April 2010

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• Competency Models Help Prepare Job Skills

• Welding Education Opportunities
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It’s part discipline, part pride and all passion that fuels Shane ‘Cajun’ Guidry, a native of New Orleans, Louisiana. “If you take pride in your work, then welding is for you,” he says. “Because every weld you make is your signature.” Shane’s passion for welding runs deeper than your average metalworker.

His work has brought him from Russia to the 40-below temperatures of Alaska. Today he works as an AWS Certified Welding Inspector, where his ‘no shortcuts’ attitude has made him a reliable team member. “For every weld I inspect, I pretend a member of my family will depend on it,” he says.

SHANE NEEDS EQUIPMENT HE CAN RELY ON. THAT’S WHY HE CHOSES TWECO. ABOARD THE U.S.S. NIMITZ HE USED TWECOTONG ELECTRODE HOLDERS TO REPAIR A WEAPONS ELEVATOR. “THEY’RE INTERCHANGEABLE, DEPENDABLE, AND SAFE,” HE SAYS.

While in Alaska, Shane used Tweco arctic cables on an exploratory drilling site. He said, “Even after dropping them seven stories down, they came up clean and ready to go again.”

SHANE GUIDRY
AWS Certified Welding Inspector
PM Testing Inc.

Shane carries the torch — will you?

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Welding and Postweld Heat Treatment of P91 Steels
Proper design, filler metals, heat treatment, and welding procedures, along with skilled personnel, all factor into joining these creep-resistant steels
W. F. Newell Jr.

Selecting an Engine-Driven Welding Machine
Before selecting your engine-drive power source know what questions to ask and the specific applications for its use
E. Snyder

Best Practices for GTAW 4130 Chrome-Moly Tubing
Here is a step-by-step approach for the successful joining of 4130
T. Bevis and A. Weyenberg

Techniques for Joining 1%Cr-3%Mo Steels
Understanding modern welding techniques will lead to successful repeatability in joining these steels
J. Brennan and B. Fletcher

Weld Integrity Critical to Tower Cranes
Welds must be strong and defect-free for the construction of tower cranes
G. Trommer

Using Competency Models to Build a Career Ladder in Welding
Competency models help determine the knowledge, skills, and abilities to perform successfully in everyday life, in school, and at work
D. W. Dickinson

Microstructural Changes in Grade 22 Ferritic Steel Clad Successively with Ni-Based and 9Cr Filler Metals
A nickel-based interlayer is demonstrated to prevent hard and soft zone formation during postweld heat treatment
R. Anand et al.

Development of a Time-Resolved Energy Absorption Measurement Technique for Laser Beam Spot Welds
The mapping of energy transfer and melting efficiency helps in the selection of welding parameters and pulse shape design
J. T. Norris et al.

Characterization of Welding Fume from SMAW Electrodes — Part II
This study classifies fume particles into three distinct morphologies and characterizes each according to composition and structure
J. W. Sowards et al.

On the cover: Cagnazzi Racing chassis fabricator Todd Bevis uses the gas tungsten arc welding process to modify the 4130 chrome-moly roll cage of a National Hot Rod Association Pro Stock dragster. (Photo courtesy of Miller Electric Mfg. Co.)
Thinking beyond the Ordinary

As publisher of the Welding Journal, all kinds of information come across my desk/computer every month. The categories are usually pretty simple to split between usable and unusable. On occasion, though, one bit of information comes in that fits snugly into that special category of bizarre. I got one the other day from a company that claims to have harnessed the brain’s electrical impulses generated by your thoughts. Here is a simplified explanation of how it works. Through relaxation or concentration you control alpha or beta brainwaves; the electrical patterns generated by these brainwaves are picked up by a headset and transferred to a computer; the company’s software transforms the brainwaves into a control signal. The computer can then send a message over the Internet that will control electrical devices. In fact, a demonstration of the company’s capabilities may have already occurred by the time you read this editorial. The company claims that during the Winter Olympics in Vancouver (Feb. 12–28), visitors will be given the opportunity to control light displays in Toronto, Ottawa, and Niagara Falls just by focusing their thoughts on the sight they are seeing. Sound a little farfetched? Definitely, but who knows. Mind control has been on the fringes of science for a long time.

I’ve also come across ongoing research in the field of welding that also sounds unbelievable. It is nanowelding. To get an idea of what we are talking about, consider that a nanometer is one billionth of a meter. Take a meter stick and divide it into a billion parts and you are looking at some very small slivers. In fact, it is material on the atomic and molecular level. What are being joined are single-wall and multiwall carbon tubes. These tubes, especially the single-wall variety, have great potential in efficient electrical and molecular level. What are being joined are single-wall and multiwall carbon tubes. These tubes, especially the single-wall variety, have great potential in efficient electrical and heat conductivity. They also have very high strength making them candidates for a variety of other products, including bulletproof vests. So far, experiments have shown that a soldering process utilizing a filler material less than 250 atoms across has been successful. Laser-stimulated discharges and electron beam irradiation have been used in joining. Experiments have also been conducted with ultrasonic welding. The welding is taking place on a minuscule scale, observed and manipulated through electron scanning and transmission electron microscopes.

You might ask why carbon tubes need to be joined in the first place. To be used in a viable product there has to be stability in the juncture where the tubes cross. Welding gives them that. All of this is highly experimental now, and it will be years before anything close to commercial production is accomplished, but it does give a new perspective to welding. It is a great example of the necessity of the welding process to the success of material fabrication for products that are on the edges of scientific advancement. So the next time someone belittles welding as an occupation, let them know that without it, some of the most advanced products of the future might never come to be.
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White House Presents Plan to Revitalize Manufacturing

The White House has prepared “A Framework for Revitalizing American Manufacturing,” which identifies seven ways in which the federal government can assist the U.S. manufacturing industry:

1. Provide workers with the opportunity to obtain the skills necessary to be highly productive;
2. Invest in the creation of new technologies and business practices;
3. Develop stable and efficient capital markets for business investment;
4. Help communities and workers transition to a better future;
5. Invest in an advanced transportation infrastructure;
6. Ensure market access and a level playing field; and
7. Improve the business climate, especially for manufacturing.

The full report is available at the following Web site: www.whitehouse.gov/sites/default/files/microsites/20091216-manufacturing-framework.pdf.

Increased Efforts on Exports Planned

The Obama Administration has established the National Export Initiative in an attempt to boost U.S. exports. This will take the form largely of increased funding for key federal agencies. Specifically, a 20% budget increase is being sought for the Commerce Department’s International Trade Administration, most of which would be used to hire additional trade experts to advise and serve as advocates for U.S. companies. In addition, to improve access to credit, the Export-Import Bank, which generally provides financing when private banks will not, will be increasing its financing available for small- and medium-size businesses from $4 billion to $6 billion in 2010, and there is a budget increase planned for this agency as well.

The National Export Initiative is being led by a newly created Export Promotion Cabinet consisting of federal agencies such as the Departments of Commerce, State, and Treasury, as well as the U.S. Trade Representative, the Small Business Administration, and the Export Import Bank. By this fall, each agency is supposed to submit a detailed plan about how it will enhance U.S. exports.

Decline in Defense Industrial Base Noted

The U.S. Department of Defense (DoD), in its 2010 Quadrennial Defense Review (QDR), for the first time acknowledges an erosion of the defense industrial base. According to the QDR, which is the most important strategic document issued by DoD, “America’s defense industry has consolidated and contracted around 20th-century platforms rather than developing the broad and flexible portfolio of systems that today’s security environment demands.” The QDR recommends that Congress abandon its “outdated hