grande Valley
B. Cebery, Fox Valley
F. Fitzpatrick, Arizona
E. Ravelo, International
J. Rodenbarger, Nebraska
D. Scott, Mobile
S. Singh, Indian
T. Baber, San Fernando Valley
G. Burrian, South Florida
T. Morris, Tulsa
P. Newhouse, British Columbia
M. Pelegriino, Chicago

President’s Roundtable
Sponsored 9-19 new members
R. Ellenbecker, Fox Valley
J. Compton, San Fernando Valley
A. Sumal, British Columbia
H. Thompson, New Orleans
G. Moore, San Diego

President’s Guild
Sponsored 20+ new members
B. Chin, Auburn-Ooppelika

President’s Honor Roll
Sponsored 1 or 2 new members
J. Barber, Connecticut
T. Blakeney, Green & White Mts.
C. Bridwell, Ozark
G. Callender, San Fernando Valley
J. Cantlin, Southern Colorado
K. Carter, Tri-River
R. Davis, Utah
G. Euliano, Northwestern Pa.
M. Haynes, Niagara Frontier
K. Hurst, Kansas City
S. Johnson, Lexington
R. Jones, Houston
K. Langdon, Johnny Appleseed
D. Mandina, New Orleans
V. Matthews, Cleveland
J. Medina, International
J. Miller, Lancaster
T. Moffitt, Tulsa
B. Morgan, Kern
F. Nguni, New Jersey
T. Rowe, Tulsa
M. Rudden, Colorado
R. Sewell, International
J. Sims, Syracuse
S. Siviski, Maine
M. Stevenson, J.A.K.
T. Thomas, St. Louis
B. Suckow, Northern Plains
R. Cook, Utah
C. Donnell, NW Ohio
J. Durbin, Tri-River
V. Facciano, Lehigh Valley
W. Galvery, Long Beach/O.Cty.
W. Harris, Pascagoula
J. Theberge, Boston
M. Arand, Louisville
J. Boyer, Lancaster
R. Boyer, Nevada
W. Davis, Syracuse
J. Fox, NW Ohio
J. Gerdin, Northwest
J. Roberts, Sacramento
D. Vranic, FLorida
K. Carter, Tri-River
R. Schmidt, Philadelphia
G. Smith, Lehigh Valley
B. Wenzel, Sacramento
B. Benyon, Johnstown-Altoona
J. Daugherty, Louisville
A. Reis, Pittsburg
G. Seese, Johnstown-Altoona
W. Garrett, Olympic
M. Vann, South Carolina
R. Vann, South Carolina
T. Garcia, New Orleans
J. Kline, Northern New York
R. Munns, Utah
W. Seyforth, N. Central Florida
S. Mattson, FLorida
H. Thompson, New Orleans
G. Rodeman, Sierra Nevada
C. Fomby, Auburn
R. Ledford, Birmingham
J. Stallsmith, South Carolina
D. Whysong, Johnstown-Altoona
H. Browne, New Jersey
D. Howard, Johnstown-Altoona
G. Putnam, Green & White Mts.
R. Rummel, Central Texas
C. Schiner, Wyoming
P. Swatland, Niagara Frontier
V. Harton, Northern Plains
J. Hill, Puget Sound
M. McLaughlin, Reading
J. Fitzpatrick, Arizona
R. Madrigal, LA/Inland Empire
A. Mattux, Lexington
G. Moore, San Diego
D. Roskiewich, Philadelphia
J. Smith, Greater Huntsville
J. Grossman, Central Michigan
E. Hinojosa, LA- Inland Empire
R. Jones, Puget Sound
A. Badeaux, Washington
T. Bridigum, Northwest
S. Colton, Arizona
D. Hitchman, San Diego
D. Kearns, Northern Michigan
R. Richwine, Colorado
R. Richwine, Indiana
J. Strickland, Arizona
Actions of the AWS Districts Council

On Nov. 23, 2010, after due consideration, the AWS Districts Council approved:

- Disbanding the Allegheny Section (Dist. 6);
- Changing the name of the Western Michigan Section to West Michigan Section (Dist. 11);
- Student Chapter (SC) charters for the Aiken Technical College SC (Dist. 5); FCAVTS SC (Dist. 7), Parkway West Career and Technology Center SC (Dist. 7); AWS Boilermakers 104 SC (Dist. 19); and University of Alberta SC (Dist. 19);
- Reinstating the Central New Mexico SC (Dist. 20);
- Changing the name of the Kankakee River Valley SC to JAK3 SC (Dist. 13);
- Disbanding the Western Area Career and Technology Center SC (Dist. 7) and Maysville Community and Technical College SC (Dist. 14).

District Director Awards Announced

District 17 Director J. Jones has nominated the following members for the District 17 Director award:

Allie Reynolds — Central Arkansas
William H. Kielhorn — East Texas
Matt Fair — Central Arkansas
O. Paul Morgan — Tulsa
Angela Harrison — Central Arkansas
Bryan Parsons — Central Texas
Virginia Fagan — Ozark
J. Rufner — Tulsa

Dan Lawson — Tulsa
Ed Norman — Ozark
Firdosh Mehta — North Texas
Carr DuPuy — Central Texas
Elton E. Stuckly Jr. — Central Texas

District 18 Director, John Bray, nominated the following members for the District 18 Director award:

Connie Rosbrough — Houston
Joe Scott — Houston
Gale Fisher — Houston

Clay Savoy — Lake Charles
Richard Salinas — Rio Grande Valley
Morris Weeks — Sabine
Steve Sigler — San Antonio
Rachel Marin — San Antonio
J. W. Rails — Corpus Christi

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

North Florida and Tulsa Win Membership Awards

The North Florida Section (Dist. 5) has been awarded the Henry C. Neitzel National Membership Award for the greatest net numerical increase in membership for fiscal year 2009–2010.

The Tulsa Section (Dist. 17) won the Henry C. Neitzel National Membership Award for the greatest net percentage increase for 2009–2010.

The Section in each District that achieved the greatest percentage increase in membership for 2009–2010 is

Dist. Section
1 Montreal
2 Philadelphia
3 Reading
4 Southwest Virginia
5 North Florida
6 Twin Tiers
7 Mid-Ohio Valley
8 Northeast Mississippi
9 Acadiana
10 Drake Well
11 West Michigan
12 Lakeshore
13 Poria
14 Tri-River
15 Saskatoon
16 Mid-Plains
17 Tulsa
18 Corpus Christi
19 British Columbia
20 Idaho/Montana
21 San Fernando Valley
22 Sierra Nevada

AWS Levels of Membership Defined

As an AWS Sustaining Company Member, your company may have up to ten Individual Members ($800 value) listed on its roster at no additional charge. You may add your customers to the roster as a special “thank you.”

Supporting Company Members may have up to five Individual Members (a $400 value) listed under the corporate umbrella.

Welding Distributor Members receive up to five Individual memberships (a $400 value), as well as a listing on the Distributor Locator Map on the AWS Web site. The listing provides a hyperlink that will take visitors directly to your company’s Web page.

Educational Institution Members may have up to three Individual Members (a $240 value) listed on the school’s member roster at no additional charge.

Individual Members included in your company’s corporate membership receive a subscription to the monthly Welding Journal, as well as discounts on AWS publications, certification exams, educational seminars, and conferences.

Order Publications Update

Contact Rhonda Brown, Foster Printing Services, rhondab@fosterprinting.com, for electronic and printed Welding Journal articles in quantities of 100 or more.

Contact Ruben Lara, rlara@aws.org, for copies of Welding Journal articles.

Purchase AWS standards, books and other publications from World Engineering Xchange, orders@awspubs.com; www.awswpubs.com; (888) 935-3464; (305) 824-1177; FAX (305) 826-6195.
Shown at the District 1 conference are (kneeling, from left) Douglas Desrochers and Rejean Roy; (standing, from left) Jim Reid, District 1 Director Tom Ferri, Paul Witteman, Walter Chojnacki, Scott Lee, Dave Paquin, Bob Lavoie, Russ Norris, and Mike Gendron.

Shown at the District 2 conference are (front, from left) Terry Perez, Brian Cassidy, and Harry Ebert; (back, from left) Kenneth Temme, Al Fleury, District 2 Director Ken Stockton, Don Smith, Ray O’Leary, Jim Dolan, Vince Murray, Harland Thompson, and Thomas Gartland.

**District 1**

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

**District 1 Conference**

**JUNE 11, 12**

Activity: The conference activities began with an evening tour of Metso Paper in Biddeford, Maine, followed by a lobster or steak dinner. The conference was held at the Holiday Inn by the Bay in Portland, chaired by Tom Ferri, District 1 director. Attending were Bob Lavoie, Dave Paquin, and Jim Reid (Boston); Mike Gendron, Scott Lee, Russ Norris, and Rejean Roy (Maine); Phil Witteman (Green & White Mountains); Albert Moore (Connecticut); Douglas Desrochers (Central Mass./R.I.); and AWS staff representative Mary Ruth Johnsen, editor, Welding Journal and Inspection Trends.

**District 2**

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

**District 2 Conference**

**JUNE 5**

Activity: Section representatives met in Jackson, N.J., for the annual meeting, conducted by Ken Stockton, District 2 director. Attending were Long Island Section...
Lancaster Section officers are shown at the May 17 board meeting. Shown from left (standing) are Dave Watson, Brian Gross, John Boyer, Russ Ross, Trina Siegrist, and Tim Siegrist; (sitting) are Justin Heistand and Chair Mike Sebergandio.

members Brian Cassidy, Thomas Gartland, Ray O’Leary, and Harland Thompson; New Jersey Section members Jim Dolan, Harry Ebert, Al Fleury, Vince Murray, and Don Smith; and Philadelphia Section member Kenneth Temme. The AWS staff representative was Terry Perez, AWS director, Certification Operations.

NEW JERSEY
May 8
Activity: The Section, under the management of George Sheehan, hosted the 2010 SkillsUSA contest at Somerset County Vocational Technical High School in Bridgewater, N.J.

SkillsUSA contestants are shown working at the New Jersey Section-sponsored event.

District 3
Michael Wiswesser, director
(610) 820-9551
mike@welderinstitute.com

LANCASTER
May 17
Activity: The Section’s executive board met at American Home Bank to plan upcoming events and fund-raising ideas, and nominees for District 3 scholarships. Attending were Chair Mike Sebergandio, Dave Watson, Brian Gross, John Boyer, Russ Ross, Trina Siegrist, Tim Siegrist, and Justin Heistand.

JUNE 4
Activity: The Lancaster Section members conducted a welding careers program including a hands-on demo of an advanced pulse welding machine for students and faculty at Hempfield High School in Landisville, Pa. The speakers included Justin Heistand, David Watson, and Chairman Mike Sebergandio.
Win Great Prizes in the 2010-2011 AWS Member-Get-A-Member Campaign*

ABOUT: AWS is looking for individuals to become part of an exclusive group of AWS Members who get involved and win. Give back to your profession, strengthen AWS and win great limited-edition prizes by participating in the 2010-2011 Member-Get-A-Member Campaign. By recruiting new members to AWS, you’re adding to the resources necessary to expand your benefits as an AWS Member. Year round, you’ll have the opportunity to recruit new members and be eligible to win special contests and prizes. Referrals are our most successful member recruitment tool. Our Members know first-hand how useful AWS Membership is, and with your help, AWS will continue to be the leading organization in the materials joining industry.

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

PRIZE CATEGORIES

President’s Honor Roll: Recruit 1-2 new Individual Members and receive an AWS Sportpack bag.

President’s Club: Recruit 3-8 new Individual Members and receive an AWS hat and an AWS Sportpack bag.

President’s Roundtable: Recruit 9-19 new Individual Members and receive an AWS polo or denim shirt, hat and an AWS Sportpack bag.

President’s Guild: Recruit 20 or more new Individual Members and receive an AWS Messenger Bag, an AWS polo or denim shirt, a one-year free AWS Membership, the "Shelton Ritter Member Proposer Award" Certificate and membership in the Winner’s Circle.

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

SPECIAL PRIZES

Participants will also be eligible to win prizes in specialized categories. Prizes will be awarded at the close of the campaign (June 2011).

Sponsor of the Year: The individual who sponsors the greatest number of new Individual Members during the campaign will receive a plaque, a trip to the 2011 FABTECH Show, and recognition at the AWS Awards Luncheon at the Show.

Student Sponsor Prize: AWS Members who sponsor two or more Student Members will receive an AWS Sportpack bag.

The AWS Member who sponsors the most Student Members will receive a complimentary, one-year AWS Membership, an AWS polo shirt, hat and an AWS Sportpack bag.

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

LUCK OF THE DRAW

For every new member you sponsor, your name is entered into a quarterly drawing. The more new members you sponsor, the greater your chances of winning. Prizes will be awarded in November 2010, as well as in February and June 2011.

Prizes Include:

* Complimentary AWS Membership renewal
* AWS t-shirt
* AWS hat

SUPER SECTION CHALLENGE

The AWS Section in each District that achieves the highest net percentage increase in new Individual Members before the June 2011 deadline will receive special recognition in the Welding Journal.

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

*The 2010-2011 MGM Campaign runs from June 1, 2010 to May 31, 2011. Prizes are awarded at the close of the campaign.
AWS MEMBERSHIP APPLICATION

4 Easy Ways to Join or Renew:

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

Check the appropriate box:
[ ] Mr. [ ] Ms. [ ] Mrs. [ ] Dr. Please print • Duplicate this page as needed

Last Name
First Name
Middle Initial
Title
Date of Birth

Were you ever an AWS Member? [ ] YES [ ] NO
If “YES,” give year and Member #

Primary Phone ( ) Secondary Phone ( )
FAX ( ) E-Mail

Did you learn of the Society through an AWS Member? [ ] YES [ ] NO
If “YES,” Member’s name:
Member’s # (if known):

NOTE: This address will be used for all Society mail.
Company (if applicable)
Address
Address Con’t.

City_ State/Province_ Zip/Postal Code_ Country_ 

PROFILE DATA
Who pays your dues?: [ ] Company [ ] Self-paid
Sex: [ ] Male [ ] Female
Education level: [ ] High school diploma [ ] Associate’s [ ] Bachelor’s [ ] Master’s [ ] Doctoral

PAYMENT INFORMATION (Required)

ONE-YEAR AWS INDIVIDUAL MEMBERSHIP $80
TWO-YEAR AWS INDIVIDUAL MEMBERSHIP $135

New Member? [ ] Yes [ ] No

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

International Members add $50 for optional hard copy of Welding Journal (note: digital delivery of $7 is standard)
(Members add $80 for book selection and $50 for international shipping)
Domestic Members add $25 for book selection (note: $50 is for international shipping)
International Members add $75 for book selection (note: $50 is for international shipping)

TOTAL PAYMENT

AWS STUDENT MEMBERSHIP [ ] Domestic (Canada & Mexico incl.) $15 [ ] International $50

NOTE: Dues include $18.70 for Welding Journal subscription and $4.00 for the AWS Foundation.

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

Check: [ ] American Express [ ] Diners Club [ ] Carte Blanche [ ] MasterCard [ ] Visa [ ] Discover [ ] Other

Your Account Number
Expiration Date (mm/yy)

Signature of Applicant: ______________________

Office Use Only
Check # ____________________________ Account # ____________________________

Source Code WJ
Date
Amount

Two-year Individual Membership Special Offer: applies only to new AWS Individual Members. [ ] Domestic Membership includes $25 for book selection and $50 for international shipping. [ ] Multi-year Discount: applies only to new AWS Individual Members. Select one of the six listed publications for an additional $25. International Members add $75 for book selection and $50 for international shipping. [ ] Multi-year Discount: applies only to new AWS Individual Members. Select one of the six listed publications for an additional $25. International Members add $75 for book selection and $50 for international shipping. [ ] Multi-year Discount: applies only to new AWS Individual Members. Select one of the six listed publications for an additional $25. International Members add $75 for book selection and $50 for international shipping.

BOOK/CD-ROM SELECTION
(Pay Only $25... up to a $192 value)

NOTE: Only New Individual Members are eligible for this selection. Be sure to add $25 to your total payment.

[ ] Jefferson’s Welding Encyclopedia (CD-ROM only)
[ ] Design and Planning Manual for Cost-Effective Welding
[ ] Welding Metallurgy
[ ] Welding Handbook (9th Ed., Vol. 3)
[ ] Welding Handbook (9th Ed., Vol. 2)
[ ] Welding Handbook (9th Ed., Vol. 1)

For more book choices visit www.aws.org/membership

New Member [ ] Renewal

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

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

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

Technical Interests (Check all that apply):
A [ ] Ferrous metals
B [ ] Aluminum
C [ ] Nonferrous metals except aluminum
D [ ] Advanced materials/Intermetallics
E [ ] Ceramics
F [ ] High energy beam processes
G [ ] Arc welding
H [ ] Brazing and soldering
J [ ] Resistance welding
K [ ] Thermal spray
L [ ] Cutting
M [ ] NDT
N [ ] Safety and health
O [ ] Bending and shearing
P [ ] Roll forming
Q [ ] Stamping and punching
R [ ] Aerospace
S [ ] Automotive
T [ ] Machinery
U [ ] Marine
V [ ] Piping and tubing
W [ ] Pressure vessels and tanks
X [ ] Sheet metal
Y [ ] Structures
Z [ ] Other

Automation
Robotics
Computerization of Welding
Delegates to the District 5 conference are shown in Columbia, S.C.

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**District 5**  
Steve Mattson, director  
(904) 260-6040  
steve.mattson@yahoo.com

**District Conference**  
JUNE 5  
Activity: The Columbia Section hosted the District 5 conference in Columbia, S.C. Director Steve Mattson chaired the meeting.

**NORTH CENTRAL FLORIDA**  
MAY 11  
Activity: The Section hosted a welding contest at Community Technical Adult Education in Ocala, Fla. Fifteen welders competed. Top prizes went to Dallas Maynard and Erica Smith, professional and student class, respectively. Incoming officers were elected: Curtis Warren, chairman; Jennifer Skyles and Chris Owen, vice chairs; Bill Myers, secretary; Bill Seyfarth, treasurer; and members-at-large, J. T. Mahoney, Michael Bannester, Greg Hofmann, and Mark Geiger, past chairman.

**District 6**  
Kenneth Phy, director  
(315) 218-5297  
KAPhylnic@gmail.com

**ROCHESTER**  
JUNE 10  
Activity: Chair Ron Allen presented Johnathan Gustavson a $2000 District scholar-ship and a $1000 Section scholarship to pursue his welding education. The presentation was made in Lima, N.Y. Attending were Johnathan’s parents Kim and John.

**District 7**  
Don Howard, director  
(814) 269-2895  
howard@ctc.com

**COLUMBUS**  
JUNE 10  
Activity: The Section hosted its annual golf outing and social event at The Players Club at Foxfire. Eight teams participated in a scramble with a shotgun start. Phil Weisenbach was the winning team captain.

Shown, from left, are Rochester Section Chair Ron Allen, scholarship awardee Johnathan Gustavson, and his parents, Kim and John Gustavson.

Shown at the Columbus Section golf outing are Phil Weisenbach (left) and Bryan H. Lyons, Section chairman.
Shown are the delegates attending the District 8 conference.

Birmingham Section members and guests are shown during their tour in May.

Shown at the Birmingham Section program are (from left) Roy Ledford, District 8 Director George Fairbanks, and Jim Cooley.

District 8
Joe Livesay, director
(931) 484-7502, ext. 143
joe.livesay@ttcc.edu

District 8 Conference
JUNE 10, 11
Activity: Participating were District 8 Director Joe Livesay, Conrad Young, Steve Latham, Joe Smith, Chuck Robertson, Denny Cole, Josh Burgess, George Smith, Gary Gammill, Sam Gray, Robbin Shull, Ervin Perrigan, Jim Thompson, Rayburn Johnson, Ed Monroe, Tavares Irons, Rodney Patterson, Floyd Patterson, Joe Smith, David Carwile, Tim Parker, Craig Johnson, Kevin Reed, Danny Coggins, and Linda Henderson, AWS staff representative. The event was held in Starkville, Miss.

BIRMINGHAM
May 11
Activity: The Section members, students, and guests toured the Gardendale High School welding department facilities in Gardendale, Ala. Welding instructor Tim Turner conducted the tour and discussed the welding curriculum. District 8 Director George Fairbanks presented Roy Ledford the Section Educator Award and the Section Meritorious Award to Jim Cooley.

CHATTANOOGA
May 21
Activity: The Section hosted its annual fish fry and scholarship fund-raising event at Camp Columbus in Chattanooga, Tenn., for 244 attendees.

NORTHEAST MISSISSIPPI
May 21
Activity: The Section hosted its installation of officers at Richey’s Steak House in Starkville, Miss. Outgoing Section Chairman Sam Gray introduced Ervin Perrigan as the incoming chair.

District 9
George D. Fairbanks Jr., director
(225) 473-6362
fits@bellsouth.net
Shown at the Mobile Section program are (front, from left) Chair Teresa Hart, Kenneth Monie, Patrick Garrison, Devona Marshman, and Scott Cargine; (back row, from left) Jerry Betts, Will Overacre, Ryan Bronckowski, Charles Bondurant, and Nathaniel Phillips.

Donnie LeSage discussed safety inspection codes at the Baton Rouge Section program.

Janna Walsh receives a speaker plaque from Jerry Betts, Mobile Section scholarship chair.

**BATON ROUGE**

**March 25**  
**Speaker:** Donnie LeSage  
**Affiliation:** Louisiana Fire Marshal’s Office, Boiler division  
**Topic:** State inspection requirements for boilers, rides, fireworks, etc.  
**Activity:** The program, held at PAX, Inc., included a tour of the facility, conducted by Markkevin Spencer.

**MOBILE**

**May 13**  
**Speaker:** Janna (Boevink) Walsh  
**Topic:** How an AWS scholarship helped her to achieve her welding profession goal  
**Activity:** Jerry Betts, scholarship chair, presented Section scholarships to Kenneth Monie, Patrick Garrison, Devona Marshman, and Scott Cargine. Forty-four people attended this election of officers program held at Saucy Q. Barbecue in Mobile, Ala.

Chattanooga Section members and guests enjoy the fish-fry at Camp Columbus in May.

Shown at the NE Mississippi Section program are (from left) Treasurer Gary Gammill, Chair Sam Gray, Vice Chair George Smith, and Ervin Perrigan, incoming chairman.

The Baton Rouge Section members toured PAX, Inc., in March.
Milwaukee Section scholarship awardees are (from left) Jeffrey Wollin, Nathan Guida, Nicholas McDonald, Benjamin Matthews, Deven Johnson, Matthew Schneider, Melissa Emerson-Froebe, and Karl Johnson.

The Racine-Kenosha Section members and students are shown at the March program held at Gateway Technical College.

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richaharris@windstream.net

District 10
District 11
Effthios Siradakis, director
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ft.siradakis@airgas.com

NORTHWEST OHIO
May 27
Activity: The Section hosted its annual Old Timer’s and awards-presentation program at Tony Packo’s in Toledo, Ohio. Silver Membership Certificates were presented to Timothy J. Bergan, Donald G. Earls, Norm D. Zelter, and Richard A. West for 25 years of service to the Society.

District 12
Sean P. Moran, director
(920) 954-3828
sean.moran@hobartbrothers.com

MADISON-BELOIT
May 19
Speaker: Damian Kotecki, consultant
Topic: How to weld stainless steel
Activity: The program was held at Cardinal Ale House in Columbus, Wis.

Dr. Kotecki discussed welding stainless steel at the Madison-Beloit Section program.
Shown are the delegates to the District 13 conference held June 5 in Utica, Ill.

Shown at the Peoria Section program are (from left) Curt Rippey, Chair Kerwin Brown, and Shane Seals.

Karl Johnson. Karen Gilgenbach received a past chairman’s appreciation award.

RACINE-KENOSHA
March 29
Speaker: Steven Jackson, sales manager
Affiliation: ESAB Welding & Cutting
Topic: Welding and hardfacing products
Activity: The program was held at Gateway Technical College in Elkhorn, Wis.

Shown at the Milwaukee Section program are (from left) Sue Silverstein, Karen Gilgenbach, and Anni Quackenbush.


CHICAGO
May 19
Activity: The Section’s board met at Papa Passero’s Family Pizzeria in Westmont, Ill. Attending were Cliff and Anghelina Iftimie, Hank Sima, Eric Krauss, Pete Host, Chuck Hubbard, Peter Harris, Craig Tichelar, and Vicky Landorf.

PEORIA
May 7
Activity: The Section held a steak fry and awards-presentation outing at Morton Optimists Club in Morton, Ill., for 30 members and guests. Welding instructors Curt Rippey and Shane Seals received Section Educator Award certificates. District 13 Director Rick Polanin attended the event.

MILWAUKEE
May 20
Activity: The Section toured Radyne Corp. in Milwaukee, Wis. Brian Gramoll, manager, district sales, made a presentation on brazing, heat treating, curing of composite materials, and chemical vapor deposition techniques. Section scholarships were presented to Jeffrey Wollin, Nathan Guida, Nicholas McDonald, Benjamin Matthews, Deven Johnson, Matthew Schneider, Melissa Emerson-Froehle, and Karl Johnson. Karen Gilgenbach received a past chairman’s appreciation award.

District 13
W. Richard Polanin, director
(309) 694-5404
rpolanin@icc.edu

District 13 Conference
June 5
Activity: Attending the meeting were Rich Polanin, District 13 director, B. and J. Piotrowski, P. Leadingham, M. Merriman, J. Biarro, J. Greer, C. Hubbard, P. Host, E. Krauss, J. Joos, P. England, C. Rippey, and
Shown at the Kansas Section program are (from left) Bob Simon, Marc Childs, Lisa Rogers, Chair Diane Steadham, and Royce Altendorf, vice chair.

Shown at the St. Louis Section program are George Clemens (left) and Bob Anderson.

Enjoying the races are Indiana Section members (from left) Davy Jackson, Guy Blanchard, and Eric Cooper.

Jason Kaiser (left), British Columbia Section vice chair, is shown with speaker Bill Coughlin at the May 26 program.

Gary Hinkle (left) chats with Rick Polanin, District 13 director, at the Peoria Section outing.

District 14
Tully C. Parker, director
(618) 667-7795
tullyparkert@charter.net

INDIANA
May 21
Activity: The Lincoln Electric Co. hosted a day at the races for the Section members at Indianapolis Motor Speedway in Quincy, Ill. Included was a tour of the Indiana Oxygen Welding Garage, Gasoline Alley, the NDE lab, and the pit areas.

ST. LOUIS
May 8
Activity: The Section celebrated its past chairmen by sponsoring a horse race at Fairmont Park.

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macevh@aol.com

District 16
David Landon, director
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KANSAS
JUNE 17
Activity: The Section held its election of officers and committee leaders at Airgas Mid South in Wichita, Kan.

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jjones@thermadyne.com

District 18
John Bray, director
(281) 997-7273
sales@affiliatedmachinery.com

District 19
Nell Shannon, director
(503) 419-4546
nellshnn@msn.com

BRITISH COLUMBIA
May 26
Speaker: Bill Coughlin
Topic: Social networking techniques
Activity: The program was held at Ricky’s All Day Grill in Surrey, B.C., for 25 members and guests.
Delegates to the District 21 conference are shown June 5 in San Diego, Calif.

OLYMPIC
MAY 25
Activity: The Section hosted an outing at North Shore Golf Course in Federal Way, Wash. Chairman Rob Rothbauer received a certificate in appreciation for his services as chairman. Rothbauer then presented scholarships to Darin Hliboki and Carlson Potts.

SPOKANE
MAY 21
Activity: The Section held its election of officers program at Cathay Inn Restaurant in Spokane, Wash. Phil Zammit reported on the District 19 conference held in Anchorage, Alaska. The Section presented two students $531 each to enhance the scholarships they received from the AWS Foundation.

District 20
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bkoz@arctechllc.com

District 21
Nanette Samanich, director
(702) 429-5017
Nan07@aol.com

District 21 Conference
JUNE 5
Activity: The meeting, hosted by the San Diego Section, was chaired by Nanette Samanich, District 21 director. Attending were Gene Lawson, an AWS past president; Dean Wilson, nominated for AWS vice president; and AWS staff representative Wendy Sue Reeve. The meeting was held at the Holiday Inn Express Old Town in San Diego, Calif.
Mark McDowell displays his Silver Membership Certificate at the Sacramento Valley Section meeting.

George Rolla presented pipe welding techniques at the L.A.-Inland Empire Section program in April.

Sacramento Valley officers are shown at the May 19 meeting.

L.A.-INLAND EMPIRE

APRIL 29
Activity: Section Vice Chair George Rolla, president of Advanced Weldtec, Inc., Murrieta, Calif., conducted a demonstration and hands-on pipe welding presentation at Wilmington Skills Center in Los Angeles, Calif. Later, Ed Hinojosa, education chairman, led the group on a tour of the Wilmington Skills Center Laboratory, the official welder testing center for the city of Los Angeles.

SACRAMENTO VALLEY

MAY 19
Activity: The Section members met at the Lincoln Electric Co. facility in El Dorado Hills, Calif., for demonstrations of the latest welding equipment led by Mark Ehrlich and Walt Aviko. Chad Koens of The Harris Group discussed efficient cutting practices to save gas. Mark McDowell received the Silver Membership Award for 25 years of service to the Society. The incoming officers were introduced: Ken Morris, chairman; David Kilburn, vice chair; Bruce Tanner, secretary; Melvin Johnson, treasurer; Jerry Wentland, program chair; Jason Roberts, newsletter editor; Edward Kroon, SENSE chair; and Mark Reese, certificate chair. Dale Flood, District 22 director, attended the meeting.

District 22
Dale Flood, director
(916) 288-6100, ext. 172
flashflood@email.com
Guide to AWS Services

550 NW LeJeune Rd., Miami, FL 33126; (800/305) 443-9353; FAX (305) 443-7559; www.aws.org

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

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

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Welding in Sanitary Applications, High-Energy Beam Welding, Friction Welding, Rail Road Welding, Thermal Spray

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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Solutions Opportunity Squad (SOS)
Corporate Director
Monica Pfarr, ext. 461, mpfarr@aws.org

General Information
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The World of Energy – Welding’s Greatest Challenge

August 31 - September 1, 2010
San Diego, CA

Much of our welding future depends on the ability of the industry to adapt and promote its technologies to new energy industries.

Examine the many avenues of energy including the important aspects of coal-powered plants, the present and future of nuclear power, activities in pipeline construction, land-based and offshore work in liquefied natural gas, solar energy, wind power and much more…
The National Science Foundation's New Center for Integrative Materials Joining
Sudarsanam (Suresh) Babu – NSF Center for Integrative Materials Joining Science for Energy Applications - Columbus, OH

- Westinghouse’s Position in the Nuclear Renaissance
  Lance S. Harbison – Westinghouse Electric Company, Energy Center - Pittsburgh, PA

- Advances in Submerged Arc Welding of Wind Towers
  Teresa Meltf - Lincoln Electric Co. - Cleveland, OH

- Capabilities in Offshore Welding at Kiewit Offshore Services
  Richard Marslender - Kiewit Offshore Services, Ltd. - Ingleside, TX

- The Use of a Tempering Parameter for the Control of PWHT of Grade P91 and Other CESF Steels
  Jeff Henry - Structural Integrity Associates - Chattanooga, TN

- Using the Latest Technology for Heating and Welding Chrome-Moly Pipe
  James A. Byrne - Miller Electric Manufacturing Co. - Appleton, WI

- Welding Challenges of Liquefied Natural Gas Facilities
  Ben Pletcher - Chicago Bridge & Iron Co. - Plainfield, IL

- Narrow Groove Tandem GMAW and HLAW for Wind Tower and Nuclear Fabrication
  Ian Harris - Edison Welding Institute - Columbus, OH

- EV Batteries & Weld Process Variation
  Benjamin Christian and Daniel Hutchinson - General Motors LLC - Warren, MI

- Advancements in Pipeline Field Construction Welding
  Kevin A. Beardsley - Lincoln Electric Company - Cleveland, OH

- Explosion Welding and Its Application in Downstream Oil Refineries
  Michael Blakely - Dynamic Materials Corporation - Sugar Land, TX

- Duplex Stainless Steels and Nickel-Based Alloys: An Overview
  Cheryl Botti - ATI Allegheny Ludlum - Brackenridge, PA

- Laser-Based Additive Processes for Energy – Related Applications
  Todd Palmer - Pennsylvania State University - State College, PA

- Energy Applications for Advanced Joining Processes
  Ed Hansen - ESAB Welding & Cutting Products - Florence, SC

- The Nuclear Scene
  Nate Ames - Edison Welding Institute - Columbus, OH

- Dissimilar Metal Welding
  Donald J. Tillack - Tillack Metallurgical Consultants Inc. - Catlettsburg, KY

For more information on attending or exhibiting at the conference, please visit www.aws.org/conferences or call 800-443-9353 ext. 462
An 11-page, well-illustrated, technical data brochure details the Fluke 345 Power Quality Clamp Meter capable of sampling volts and amps at high frequency and integrating these data to display power readings. It is useful for many applications, including measuring switching loads and monitoring switching energy on older model pulsing welding power supplies. Its data-logging feature can identify intermittent faults by logging any power parameter for minutes or months, including harmonics. It also analyzes and logs harmonics digitally or graphically on the built-in bright color display screen. Nuisance inrush currents causing tripping can be monitored from 3 to 300 s. The meter is rated at 1400 A AC, and the Hall Effect system permits measuring DC currents to 2000 A without the need to break the circuit. Specifications and illustrations are presented for data-logging, analyzing, and logging harmonics graphically and digitally, with three-phase capacity for balanced loads.

Fluke Corp.
www.fluke.com
(800) 443-5853

New Cutting and Positioning Equipment Catalog Released

A 60-page, full-color, well-illustrated catalog details the company's broad line of cutting and positioning equipment for the metalworking industry. Included are photos, descriptions, and the latest technical specifications for thermal cutting machines, positioners, Ransome welding equipment, portables, and gas apparatus. The company's extensive customer support programs are also detailed. View and download the catalog from the Web site, or call for a free copy.

Koike Aronson, Inc.
www.koike.com
(800) 252-5232

Water Jet Intensifier Pumps Pictured in Brochure

A four-page, full-color brochure illustrates and details the company's precision water jet intensifier pumps rated at 30 to 200 hp, pressures from 60,000 to 90,000 lb/in.², and flow rates from 0.65 to 4 gal/min. A full-page chart compares eight models for numerous physical, power, and performance characteristics. Photos display the tie-rod design, on-board water filtration system, hydraulic accumulators, maintenance access panels, and the Wye-Delta motor starter. A schematic diagram details the numerous parts of the waterjet system and compares the intensifier system vs. direct-drive pumps. Detailed are the tie-rod design features for longer life, and matched-metal components to prevent galling of hydraulic components.

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

Revised Laser Safety Standard Issued

Just released, the 126-page ANSI Z136.4 (2010), Recommended Practice for Laser Safety Measurements for Hazard Evaluation, provides guidance for optical measurements associated with laser safety requirements to assist those responsible for conducting laser hazard evaluations and ensure that appropriate control measures are implemented. Included are clearly written definitions, examples, and other practical information for manufacturers, laser safety officers, technicians, and other trained laser users. Changes include the addition of many new terms and definitions as well as revised definitions from the 2005 standard. Significant revisions can also be seen in updated figures, tables, and charts as well as revised and new sections throughout the standard. Available in paperback or searchable electronic versions, the price is $172 list, $152 for institute members. This document is intended to be used with ANSI Z136.1 — 2007, Safe Use of Lasers.

Laser Institute of America
www.laserinstitute.org
(800) 345-2737

Premium Electrodes Detailed in Catalog

The expanded 96-page full-line catalog provides detailed information on more than 165 electrodes, including flux cored, metal cored, carbon steel, low-alloy steel, stainless steel, nickel alloys, and hardfacing products. Presented are electrode descriptions, classifications, shielding gases, welding positions, characteristics, typical mechanical properties, typical deposit compositions, and applications. The enhanced table of contents makes it easier to find the category of wire needed for
A new brochure highlights filler metal products for the power-generation industry, including welding creep-resistant filler metals to meet industry specifications for hydrogen, X-Factor, and chemical analysis, marketed under the Atom Arc, Arcaloy, and Dual Shield brand names. The products are widely used in the construction of hydrocarbon power-generation facilities, especially for heat exchangers, header systems, and associated piping to provide improved strength at elevated temperatures through the additions of chromium, molybdenum, and certain alloys. The filler metals are intended for welding grades of creep-resistant steel including P11, P22, P5, and P91.

ESAB Welding and Cutting Products
www.esabna.com
(800) 372-2123

Specialty Abrasive Products Pictured

The sixth edition of Fundamentals of Tool Design is a fully illustrated text covering general tool design, materials used for tooling, cutting tool design, work holding concepts, jig and fixture design, power presses, die design and operation, inspection and gauge design, tool design for joining processes, modular and automated tool handling, computer applications in tool design, and geometric dimensioning and tolerancing. Updates include an instructor’s guide with answers to the review questions, expanded broaching examples and concepts, revised tool materials and, mechanical definitions and reference tables, new appendices and reference charts, and more review questions. Available as a hard-cover, 464-page book or on nine DVDs. Price is $110 list, $90 to society members.

Fischer Technology, Inc.
www.helmut-fischer.com
(860) 683-0781

Coating Thickness Gauges Pictured in Brochure

An eight-page brochure details the features of the company’s line of portable instruments for making precise nondestructive measurement of coatings thicknesses using magnetic induction and/or the eddy current methods. The Deltascope® magnetic induction models measure nonferromagnetic metal coatings, e.g., chrome, copper, zinc, paint, lacquer, enamel, or plastic coatings on steel and iron. The Iso- scope® eddy current models measure paint, lacquer or plastic coatings as well as anodic coatings applied to nonferromagnetic metal substrates. The Dualscope® models utilize both eddy current and magnetic induction methods. Also displayed are the Fischerscope® X-ray XDAL® machine for thickness measurements using the X-ray fluorescence method, and the Fischerscope® MMS® PC universal measurement system using magnetic, magnetic induction, eddy current, and beta backscatter methods for general coating thickness measurements.

Fischer Technology, Inc.
www.helmut-fischer.com
(860) 683-0781
SuperFlash Fills Three Key Posts

SuperFlash Compressed Gas Equipment, IBEDA, Inc., Westlake, Ohio, has elected Victoria E. Marquard-Schultz as general counsel and regulatory compliance director. Jon Schultz was appointed assistant sales manager for national accounts, and Jeff Smallheer was named lead design and product engineer for the development of new compressed gas and safety products. Marquard-Schultz has years of experience in the compressed gas industry with work at the federal and state government levels. Schultz will manage several new product groups including custom heating solutions, thermal spray, and compressed gas manifolds and gas management. Smallheer previously worked for Western Enterprises for five years where he was involved with compressed gas equipment projects.

LIA Announces Awards

The Laser Institute of America (LIA), Orlando, Fla., will present Steven Chu and Charles Townes prestigious awards at its International Congress on Applications of Lasers and Electro-Optics (ICALEO®) to be held Sept. 26–30 in Anaheim, Calif. U.S. Secretary of Energy Chu will receive the Arthur L. Schawlow Award. Dr. Townes won the Nobel Prize in Physics in 1994 for “fundamental work in the field of quantum electronics, which has led to the construction of oscillators and amplifiers based on the maser-laser principle.”

AMT Names Automotive General Manager

Jeff Smallheer

SuperFlash Compressed Gas Equipment, IBEDA, Inc., Westlake, Ohio, has elected Victoria E. Marquard-Schultz as general counsel and regulatory compliance director. Jon Schultz was appointed assistant sales manager for national accounts, and Jeff Smallheer was named lead design and product engineer for the development of new compressed gas and safety products. Marquard-Schultz has years of experience in the compressed gas industry with work at the federal and state government levels. Schultz will manage several new product groups including custom heating solutions, thermal spray, and compressed gas manifolds and gas management. Smallheer previously worked for Western Enterprises for five years where he was involved with compressed gas equipment projects.

NanoSteel® Hires Sales VP

The NanoSteel© Co., Providence, R.I., a supplier of patented thermal spray coatings and hardfacings for wear plate applications, has named Ken Grieshaber vice president, sales and business development. Prior to joining the company, Grieshaber led sales and marketing activities at H2Gen Innovations, Inc.

Sales Director Tapped at Carell and Eagle Bending

Eagle Bending Machines and Carell Corp., Stapleton, Ala., has promoted Jeremiah Weekley to director of sales. Previously, Weekley worked six years in various positions in the company's sales, service, and parts departments.

Genesis Plastics Welding Appoints President, CEO

Genesis Plastics Welding, Fortville, Ind., a manufacturer of radio-frequency welded thermoplastic products, has promoted Tom Ryder to president and CEO. Ryder, with the company for 20 years, most recently served as COO and vice president of sales and marketing.

Thermadyne Appoints VP of Engineering

George Dunning

Thermadyne Industries, Inc., St. Louis, Mo., a manufacturer of metal cutting and welding products, has appointed George Dunning vice president of engineering, based at the company's office in Denton, Tex. Most recently, Dunning served as vice president of engineering and quality for the Overhead Door Corp. located in Lewisville, Tex.

Controlled Automation Names Representative

Controlled Automation, Bauxite, Ark., a supplier of automated fabricating machinery, has named Jeff Davis its sales representative for South America. Davis is based at the company's Medellin, Colombia, office.

TWI Names Chief Executive

TWI Ltd., Great Abington, Cambridge, UK, has named Christoph Wiesner chief executive, effective July 1. He
succeeded Bob John who held the post for six years. Wiesner, with the company since 1991, most recently served as TWI research and technology director.

Aluminum Assn. Fills Three Key Posts

The Aluminum Association, Arlington, Va., has promoted Karen Bowden to vice president of administration and corporate treasurer. Previously, Bowden served as director of administration and treasurer. Parvaneh Shafiee has been promoted to director, alloys and product standards. Shafiee previously served as manager, alloy and product standards registration. The board of directors has announced that Kevin Kramer has agreed to serve as chairman of the Membership Development Committee tasked with recruiting new companies into the association. Kramer is president, Alcoa Growth Initiatives, and a member of the Board’s Executive Committee.

Obituaries

Arthur W. Schueler

Arthur W. Schueler, an AWS Life Member, died June 13 in Three Rivers, Mich. Schueler, born in South Bend, Ind., in 1942, graduated first from Mercerburg Academy in Mercersburg, Pa., followed by Miami University in Oxford, Ohio. He built his father’s business, Mittler Supply, Inc., from a small mom and pop operation into one of the largest independently owned gas and welding supply chains in the country. Schueler’s passion was collecting, restoring, and racing vintage automobiles and wooden speed lake boats. Mittler is survived by his wife, Charlotte, two sons, a daughter, and six grandchildren.

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Essentials of Safety Seminars. Two- and four-day courses are held at numerous locations nationwide to address federal and California OSHA safety regulations. Call American Safety Training, Inc. (800) 896-8867, or visit www.trainoshia.com.


Firefighter Hazard Awareness Online Course. A self-paced, ten-module certificate course taught online by fire service professionals. Fee is $195. Call Industrial Scientific Corp. (800) 338-3287, or visit www.indsci.com.

Gas Detection Made Easy Courses. Online and classroom courses for managing a gas monitoring program from gas detection to confined-space safety. Call Industrial Scientific Corp. (800) 338-3287, or visit www.indsci.com.

Hollier NDT Courses. Hollier, 277 W. Main St., Ste. 2, Niantic, CT 06357; (860) 739-8950; FAX (860) 739-6732.

Inpection Courses on ultrasonic, eddy current, radiography, dye penetrant, magnetic particle, and visual at Levels 1-3. Meet SNT-TC-1A and NAS-410 requirements. Call TEST NDT, LLC, (714) 255-1500, or visit www.testndt.com.


Laser Safety Training Courses. Courses based on ANSI Z136.1, Safe Use of Lasers, presented in Orlando, Fla., or at customer’s site. Call Laser Institute of America, (800) 345-3737, or visit www.laserinstitute.org.

NEW PRODUCTS
— continued from page 22

Hardfacing Covered Electrode Line Is Launched

SHS 9700E, the company’s first covered electrode, is offered for hardfacing applications. An addition to its patented portfolio of Super Hard Steel® (SHS) alloys, the product is a premium alloy featuring an ultrarefined, near-nanoscale crystalline microstructure that results in high hardness, up to 70 HRc, and good resistance to abrasive wear. It comes in 10- and 50-lb boxes and in bulk.

The NanoSteel® Co., Inc.  
www.nanosteelco.com  
(877) 293-6266

Torch Height Control Reduces Cut-to-Cut Cycles

The ArcGlide® THC torch height control offers optimized consumable life and the ability to nearly double the number of parts cut per hour. It’s engineered to continuously sample and automatically adjust the arc voltage, ensuring the torch is the right distance from the plate. Productivity advances are achieved through a reduction in cut-to-cut cycle time. The prepared part program and product work together to minimize unnecessary motion between cuts, while proprietary Rapid Ignition™ technology allows the torch to fire as soon as it’s in position. Color coded and keyed cables connect the torch height control to the lifter, plasma power supply, and CNC; a simple user interface and large controls ensure no operator confusion. Also, engineers added an outer shell and enclosed the slide mechanics with two layers of armored protection, plus added a pierce guard to keep molten metal from splattering back onto the control.

Hypertherm  
www.hypertherm.com  
(800) 643-0030

Monitor Offers Increased Oxygen Detection Accuracy

The OX™-100X, an improved OX™-100 oxygen monitor, accurately measures oxygen concentration with 0.01% (100 ppm) resolution and automatically calibrates the ambient oxygen level. Monitoring this level with the product adds an element of quality control to the welding process. Using the monitor also allows the welder to check the purge gas flow rate and purge period. Its improved design provides simple one-touch operation. With quick automatic calibration, welders save time by eliminating manual calibration, expediting the monitoring process.

Aquasol Corp.  
www.aquasolcorporation.com  
(800) 564-9353

Scissor Lift Handles 2000-lb Capacity

The DXL Series of compact scissor lifts offer a full 2000-lb of lifting capacity. They are ideal for a variety of work-positioning, assembly, repair, and inspection applications in factories, warehouses, and repair shops. A double-scissor mechanism allows for a low 6-in. collapsed height while providing a 42-in. raised height. A foot switch operates a 1/2-hp motor that runs on 115-V, single-phase power. The unit comes equipped with an 18- x 30-in. platform as standard, and other platforms are available. Options and accessories that can be furnished with these lifts include casters, push button controls, special platforms, bellows guards, and limit switches.

Presto Lifts, Inc.  
www.prestolifts.com  
(800) 343-9322

Robotic Arc Welding System Eliminates Welding Defects

Power-Trac™ is an intelligent seam tracking system for robotic arc welding. It increases travel speed, eliminates defects, and reduces over welding. Typical applications include earth-moving equipment, automotive components, military vehicles, as well as tanks and vessels. A large joint library allows almost any weld seam on any material to be tracked and measured geometrically. The compact, all digital system makes integration to any robot fast and easy. Nearly no maintenance is required due to the rugged, welding specific design. The above image shows the product’s laser-vision system including a video camera for monitoring.

Servo-Robot Inc.  
www.servorobot.com  
(450) 653-7868
NEWS OF THE INDUSTRY

— continued from page 13

rocks, ‘lava’ ridges, inclines, and ‘lunar’ soil,” according to the official Moonbuggy Web site at http://moonbuggy.msfc.nasa.gov/

“Without ITW’s support, this project would have never come to fruition, and the team would not have succeeded as well as we did,” said OSU team leader Brian Hanhold. The college finished fourth place in its division (out of 35 teams) and also had the third fastest raw run time, both personal bests for the team now in its third year of competition.

The funds enabled the team to purchase raw materials and contract with outside fabricators to have certain components laser cut, plus allow more allow team members to travel to Alabama for the competition. Even with the extra funding, the team maintained its creativity using bicycle drive train components the school makes available from a program that collects bikes illegally parked or abandoned.

“The biggest construction challenge was to control the flow of component construction while maximizing individual productivity,” said Hanhold. “We learned how to work with local machine shops to contract their services and to coordinate timely delivery of components. As future engineers, this project not only challenges us to design and build a robust buggy, but to manage the open flow of information among 20 total team members. It offers a lot of real life lessons.”

Manufacturing Renaissance Council Formed in the San Francisco Bay Area

After appreciating the work done by the Chicago Manufacturing Renaissance Council, the following leaders agreed they should apply it to the San Francisco Bay Area: Executive Director Steve Mandes and Deputy Director Jim Wall of the National Institute of Metalworking Skills; Mike Egan, assistant to the executive director of the California Teachers Association; and Emily DeRocco, president of the National Association of Manufacturers Manufacturing Institute. They recently established a Manufacturing Renaissance Council in the Bay Area by coming together with the Center for Labor and Community Research, the California Manufacturing and Technology Association, the California Space Authority, and the California AFL-CIO.

Stainless Steel Welding Rod Donated to Illinois Valley Community College

Exelon Nuclear’s LaSalle County Generating Station, Mareilles, Ill., recently donated more than 1100 lb of stainless steel welding rod to Illinois Valley Community College’s welding technology program. LaSalle Station, which stocks large quantities of welding material at the site for various work activities, changed the type of weld rod material that it uses. The cost of this donated material is valued at approximately $25,000.

“Our welding department will use the material to teach stainless steel welding to the more than 100 students in our program,” said Paul Leadingham, the college’s welding program coordinator. “We appreciate Exelon’s generous donation because the material comes at a great savings to our school.”

Industry Notes

• Wipro Infrastructure Engineering signed an agreement with Wujin Hi-Tech Industrial Zone. Changzhou, China, to set up a facility for manufacturing hydraulic cylinders.

• Andy J. Egan Co., an AWS Distributor Company Member, has been named one of West Michigan’s 101 Best and Brightest Companies to Work For by the Michigan Business and Professionals Association. It received the award in communications.

• Makino’s facility in Mason, Ohio, has been designated Makino’s Global Titanium Research and Development Center where a specialized group of engineers will further the development of titanium milling technologies.

• The Professional Development Center of Glendale Community College partnered with Haas Technical Automation and joined Haas Technical Education Center to expand the center’s CNC training programs for California manufacturers.

• Hypertherm, Hanover, N.H., established the HOPE (Hypertherm Owners’ Philanthropic Endeavors) Foundation to partner with nonprofit organizations and engage in activities that strengthen and create sustainable, positive change in the community and environment.

• Richmond Community College, Hamlet, N.C., is expanding its welding certificate program to include a diploma option this fall. Chris Cesaro, an American Welding Society Certified Associate Welding Inspector, is the instructor.

• The 2010 Metalcasters Alliance for Government Affairs Conference recently held in Washington, D.C., attracted more than 125 attendees and emphasized the need for policies encouraging economic growth and improving manufacturing’s competitiveness.

• The Harris Products Group, Mason, Ohio, made donations of $10,000 each to Abilities First, Middletown, Ohio, and Challenged Child and Friends, Inc., Gainesville, Ga., to assist children and adults with disabilities.

• RathGibson, Lincolnshire, Ill., emerged from bankruptcy and transitioned ownership to an investment group led by Wayzata Investment Partners. Its name has changed to RathGibson LLC.

• Adept Technology, Inc., Pleasanton, Calif., entered an agreement to acquire privately held MobileRobots, Inc., Amherst, N.H.

• Airgas, Inc., donated nearly 200 welding helmets to the I-CAR Education Foundation. They will be distributed this fall to schools around the country with automotive collision repair programs.

• Linde Canada’s specialty gases plant in Edmonton, Alb., is celebrating its 35th anniversary. Since opening, the plant has quadrupled in size. The facility fills about 15,000 cylinders per year.

• G & L Manufacturing, Cookeville, Tenn., acquired Scientific Tube, Elgin, Ill., a manufacturer of gas tungsten arc welded stainless steel, nickel alloy, and titanium tubing.

• Camfil Farr Air Pollution Control has opened regional sales and service offices in Los Angeles, Calif.; Lincoln, Neb.; Charlotte, N.C.; Dayton, Ohio; and Dallas, Tex.

• Eagle Bending Machines, Stapleton, Ala., launched a Certified Pre-Owned Eagle division to provide factory reconditioned and certified company machines.

• The Laser Institute of America’s second annual Laser Additive Manufacturing Workshop in Houston, Tex., drew 137 attendees from 11 countries, as well as 22 vendors.

• R & B Wagner, Inc., Milwaukee, Wis., has been named one of the Milwaukee Journal Sentinel’s Top 100 Workplaces in southeastern Wisconsin for 2010. It ranked fifth out of 35 midsize companies and received a special award for career opportunities.
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Evaluation of Amplitude Stepping in Ultrasonic Welding

Amplitude stepping is investigated as a means of increasing strength and preventing tool/part adhesion and part marking

BY M. BABOI AND D. GREWELL

ABSTRACT

Ultrasonic metal welding has many advantages including speed, weld quality, consistency, and efficiency. Further improvements to this can come from enhancing weld strength and weld strength consistency and reducing tool/part adhesion by varying the weld amplitude during the process. A series of experiments was conducted using stepped amplitude and a constant amplitude for comparing corresponding weld strengths and weld quality. It was found that the use of amplitude stepping resulted in higher strength values (≈8 kN) compared to the use of a constant amplitude (≈5.5 kN) and slightly higher weld strength consistency. In addition, amplitude stepping resulted in relatively shorter cycle times when compared to welds made at constant low amplitude. It was also seen that the benefits of amplitude stepping were more pronounced with 3-mm-thick samples compared to welds made with 2-mm-thick samples.

Introduction and Background

Ultrasonic Metal Welding

Ultrasonic metal welding, invented more than 50 years ago, is a process that joins two metals by applying ultrasonic vibrations under moderate pressure. The high-frequency vibrations (typically 20 kHz) locally soften the faying surfaces to form a solid-state weld through progressive shearing and plastic deformation. The oxides and contaminants are removed by high-frequency motion ("scrubbing") producing a pure metal/metal contact interface between the parts allowing intermetallic bonds to form. Beyer states that "ultrasonic welding of metals consists of interrelated, complex processes such as plastic deformation, work hardening, breaking of contaminant films, fatigue crack formation and propagation, fracture, generation of heat by friction recrystallization, and interdiffusion" (Ref. 1).

Wodara (Ref. 2) has theorized that the solid-state weld formation takes place in three stages. The first stage consists of drawing together the surfaces to be welded (faying surfaces), causing them to self align due to the applied normal stress. The second stage is represented by the activation of the atoms at the joining surfaces (i.e., dislocations take place) and their exchange of electrons (a metallic bond formed). The third stage leads to the formation of a strong joint by chemical exchange (diffusion) of atoms occurring between the metallic substances, both locally (weld interface) and in the surrounding areas (weld zone).

One of the issues that can occur during ultrasonic metal welding is adhesion of the tooling to the samples. The Institute of Materials Science and Engineering of the University of Kaiserslautern conducted an investigation with Al sheets and flexible Al wires to understand the adhesion between the welding tip and samples. They concluded that the adhesion is due to high temperatures by applying a TiAlN-coating to the horn tip or using an interlayer (Ref. 3). It is important to note that while these works have proposed the mechanisms of ultrasonic metal welding, there remains some varied interpretations on the fundamentals.

Amplitude and Amplitude Stepping

In ultrasonic metal welding, the amplitudes are typically less than 100 µm. In addition, the frequencies are typically between 20 and 60 kHz. Because no system is infinitely rigid, any vibrating tool will have varying amplitude depending on the stiffness of the load — amplitude droop. In this case amplitude droop is a loss of vibration amplitude due to attenuation and deflection. In order to characterize the amplitude droop in the system studied in this paper, the amplitude was measured at the horn tip during a weld cycle, as shown in Fig. 1. As seen in Fig. 2, the amplitude droops from 55 to 23 µm. This is nearly a 60% amplitude droop. Amplitude measurements were also made at the center of the horn. As shown in Fig. 3, the amplitude at the center of the horn remains relatively constant. Thus, it is believed the droop is localized to the tip (Refs. 4-7).

Ultrasonic metal welding has the advantage of a relatively short cycle time (< 2 s), but its disadvantages are tool/part adhesion and part marking (Refs. 8-13). This paper evaluates a method to improve these disadvantages by using amplitude stepping instead of constant amplitude. Other research evaluated the use of buffer sheets to reduce marking but this approach required a third component be added to the weld configuration (Ref. 13), which is a disadvantage.

The amplitude in ultrasonic metal welding is defined as the peak-to-peak displacement of the horn at its work face as expressed in µm or inches. While most systems operate with constant amplitude at the converter, the amplitude can be con-
trolled electrically by adjusting the voltage into the converter. Amplitude stepping basically performs a weld using two different amplitude settings. Conventional welds are made with a single preselected value. In the case of amplitude stepping, the first amplitude setting is called the A setting and the second setting is the B setting (relative to a controller with a product code WPC-1 from Branson Ultrasonics). The trigger point for the A to B transition during the weld can be made in a number of ways, such as time, energy level, and peak power value. During the aluminum welding studies, the trigger point was based on time. The time mode was selected based on previous experience and ease of interruption.

Amplitude stepping typically starts with a high A amplitude and drops to a lower B amplitude with a trigger time of 0.2 s for coupons of 2-mm thickness and 0.4 s for coupons of 3-mm thickness. The process generally dissipates high amounts of power into weld samples during the A amplitude phase and power dissipation drops during the B phase — Fig. 4. In this case, it is proposed that the amplitude is profiled to match the various stages of the welding process. For example, the amplitude is relatively high at the start of the welding process where the weld interface is solid/solid and requires significant velocities (amplitude) to promote heating. At the end of the weld cycle, the amplitude is decreased to reduce heating and softening of the sample. In addition, the lower amplitude reduces shearing as the weld forms, reducing sample damage. While the stages of welds are not readily distinguishable, it is proposed that the start and end of stages are significantly different, requiring different amplitudes for optimized conditions. While not previously reported for ultrasonic metal welding, it has been reported for ultrasonic plastics welding (Ref. 14). In addition, it is important to note that because the dampening of the horn and stack assembly (converter, booster, and horn), the response of the mechanical system will be highly dependent on the load (weld). Small, less-stiff loads will not reduce the amplitude as quickly as highly stiff loads regardless of the change of voltage to the converter.

While amplitude stepping varies the displacement of converter, the final vibrational displacement at the weld tip is also dependent on the stiffness of the system as previously detailed in terms of droop. It is believed that the relative droop (%) is relatively independent of converter amplitude.

Objective

The objective of this work was to characterize the use of amplitude stepping and determine whether there are any benefits to its use in terms of weld strength, time, and consistency.

<table>
<thead>
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<th>Source</th>
<th>DF</th>
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<td>814910.00</td>
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Experimental Procedure

Experimental Design

Welds were made at various energy levels, where the energy level was measured by the power supply. In this case, the power supply digitally integrated the electrical power curve and the ultrasonics remained active until the preset level of energy was dissipated. The typical range of preset energy levels was between 500 and 5500 J, with increments of 10, 200, or 500 J, depending on the weld quality and the equipment capacity. For example, if the energy level was too low, the weld was not complete, and if the energy level was too high, part marking was excessive and the power supply frequently overloaded. This range was selected based on screening experiments and experience. Ten welds were made with each energy level in increasing order of the weld energy level setting and were not randomized. Weld amplitudes that were studied ranged from 40 to 60 μm. Additional details of the amplitude settings are defined in the equipment section. The weld force setting was approximately 3360 N.

In the screening experiment, welds were made over a wide range of energy values with constant and amplitude stepping to compare the benefits of amplitude stepping. As further detailed below, the amplitude stepping was controlled by a time setting.

Materials

The ultrasonic metal welding was completed with aluminum 5754 coupons of two different thicknesses: 2 and 3 mm. The pretreated and prelubricated AA5754-H111 aluminum alloy was used in “as-received” condition. The pretreatment
was a silicate coating and the lubricant a dry-film lubricant. The aluminum was purchased from Novelis, Inc. The weld samples were made from two 25.4- x 100-mm overlapping coupons, with a 25.4-mm (1-in.) overlap and the weld centered on the overlap.

**Equipment**

The weld amplitudes were varied by a WPC-1 controller manufactured by Branson Ultrasonic Corp. The controller has the ability to vary the amplitude profiling at two separate values (A and B) with several switch-over modes. The switch-over mode is the parameter that defines when the amplitude is switched from value A (typically 60 μm pp) to B (typically 43 μm pp). In this work, only time was evaluated as this is the simplest mode to visualize and it was decoupled from other welding parameters. In screening experiments, different amplitudes (50 and 58 μm pp) were also studied, but the resulting weld strength and consistency was slightly lower (~3000 N) than those described in this paper. In addition, screening experiments showed that best results were obtained with an amplitude profile of 60 (amplitude A)-43 (amplitude B) μm. Welds were made at various energy levels, where the energy level was measured by the power supply. The welding system was manufactured by Branson Ultrasonic Corp. The horn was a knurled tip and the anvil was a “flex” anvil. The details of the horn and tip are detailed in Fig. 5. The tip of the horn face was 7.8 x 5.1 mm². The weld force was held constant at 3360 N. A squeeze time of 0.2 s was used to allow the force to fully develop prior to sonic activation. Sufficient time (2-3 min) was allowed between the welds, and the tooling temperature remained consistent.

**Characterization**

All welds (10 samples for every energy level) were tested in tension at a cross-head speed of 10 mm/min resulting in shear loading at the weld zone. The maximum sustained load was used to calculate the ultimate strength. Shims were not used in the grips with the sample and thus bending stresses were not minimized. It is important to note that while weld size was generally proportional to weld energy, it was not recorded and only final weld strength was reported in terms of maximum load.

**Results and Discussion**

Amplitude stepping experiments were conducted on coupons of 3- and 2-mm thickness, and weld strength was studied as a function of the preset energy values calculated as described in the introduction.

### Study of the Shear Weld Strength Function of Weld Energy

In the experiments comparing amplitude stepping and constant amplitude for 2-mm-thick coupons, weld strength as a function of weld energy is seen in Fig. 6.

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
<th>F Ratio</th>
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<td>C. Total</td>
<td>13</td>
<td>2265664.9</td>
<td></td>
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**Table 2 — Analysis of Variance for 3-mm-Thick Coupons Comparing the Two Methods: with and without Amplitude Stepping**
The benefits of using amplitude stepping of 60–43 μm over the constant amplitude of 40 and 60 μm, respectively, is seen in the increased strength. That is to say, with amplitude stepping there are slightly lower variations and higher values in terms of weld strength. In more detail, the amplitude stepping resulted in maximum weld strength of over 6.0 kN. In comparison, the maximum weld strength achieved by using both constant amplitude of 40 and 60 μm, respectively, was only slightly over 5.5 kN. It is important to note that with amplitude stepping, final amplitude of 40 μm was not used because of frequent power supply overloads. By slightly increasing the constant amplitude value to 43 μm, it was found that overloading could be eliminated. It is also important to note that higher energy levels with a constant amplitude of 60 μm resulted in significant part marking and reduced sample strength as noted in the decrease in strength at an energy level of 1500 J.

It is important to note that the higher constant amplitude, 60 μm, resulted in higher weld strength variation and more part marking and tool/part adherence compared to the other amplitudes/profiles studied. Due to these problems, the 60 μm constant amplitude was not evaluated for the 3-mm-thick coupons.

Figure 7 shows shear weld strength as a function of the weld energy for 3-mm-thick coupons welded at constant amplitude and amplitude stepping, respectively. Welding with an amplitude stepping of 60–43 μm results in maximum shear weld strength of approximately 8.3 kN. In comparison, welding at constant amplitude of 43 μm results in a lower maximum shear weld strength value of approximately 6.2 kN. Thus, there is an approximately 34% increase in the shear weld strength when welding 3-mm-thick coupons at amplitude stepping compared to constant amplitude. It was also important that the weld time (cycle) for the welds made with amplitude stepping were typically less than 50% of the weld times for a given energy level for those welds made with a constant amplitude of 43 μm. This was expected because of the relationship between power and amplitude (Ref. 4).

**Study of the Weld Time Function of Weld Energy**

For the 2-mm-thick coupons, Fig. 8 shows weld time as a function of weld energy with both a constant amplitude of 43 μm and amplitude stepping of 60–43 μm. It can be seen that with amplitude stepping of 60–43 μm, the weld time is lower when compared to the weld time with constant amplitude of 43 μm. Thus, for coupons of 2-mm thickness, a reduction in weld time of approximately 60% was achieved by using amplitude stepping over the constant amplitude of 43 μm. This is expected since with amplitude stepping the higher amplitude portion of the weld cycle dissipates more energy. It is also seen that for the constant 43-μm amplitude there appears to be an inflection point at approximately 3500 ms. It is believed that this corresponds to the time to develop a rigid, fully developed and solidified weld,
which dissipates high energy levels. That is to say, the stiffness of the weld is sufficiently high to dissipate higher power (rate of energy) levels, reducing the time required to dissipate additional energy.

Weld time as a function of weld energy for the 3-mm-thick coupons at both a constant amplitude of 43 μm and amplitude stepping of 60–43 μm is illustrated in Fig. 9. Again it is seen that for any given energy value, the weld time is less for amplitude stepping compared to a constant amplitude. For coupons of 3-mm thickness, an approximate reduction of 70% in weld time was achieved when using amplitude stepping over the constant amplitude.

Statistical Study Comparing the Amplitude Stepping with Constant Amplitude

To confirm the significance of the difference in consistency, a statistical comparison between the two groups (Group 1: standard deviations of the weld strength values resulted from welding with amplitude stepping, and Group 2: the standard deviations of the weld strength values resulted from welding with constant amplitude) was performed.

Table 1 details the analysis of variance tested between the two groups for 2-mm-thick coupons. It can be seen that the probability p-value is less than 0.05; thus, there is a significant difference between the means of the standard deviations of the two groups. To further characterize the difference between the two groups, Fig. 10 shows that Group 1 (welding with amplitude stepping) resulted in a lower value of the standard deviation. Thus, with welding 2-mm-thick coupons, amplitude stepping leads to more consistent welds.

Table 2 represents the analysis of variance tested between the two groups for the 3-mm-thick samples. It is seen that the p-value is less than 0.05; thus, there is a significant difference between the means of the standard deviations of the two groups. In more detail, Fig. 11 shows that the Group 1 (welding with amplitude stepping) has a lower value in standard deviation, proving that welding 3-mm-thick samples with amplitude stepping results in more consistent welds.

Conclusions

In this study it was demonstrated that amplitude stepping allows for better matching of amplitude to the various stages of the weld. For example, by initiating the welding process with relatively high amplitude, fast heating and efficient welding can be promoted. Once the material is softened, the amplitude can be reduced to minimize shearing of the weld. Thus, amplitude stepping increases weld strength and reduces weld time. However, it was seen that amplitude stepping did not affect tool/part adhesion, thus there was no noticeable improvement of the horn adhesion.

Thus in summary:
• Amplitude stepping allows better matching of amplitude to the various stages of the weld.
• Amplitude stepping increases weld strength and reduces weld time.

In conclusion, independent of the thickness of the coupons to be welded, amplitude stepping has positive impacts on the shear weld strength, time, and consistency. However, the benefits of the amplitude stepping appear more pronounced for the 3-mm-thick coupons compared to the 2-mm-thick coupons.

Acknowledgment

This work was supported in part through NIST ATP Cooperative Agreement 70NANB3H3015, being funded by Branson Co. and NIST.

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Robotic Shielded Metal Arc Welding

A methodology was developed for robotic welding with SMAW covered electrodes using a variation of the tool center point

BY E. J. LIMA II AND A. Q. BRACARENSE

ABSTRACT

In this work, the development and validation of a methodology for robotic welding with covered electrodes (SMAW) using a variation of the tool center point (TCP) model is shown. The covered electrode becomes part of the kinematic model of the robot as an additional prismatic joint, whose movement is determined by the electrode consumption or melting rate. This allows programming the trajectory to be welded similarly to welding processes with continuous wire feeding (GMAW or FCAW). In these processes, the points of beginning and end of each section of the trajectory are defined by the programmer and the robot performs, by default, the predefined trajectory of the TCP between these points, while the wire is fed independently of the robot movement.

The robot performs feeding of the covered electrode through a diving movement while carrying out the advance movement along the trajectory. A closed loop mesh controls the length of the electric arc using the measurement of the voltage supplied by the welding machine. This compensates for the variation in the electrode voltage drop due to its length and temperature in order to maintain the arc length constant throughout the weld.

Introduction

Despite being extensively used and being especially suited for applications such as underwater welding and hot tapping in gas and oil pipelines, the shielded metal arc welding (SMAW) process, using covered electrodes, has been avoided for some applications due to a possible lack of weld quality with regard to microstructure homogeneity, physical appearance, and size. These factors are directly related to the fact that this process is, currently, predominantly manual, and the welder is unable to perform all the welds exactly equal. It should be also considered that underwater and hot tapping applications are dangerous for humans to perform. Mechanization of the process already exists and helps to increase the repeatability; however, there are limitations regarding the weld geometry, which is determined by the mechanism.

Aiming at improving the safety and weld quality together with repeatability provided by mechanization while maintaining the flexibility of the manual process, the robotization of the process (Ref. 1) appears as a possible solution. So, the process could be performed by a submarine robot in the underwater welding or by a mobile industrial robot for hot tapping. In the case of repair welding, the presented methodology may be used in association with a joint tracking or vision system for automatic groove identification.

However, with robotization, the problem is the melting rate of the covered electrode is not constant throughout the welding execution, depending on the electrode diameter and welding current. This is due to the fact that the welding current crosses the entire length of the electrode that has not yet melted, heating it by Joule effect. This heat, in a direct way, facilitates the fusion of the electrode, which increases its fusion rate. Thus, if the welding is performed with constant dive speed, the weld will come out with nondimensional homogeneous characteristics (Ref. 2), since the melting rate, and consequently, the deposition rate along the weld, increase. Experimental results (Ref. 3) showed that, in addition to obtaining an irregular weld without complete penetration, a constant diving speed can lead to arc extinction in a short time after the start of welding.

This work shows development and validation of the robotization of the welding process with covered electrode. Presented are a literature review of previous research with the ultimate goal of automating the process, the proposed methodology for the generation of trajectories to control the length of the electric arc, implementation of the proposed methodology in an industrial robot, and the results of the robotization of the process.

Bibliographic Review

Kang (Ref. 4) shows the development of a tool to mechanize underwater welding with SMAW. Because with this type of welding it is difficult for the welder to maintain a constant arc length, the weld beads usually have irregular aspects. Based on the arc voltage control (AVC), the mechanism regulates the electrode feeding speed according to the voltage measured between the electrode holder and the base metal, while the welder moves the holder along the welding path. This approach does not consider, however, variations in the electrode electrical resistivity due to the increase of temperature by Joule effect. This causes incorrect measurement of the electric arc voltage, since there are voltage drops along the electrode length.

Oliveira (Ref. 3) shows the design of a robot with two degrees of freedom that performs, respectively, the translational and diving movements of the electrode. The use of this robot allows variations in diving speed in order to offset the effects of increasing temperature, considering the models obtained in Batana and Bracarense (Ref. 1). However, Oliveira’s methodology considers the open loop control of the arc length, using as diving speed the value of the fusion rate obtained through mathematical models. Therefore, it does not guarantee a homogeneous weld, since there is no guarantee that the

**KEYWORDS**

Robots
Control
Shielded Metal Arc Welding (SMAW)
length of the electric arc remains constant. The present work uses a closed loop control and proposes use of a model of the voltage drop on the covered electrode according to its length and temperature. This obtains a more precise measurement of the electric arc voltage for use as feedback to the robot controller, guaranteeing weld bead uniformity.

Methodology

Trajectory Generation in Robotic Shielded Metal Arc Welding

In shielded metal arc welding, it is not sufficient to follow a predefined trajectory over the groove, as in the gas metal arc (GMA) and flux cored arc (FCA) processes, where wire feeding is automatic. In SMAW, it is necessary to make the feeding movement in order to maintain a constant arc length. As the melting rate is not constant due to the heating caused by the Joule effect, feeding speed has to be regulated during execution.

The methodology used (Ref. 5) allows programming of tool center point (TCP) movement in a similar way as in GMAW and FCAW, in a way transparent to the user. So, it is only necessary to program the weld bead geometry or trajectory over the groove without caring about the electrode melting.

The electrode is considered here as a prismatic joint of the robot. Considering the joint length given by the electrode length, the TCP moves on the programmed trajectory and, at each sampling period, a new joint displacement is calculated and updated in the robot kinematics model. Therefore, the diving movement of the electrode holder is independent of the welding movement.

Figure 1 shows a model for the electrode holder for robotic SMAW with attached frames.

The frame \(I\) or the last joint frame of the robot may be determined considering \(\{C\}\) as an intermediate frame, located at the completed consumed electrode and \(\{T\}\) as the TCP frame. Then,

\[
\begin{align*}
\mathbf{T}^N &= \mathbf{T}^C \mathbf{T}^T \\
\end{align*}
\]

such that \(\mathbf{T}^C\) represents the prismatic joint associated with the electrode. The kinematic model to compute the TCP position is given by

\[
\begin{align*}
\mathbf{T}^N &= \mathbf{T}^C \mathbf{T}^T \\
\end{align*}
\]

where \(\mathbf{T}^N\) is the N joint robot kinematics model.

Equation 2 may be solved for \(\mathbf{T}^N\)

\[
\mathbf{T}^N = \mathbf{T}^C \mathbf{T}^{-1} \\
\]

and the robot joint positions may be calculated using the inverse kinematics model applied to the matrix \(\mathbf{T}^N\).

Considering the initial and final electrode holder positions shown in Fig. 2 and the melting rate experimentally obtained by Batana (Ref. 6), Fig. 3A shows the TCP and electrode holder trajectories during welding. The electrode tip moves along a predetermined trajectory while the electrode holder makes the diving movement. As the electrode is parallel to the Z axis, the electrode holder diving movement is made in this direction as it moves in the X direction. In this case, the independence of the TCP advance movement and the electrode holder diving movement is easily stated. However, considering now a welding angle of 45 deg, these movements are not independent — Fig. 3B.

This methodology can be extended to nonlinear trajectories, as in orbital welding or for hot tapping in pipelines. The operator only has to program the welding trajectory in the same way as is done for welding processes with continuous wire feeding. Figure 4A shows the pro-
programmed TCP trajectory on the tube and the electrode holder trajectory for a 90-deg welding angle; Fig. 4B shows those trajectories for a 45-deg welding angle. More complex welding trajectories may be programmed using a sequence of linear and circular movements as in other welding processes.

**Electric Arc Length Control**

Previous works (Refs. 3, 6, 7) seeking robotization of the welding process with covered electrodes suggested development of models for electrode melting rate that considered current and temperature to determine the speed of the electrode holder diving. Thus, when making the diving movement at speeds equal to the melting rate, the arc length should remain constant throughout welding. However, imperfections in the models, errors in current and temperature measurements, and other disturbances cause small differences between the value of the calculated melting rate and the real melting rate. These differences, even if small, can cause great variations in the arc length since it depends on the integral of the instantaneous difference. This shows that an “open loop control,” as used by Oliveira (Ref. 3), is not suitable for the system.

The solution used here is to make a measurement of the arc length to determine the diving speed and use it in a “closed loop controller.” In this case, a reference value for the arc length is given and the error calculated as the difference between the reference and the measured length from the electric arc.

One solution for the problem of measuring the arc length is to measure the voltage in the electric arc \( V_{\text{arc}} \), since they are directly related. In the process, a constant-current power source is used. The problem is that it is not possible to directly measure the arc voltage because, during welding, the electrode tip near the melting front is not accessible. It is possible, however, to measure the voltage supplied by the power source \( V_{\text{source}} \) through the entire electrical circuit, as shown in Fig. 5, which includes the voltage drop in the cable, holder, base metal \( (V_{\text{cl}} + V_{\text{C}}) \) and, mainly, along the extension, not yet melted, of the electrode, \( V_{\text{elect}} \).

It may be considered that the sum of the voltage drops in the cable, electrode holder, and base metal \( (V_{\text{cl}} + V_{\text{C}}) \) are constant along the weld since the power source keeps the welding current constant. However, the voltage drop along the electrode that has not yet been melted, \( V_{\text{elect}} \), is not constant, due to the reduction of its length and the increase in its electrical resistivity with temperature. Thus, even if the controller keeps the \( V_{\text{source}} \) constant through control of the diving speed, it does not guarantee that \( V_{\text{arc}} \)
Fig. 8 — Values of welding voltage for different controllers: A — $K_p = 20$ and $K_i = 7$, B — $K_p = 40$ and $K_i = 5.5$.

Fig. 9 — Electrode voltage drop during welding.

Fig. 10 — Beads on plate performed by the robot using E6013 electrodes, which demonstrated the repeatability of the process.

Fig. 11 — Welds made using E7018 electrodes demonstrating the flexibility and repeatability of the process.

is constant throughout the process, and therefore does not guarantee a constant arc length. In this study, a model of the electrode voltage drop, as a function of temperature to compensate for the effect of its variation was used.

The electrode voltage drop, $V_{elec}$, may then be modeled as

$$V_{elec} = \rho(T) \frac{l_{elec}(t)}{A} I$$

where $\rho(T)$ is the electrode electrical resistivity as a function of temperature, $l_{elec}(t)$ is the electrode length not yet melted, $A$ is the area of the electrode wire, and $I$ is the welding current. Since the electrical conductivity of the core wire is two orders of magnitude greater than the coating (Ref. 8), one can consider only the resistivity and its cross-sectional area. As the electrical resistivity $\rho$ of the core wire material varies with its temperature, it is important to know the temperature behavior along the electrode during the process. In Ref. 9, the authors conclude that the longitudinal temperature profile along the covered electrode is practically constant. Its heating is due to the Joule effect caused by the high electrical current crossing the electrode. Conduction of the heat the electric arc generates to the electrode is often slower than the fusion rate, which causes the temperature to be constant along the electrode length. Then, temperature can be measured during welding using thermocouples (Ref. 10) placed under the coating near the electrode holder.

**Equipment and Materials**

To validate the methodology, an anthropomorphic industrial robot, with six rotational degrees of freedom was used. The robot uses a controller that allows programming from simple linear, circular, and joint-to-joint movements to creation of complex programs, including changes of parameters at run time (Ref. 11). These characteristics make possible implementation of the proposed methodology for trajectory generation and control of the electric arc length during welding. To perform data acquisition, a modular I/O-SYSTEM 750 was used that communicates with the robot controller through a DeviceNet interface. For the tests, a constant-current power source, capable of supplying currents up to 250 A and an open circuit voltage of 70 V was used. A drill chuck was used as the electrode holder (Ref. 10). The supply current is made through the jaw of the chuck, which is in turn electrically isolated from the holder by a piece of nylon. To enable arc initiation at the welding start point, a composite specially developed to burn when submitted to the electric current (Ref. 12) was used. When the composite is burned, the arc is established and the robot starts moving. At the end point, a quick movement of the electrode interrupts the electrode and terminates the arc.
Using the robot routines to define tools, the TCP models with the complete electrode and with the melted electrode were defined — Fig. 6.

The proposed methodology allows welding with covered electrodes of any length, diameter, and type of coating, since it performs closed loop control of the process. Thus, the proposed methodology was validated with rutile-type covered electrodes (Ref. 13). Figure 7 shows the closed loop system, where $V_{\text{ref}}$ is the reference voltage, $e$ is the control error, $l_{\text{elec}}$ is the electrode length, $v_d$ is the diving speed the robot provides, and $V_{\text{source}}$ is the voltage measured between the welding source terminals.

The PI controller is used to determine the new value for $l_{\text{elec}}$ at each sample period to be used in the kinematics model of the robot (Equation 3). As the transform matrices are updated, the robot makes the diving movement ($v_d$), making the error ($e = V_{\text{ref}} - V_{\text{source}}$) as small as possible.

Figure 8 shows the measurement of the electric arc voltage during welding using the initial controller values ($K_p = 20$ and $K_i = 7$) and the values after the PI controller tuning ($K_p = 40$ and $K_i = 5.5$). The reference value for the voltage is $V_{\text{ref}} = 25$ V.

During the process, it was possible to observe that although the robot can keep the mean voltage constant, the arc length increases significantly at the end of the weld, as discussed previously. To compensate for this effect, the model of the electrode voltage drop in function of its length and temperature was used to correct the feedback signal the controller uses, as described previously. For this, tests were made to obtain the curve of temperature vs. time. Type K thermocouples were used for monitoring temperature during welding (Ref. 10).

Welding tests were then made using this compensation. The reference voltage ($V_{\text{ref}}$) was set to 21 V. Figure 9 shows the voltage on the electrode ($V_{\text{elec}}$) as a function of time. Despite the voltage drop compensation in the electrode varies of only 0.5 V, it was observed that the length of the arc remained constant throughout the execution of the weld, reinforcing the need for such compensation.

To prove the repeatability achieved with automating the process, several beads on plate were performed using 4-mm-diameter E6013 electrodes, 175-A welding current, 21-V reference voltage, and 2.5 mm/s welding speed. Figure 10 shows the appearance of the welds. Despite the spatter problem, it is possible to observe that all the welds are identical, demonstrating the repeatability obtained with the robotization of the process.

With the aim of demonstrating the flexibility of the methodology used with respect to the variety of electrodes, tests were made using 3.25-mm-diameter E7018 electrodes. The best welds were obtained using 150-A current, 2.5 mm/s speed, and 26.5-V reference voltage. Figure 11 shows the appearance of welds.

As can be observed, the welds were more uniform, with less spatter than those obtained with E6013 electrodes. It is important to note that the E7018 electrodes, despite producing better quality welds, are more difficult to use in manual welding. In the experiments, however, these electrodes did not present any operational difficulties in relation to E6013 electrodes, but it was necessary to conduct some additional experiments to adjust the reference voltage as the voltage of the electric arc varies considerably with the change of the electrode coating.

To demonstrate the generality of the developed methodology for generating the trajectories, orbital welding on a 14-in.-diameter steel tube was conducted. The welding started in the flat position, going downward in a vertical position with the electrode at an angle of 45 deg, pulling...
the weld bead. E7018 electrodes were used with a current of 130 A, welding speed of 5.5 mm/s, and reference voltage of 18 V. Figure 12 shows the robot positioned with the electrode at the arc opening and after its extinction.

Figure 13 shows the appearance of two welds made on the pipe with the same welding parameters, demonstrating the repeatability of the process.

Conclusions

This work presents the robotization of the welding process with covered electrodes, combining the flexibility of the process and the repeatability and safety of the automation. A methodology was developed to generate the electrode holder trajectory during welding in order to move the weld bead forward along the base metal with the welding speed and angle programmed by the operator, keeping the electric arc length constant. The arc length is controlled using a closed loop feedback controller of the arc voltage.

To avoid increasing the electric arc along the weld, an effect that occurs when considering the arc voltage as the measured voltage in the power source terminals, a model for electrode voltage drop, allowing a more precise determination of electric arc voltage value was developed and used. The model for the electrode voltage drop should take into account its temperature, because its resistivity varies significantly with heating.

The use of an industrial robot with a flexible programming interface allowed the programming of the generation during execution time of the electrode holder trajectory and calculation of electrode consumption.

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References

Materials Transfer in Electro-Spark Deposition of TiC_p/Ni Metal-Matrix Composite Coating on Cu Substrate

Experiments indicated the material transferred from the depositing electrode to the substrate by producing one deposition each time, primarily through direct molten-metal to molten-metal contact

BY S. K. TANG, T. C. NGUYEN, AND Y. ZHOU

ABSTRACT

Electro-spark deposition (ESD) is a microwelding process that utilizes short duration of electrical pulses to deposit electrode materials to a metallic substrate. In this paper, the material transferred from the depositing electrode to the substrate was investigated by producing one deposition each time. Titanium carbide particles/nickel metal-matrix composite (TiC_p/Ni MMC) was used as the electrode to coat the copper (Cu) substrate in the static mode and the dynamic mode experiments. The movement of the depositing TiC_p/Ni electrode was strictly controlled in static mode experiments and the electrode movement was governed by a spring mechanism. Phenomenological models were developed to detail the events taking place during a single deposition in static and dynamic modes, respectively. The experimental results indicated that the material transferred between the depositing electrode and the substrate is primarily through direct molten-metal to molten-metal contact.

Introduction

Electro-spark deposition (ESD) is a microwelding process that is capable of depositing wear and corrosion resistance coatings to repair, improve, and extend the service life of the components and tools (Refs. 1–5). Chen et al. (Refs. 6, 7) deposited titanium carbide particles/nickel metal-matrix composite (TiC_p/Ni MMC) coating by the ESD process to extend the electrode life in resistance spot welding. During the coating process, short duration of electrical pulses ranging from few microseconds to milliseconds are used to deposit the electrode material onto component’s surface producing a protective layer. The low net heat input and the ability to form metallurgical bonding of coating to substrate are some of the noticeable advantages of the ESD coating process (Refs. 1–5). However, the materials transfer mechanism from the depositing electrode to the substrate during the ESD process is not well understood. There are several theories to the material transfer mechanism during the ESD process. The first theory suggests that the electrode materials are transferred to the substrate via solid, liquid, or gaseous states (Ref. 8). The second theory proposes that the materials transfer mechanism in the ESD process is similar to short-circuit (Ref. 2), globular or spray transfer modes typically observed in the gas metal arc welding (GMAW) process (Ref. 9). The third theory describes the detachment of molten droplets from the electrode tip and impinging onto the substrate surface (Ref. 10). Limited experimental work has been done on validating the proposed theories. As a result, the objective of this study is to enhance the current understanding to the material transfer from the depositing electrode to the substrate during the ESD process. To accomplish this task, the ESD process was set up to produce one deposition each time. Based on the experimental observations, phenomenological models will be developed to detail the events taking place during the ESD process. Afterward, multiple ESDs were performed at the same substrate location to document the coating evolution.

Materials and Experimental Procedure

Materials

In the present study, the depositing electrode material was the TiC_p/Ni MMC. The 6-mm-diameter electrodes were manufactured by sintering TiC particles that were approximately 5 μm in diameter. In this metal matrix composite, nickel (Ni) and molybdenum (Mo) were used as binding agents. The sintered TiC_p/Ni MMC electrode tip was then ground to 1.5 mm diameter for this study.

The substrate used in the present study was a precipitation-strengthened and work-hardened Class 2 copper (Cu) alloy with the C18150 ASTM specification. In the material transfer and coating evolution studies, the Cu substrate was a circular specimen 25.4 mm in diameter and 1.5 mm thick. In the mass gain and loss quantification study, the Cu substrate was cut into 10 × 10 × 0.8 mm rectangular specimens. Prior to any experiment, the Cu substrate was mechanically ground with 320-grit silicon carbide emery paper and rinsed with acetone to obtain a thin and uniform surface oxide layer.

Table 1 shows the nominal chemical composition of the depositing and substrate materials, respectively.

KEYWORDS

Electro-Spark Deposition (ESD)
Titanium Carbide Particles/Nickel Metal-Matrix Composite (TiC_p/Ni MMC)
Copper (Cu) Substrate
Dynamic Deposition Mode
ESD Equipment Setup

The ESD equipment setup used in the present study was designed and built at the Centre of Advanced Materials Joining (CAMJ), University of Waterloo. Figure 1 shows a schematic electrical diagram of the ESD circuit. The ESD circuit consisted of two 1000-µF capacitors, a voltage source, a relay switch, and a computer-controlled driver circuit. The capacitors were used to store and discharge the electrical power during the deposition process. The voltage source was an adjustable constant voltage power supply that could charge up the capacitors to a preset voltage level. The relay was used to control the charge or discharge modes of the ESD circuit. This relay switch was controlled by a computer-controlled driver circuit. In the present study, the ESD circuit was always set to charge mode by default setting of the program. When ready, a command would be inserted into the program to switch the relay into discharge mode.

ESD Coating Studies

In the present study, the TiCp/Ni coatings were deposited onto Cu substrate by the static and dynamic modes. The movement of the TiCp/Ni electrode was strictly controlled in static mode experiments. Meanwhile, in dynamic mode experiments, the electrode movement was governed by a spring mechanism. The experiments were conducted using a 35 V charging voltage and 2000 µF capacitance in room-temperature air.

Figure 2 shows the ESD experimental setup used during the static deposition mode testing. The single axis stage was used to hold the TiCp/Ni rod during the deposition process. It was connected to the positive terminal of the ESD circuit and mounted on a second single axis stage. During static mode testing, the TiCp/Ni MMC electrode was manually moved toward the Cu substrate. The depositing electrode was set at a 30-deg offset angle as shown — Fig. 2. After the TiCp/Ni electrode was brought to contact with the Cu substrate, the relay switch was turned to discharge mode to create one ESD.

In dynamic deposition mode testing, the TiCp/Ni electrode was mounted on the spring-loaded mechanical apparatus as shown — Fig. 3. The spring-loaded mechanical apparatus consisted of a single axis stage, an electrode holder mounted on linear bearing, and springs and threaded rod assembly that replaced the second single axis stage. The TiCp/Ni electrode was initially pushed against Cu substrate. This location was referred to as the zero reference point. Then, the TiCp/Ni electrode was pulled backward to a location previously set on the springs-threaded rod assembly. At this time, the relay was switched to discharge mode, and the springs-threaded rod assembly was released. The previously compressed spring on one side of the springs-threaded rod assembly sprang forward and brought the TiCp/Ni electrode into contact with the Cu substrate. This initiated the ESD. While the TiCp/Ni electrode was moving toward the Cu substrate, a spring on the other side of the springs-threaded rod assembly underwent a compression. This spring would be responsible for moving the TiCp/Ni electrode back away from the Cu substrate after the discharge, to prevent the TiCp/Ni electrode from permanently sticking to the Cu substrate. Eventually, the TiCp/Ni electrode was returned to the original

Table 1 — Nominal Compositions of Depositing and Substrate Materials

<table>
<thead>
<tr>
<th>Materials</th>
<th>Ti</th>
<th>Ni</th>
<th>Mo</th>
<th>W</th>
<th>Cu</th>
<th>Cr</th>
<th>Zr</th>
</tr>
</thead>
<tbody>
<tr>
<td>TiCp/Ni MMC</td>
<td>68.36</td>
<td>15.44</td>
<td>13.40</td>
<td>2.80</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>C18150 Cu Alloy</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>99.11</td>
<td>0.84</td>
<td>0.05</td>
</tr>
</tbody>
</table>
To study the TiC\textsubscript{p}/Ni MMC coating evolution, the dynamic mode testing was used repeatedly to create multiple ESD deposits at the same Cu substrate location. To quantify the mass gain and loss on the Cu substrate and TiC\textsubscript{p}/Ni electrode, respectively, 20, 40, 60, 80, and 100 ESD deposits were made using the spring-loaded mechanical apparatus. The deposition process was the same as described in the dynamic deposition mode testing. Both the TiC\textsubscript{p}/Ni electrode and copper substrate were weighed before and after depositions using a Scientech SM124D analytical balance. In the mass gain and loss study, each testing condition was replicated three times.

Microstructural characterization and chemical analysis were performed using scanning electron microscopy (SEM) and energy-dispersive spectroscopy (EDS) analysis. The surface morphology of the deposition spot was observed under a JEOL JSM 6460 SEM with an attached Oxford Instruments INCA-350 EDS. The EDS elemental mapping and spot analysis were performed to characterize the electrode materials distribution on the ESD spot.

Results

Static Deposition Mode Experiments

Figure 4 shows the SEM image of topographic morphology and accompanying EDS elemental mapping of one ESD of TiC\textsubscript{p}/Ni on Cu substrate in static mode. An elliptical crater was created at the center of the deposition area. The molten metal was expelled outward and resolidified on the periphery of the crater. Because the crater was elliptical, the expelled material was not distributed evenly around the periphery. As reported elsewhere (Ref. 11), higher depositing voltages resulted in more molten substrate metal expelled from larger and deeper elliptical crater.

As indicated by the white dashed line in Fig. 4A, a white region surrounding the crater of the deposition is observed. This was possibly caused by the cathode pulverization that is often observed in the reversed polarity gas tungsten arc welding (GTAW) process to remove the surface oxide film on the substrate during welding (Ref. 12). This observation suggests that the ESD process is a self-cleaning process. In addition, the SEM/EDS elemental mapping shows that there is little trace of materials transferred between the TiC\textsubscript{p}/Ni electrode and the Cu substrate — Fig. 4B–D.

Figure 5A shows the SEM image of a TiC\textsubscript{p}/Ni depositing electrode after performing three single depositions in static mode while Fig. 5B is a close-up SEM image of one of the depositing areas. As clearly shown in Fig. 5B, the solidification structure at the edge of the TiC\textsubscript{p}/Ni depositing electrode suggests that melting of the TiC\textsubscript{p}/Ni electrode had occurred during the deposition process. Figure 6 shows the variations of current and voltage as functions of time recorded during single deposition in static mode. The voltage level dropped from the
initial value of 35 to 18 V. Meanwhile, the current suddenly increased to 225 A. After reaching the peak of 225 A, the current rapidly declined back to 0 A, while the voltage was leveled out at 18 V. The voltage and current plot of Fig. 6 illustrates that the capacitors were partially discharged.

**Dynamic Deposition Mode Experiments**

Figure 7 shows the SEM image of topographic morphology and accompanying EDS elemental mapping of ESD single deposition of TiC\textsubscript{p}/Ni onto Cu substrate in dynamic mode. The deposition spot had the same surface appearance as the static mode. An elliptical crater was created at the center of the deposition area, and the expelled molten Cu substrate solidified along the minor axis of the elliptical crater. As in the static mode, a white region surrounding the crater was also observed — Fig. 7A. Unlike the static mode, there was quantitative evidence of TiC\textsubscript{p}/Ni material transferred to the Cu substrate as shown on the EDS elemental mappings of Fig. 7B–D. The single deposition spot consisted of the Cu substrate and small amount of TiC and Ni. As mentioned previously, the depositing electrode was composed of TiC particles with Ni as one of the binding agents. Overall, high concentrations of titanium and nickel were found at the center of the deposition crater as illustrated by the chemical analysis — Fig. 8.

Figure 9 shows the SEM and EDS elemental mapping images of the end surface of TiC\textsubscript{p}/Ni electrode used in single dynamic deposition experiments. In Fig. 9A, three different melted areas are approximately located at the 10, 1, and 5 o’clock positions, respectively. The 10 o’clock melted area is the area of interest in the subsequent discussion. Meanwhile, the remaining melted areas came from other single deposition experiments. As shown in Fig. 9B, a molten structure was evident at the edge of the TiC\textsubscript{p}/Ni depositing electrode. In addition, copper was found at the edge of the molten area on TiC\textsubscript{p}/Ni electrode. In fact, SEM/EDS elemental mapping of Fig. 9D shows the presence of copper at both the top and bottom of the depositing area on the TiC\textsubscript{p}/Ni electrode. This is a clear evidence of copper pickup during the dynamic deposition process.

Figure 10 shows the current, voltage, and displacement as function of time during single deposition in dynamic mode. In this case, the capacitors were completely discharged during the deposition process. The voltage level dropped from 35 to 0 V, and two current peaks were observed. The discharge cycle can be divided into two halves. First, the voltage level dropped from the initial value of 35 to 16 V. Meanwhile, the current suddenly increased to 350 A, and the displacement kept rising. After the current reaching the peak of 350 A, the current rapidly declined to 50 A, and the voltage declined linearly to 13 V. At this stage, the displacement curve reached its peak at 4 μm. In the second half of the discharge cycle, the voltage decreased rapidly from 13 to 1 V. At the same time, the current quickly increased to 225 A, and the displacement declined slowly. After the current reaching the second peak of 225 A, the current rapidly declined to 0 A, and the voltage leveled at 0 V.

**ESD Coating Buildup by Multiple Depositions at the Same Spot**

In this study, the ESD coating evolution was observed using multiple depositions at the same spot on the Cu substrate. For this part of the study, the applied voltage was set at 35 V. Figure 11A–H shows the SEM topography micrographs of the first eight TiC\textsubscript{p}/Ni multisingle depositions on the same spot. Figure 11I–L shows the topography of the TiC\textsubscript{p}/Ni coating after 20, 40, 60, and 80 depositions on the same spot, respectively. As illustrated by these figures, the deposition spot was progressively getting bigger, and more TiC\textsubscript{p}/Ni material was deposited on the substrate as the number of depositions increased. Initially, the first deposition is identical to the single deposition observed in dynamic mode experiment. An elliptical crater was formed as the substrate’s material and surface contaminant were expelled outward from the deposition crater. After the first deposition, the elliptical crater on the Cu substrate contained a mixture of Cu, TiC, and Ni concentrations similar to that observed in Fig. 8. Meanwhile, the TiC\textsubscript{p}/Ni electrode was covered by a thin film of re-solidified materials as shown in Fig. 9.

As illustrated in Fig. 12A, after three consecutive deposits, the deposition spot was changed from the elliptical crater to
the typical splash appearance of ESD coating (Refs. 8, 10, 13). After further depositions, the coating began to crack as shown in Fig. 12B and C. In Fig. 12D, a dense coating was formed but separated by cracks, and the ESD splash appearance was no longer observed.

Discussion

Phenomenological Models for the Formation of ESD Single Deposition

Based on observations of the surface morphology of Cu substrate, the surface of the TiC\(_p\)/Ni electrode, SEM/EDS analysis results and the collected current and voltage data, a model detailing the events taking place during the formation of a single deposition in static mode was developed. Figure 13 shows schematically the phenomenological model of the formation of one deposition in static mode. The model can be divided into three stages. In stage 1 (S1), the TiC\(_p\)/Ni electrode was manually brought into contact with the Cu substrate using the single axis stage. There was no further movement after the TiC\(_p\)/Ni electrode touched the Cu substrate. During this stage, the relay switch was opened and thus the ESD circuit was still in the charge mode. As a result, as illustrated in Fig. 6, the voltage stayed in the preset level with no current flowing.

The second stage began with the closing of the relay switch to initiate the discharge of the capacitors. At the beginning of stage 2 (S2), current quickly increased as the voltage dropped. At the microscopic level, there are no two surfaces that are completely flat (Ref. 13). When the electrode and the substrate were brought into contact, only the asperities on the two surfaces were actually touched — Fig. 13. As a result, the current was allowed to pass through these local contact points during discharge. The resistance heating (PR) at these local contact areas caused melting and vaporizing of the electrode and the substrate materials — Figs. 4, 5. In addition, because of the high current density at these local contact points, a spark was initiated between the electrode and the substrate. The spark expelled the molten Cu substrate forming a crater at the depositing location. The elliptical appearance of the crater was the result of the sharp edge geometry of the electrode and the 30 deg contact angle with the substrate — Fig. 3. The molten metal expulsion removed surface contaminants, thereby improving the overall bonding quality between the substrate and the coating material (Refs. 8, 10, 11, 13). After the molten metal expulsion, a narrow root opening was formed between the electrode and substrate, preventing further discharge of the capacitors in stage 3 (S3).

As observed from Fig. 4, the surface appearance of the deposition spot is different from the observations reported by Liu et al. (Ref. 13). In the latter case, the
splash of the coating material on the substrate was reported. This splash appearance of the coating material was the result of the spraying and impinging of molten coating droplets on the substrate surface (Ref. 10). As observed in the present study, the elliptical crater appearance of the deposition crater was formed by the expulsion of molten substrate material. During sparking, a trace of the TiCp/Ni material was ejected from the electrode tip and then resettled on the surface of the Cu substrate. This could account for the trace evidence of TiCp/Ni material on the Cu substrate shown in Fig. 4. Based on this experimental observation, the direct spraying of coating electrode material to the substrate did not occur.

In a typical ESD process, the depositing electrode is momentarily stuck to the substrate (Refs. 13, 16). In the present study, however, the static mode did not mimic the ESD process entirely as the TiCp/Ni electrode movement was restricted. As a result, to further examine the events taken place during a single ESD, a phenomenological model was also developed for the dynamic deposition mode and will be discussed next.

Figure 14 shows the model of the formation of one deposition in dynamic mode. This model can be divided into four stages. In stage 1 (D1), the depositing electrode was traveling toward the substrate as indicated by the increase in the displacement curve in Fig. 10. At this point, no physical contact was made between the electrode and substrate. Thus, there was no current flow at this moment, and the voltage stayed at the preset level of 35 V. In stage 2 (D2-D3), the depositing electrode was brought into contact with the substrate to initiate the discharge. Voltage started to drop rapidly and gave rise to the first current peak. During stage 3 (D4-D5), the displacement of the TiCp/Ni electrode reached its peak in stage 3 (D4). During stage 3, a thin molten film of both the electrode and substrate materials was formed via a direct molten-metal to molten-metal contact. Consequently, the electrode material was transferred onto the substrate at the points of contact. In addition, during this molten-metal to molten-metal contact, part of the molten Cu substrate material that was ejected to the edge of the crater adhered to the electrode surface as shown — Fig. 9. The capacitors discharged the remaining energy and created the second current peak dur-
ing this stage. In the last stage (D5), the TiCp/Ni electrode was retracted to prevent the local bonding between the Cu substrate and the TiCp/Ni electrode. The deposited electrode materials were then solidified on the substrate. Finally, the TiCp/Ni electrode returned to its original position for subsequent depositions.

ESD Coating Buildup on the Substrate

The change of the coating surface appearance during the deposition process was caused by the continuous surface melting and surface erosion of both the TiCp/Ni electrode and the Cu substrate. After the first deposition, the TiCp/Ni electrode was covered by a thin film of resolidified TiCp/Ni (see Fig. 9), and the deposition spot on the Cu substrate was covered by a thin layer of the mixture of Cu and TiCp/Ni. As the deposition progressed, the elliptical crater appearance had disappeared. On subsequent depositions, the contact area between the electrode and the Cu substrate was increased. With a larger contact area, the overall current density was reduced. As a consequence, the amount of molten materials from both the electrode and the Cu substrate were diminished, thereby limiting the amount of metal transferred via molten-metal to molten-metal contact.

After multiple depositions, cracking of the TiCp/Ni coating was observed. During the deposition process, the molten...
TiC\textsubscript{p}/Ni was deposited on the Cu substrate. Because the substrate was a greater heat sink due to the high thermal conductivity of copper, the molten TiC\textsubscript{p}/Ni rapidly solidified, thus creating residual tensile thermal stress in the coating (Ref. 4). As the deposition progressed, the buildup of the thermal stress caused more cracks to nucleate and to propagate within the brittle ceramic coating.

**Material Transfer between Depositing Electrode and Substrate**

As mentioned in the previous section, the ESD coating is the buildup of the coatings by depositing the TiC\textsubscript{p}/Ni on the previous deposition spot. Figure 15A and B shows the weight gained by the substrate and the weight lost by the TiC\textsubscript{p}/Ni depositing electrode during the ESD process. It is shown that the Cu substrate weight gain increased as the numbers of depositions increased. On the other hand, the TiC\textsubscript{p}/Ni depositing electrode lost more weight as the numbers of depositions increased. Interestingly, the TiC\textsubscript{p}/Ni weight loss was always greater than the Cu weight gain.

In order to understand the material transfer during the ESD process, the theory of electrode erosion by electrical discharge should be revisited. Various researchers proposed that the electrode erosion by electrical discharge could be taken place in the following three distinct phases: solid, liquid, or vapor (Refs. 17, 18). The solid or vapor phase erosion of the electrode would lead to a net loss while only the liquid phase erosion had a positive net gain on materials transferred during the ESD process.

In solid phase erosion, the eroded solid particles by mechanical impact would not adhere to either the electrode or the substrate surfaces. In vapor phase erosion, the vaporized electrode and substrate materials mostly dissipated to the surrounding. In the static mode experiments of the present study, there was no direct molten-metal to molten-metal contact. Only a small amount of the vaporized materials were condensed and redeposited on the substrate surface. As a result, there was only a trace of materials transferred between the TiC\textsubscript{p}/Ni electrode and the Cu substrate in static mode deposition.

In liquid phase erosion, a portion of the molten electrode and molten substrate were coupled due to the molten-metal to molten-metal contact, and coating was formed on the substrate surface. The importance of the molten-metal to molten-metal contact was clearly illustrated by the comparison between the static and dynamic single deposition testing. In static deposition mode, there was no contact between the electrode and the substrate while there was contact in dynamic mode. In the former, there was a trace of electrode materials transferred to the substrate — Fig. 4. On the other hand, in the dynamic mode that had a direct molten-metal to molten-metal contact, the electrode material was clearly present in the Cu substrate crater — Fig. 7. As a result, in this study, the main contribution to the Cu substrate weight gain was obtained through the TiC\textsubscript{p}/Ni liquid phase erosion of the depositing electrode. Other phase erosions might also occur on the Cu substrate. The net weight gain of the substrate was then the difference in the weight gain from the TiC\textsubscript{p}/Ni deposit minus any copper weight loss due to vapor and solid phase erosions. Meanwhile, the TiC\textsubscript{p}/Ni electrode weight loss was mostly caused by liquid phase erosion. In addition, the TiC\textsubscript{p}/Ni electrode was also eroded by vapor and perhaps solid phases. In these latter cases, the eroded electrode material did not recondense on the Cu substrate.
therefore causing the electrode weight loss to be greater than the substrate weight gain.

According to the above phenomenological model, the materials transfer mechanism between the electrode and substrate was primarily through direct molten-metal to molten-metal contact. This is similar to the hypothesis suggested by Galinov et al. (Ref. 8) who proposed that the molten material on the electrode surface was partly driven away and adhered to the substrate surface. Because the material transfer was through the physical contact between the electrode and the substrate at the center of the deposition crater, the content of the electrode material was expectedly concentrated at the center of the deposition spot as shown — Fig. 8.

In Fig. 15, the amount of weight gained by the Cu substrate and weight lost by the TiCp/Ni electrode apparently leveled off after 60 depositions. As discussed previously, as the coating was building up, the contact area between the electrode and the substrate was also increased. This resulted in an overall current density reduction. It, therefore, is not surprising that beyond 60 depositions, the amount of weight gained by the Cu substrate and the amount of weight lost by the electrode have reached an upper limit.

Conclusions

In this study, the material transfer mechanism from TiCp/Ni electrode to Cu substrate during the ESD process was investigated. Once the electrode contacted substrate, an electrical spark was formed due to the extremely high current density at the local contact points. The spark melted and eroded both the substrate and electrode. The crater at the center of the deposition spot was caused by outward expulsion of the molten substrate material.

A very narrow root opening was created between the TiCp/Ni depositing electrode and Cu substrate. At this stage, there was a trace of material transferred between the depositing electrode and substrate. Due to the forward motion of the electrode, the material transfer between the depositing electrode and substrate occurred during the direct molten-metal to molten-metal contact. The TiCp/Ni electrode weight loss was always greater than the Cu substrate weight gain due to the solid and vapor phase erosion of the electrode. The Cu weight gain was the result of weight gain from the TiCp/Ni deposit minus any Cu weight loss.

Acknowledgment

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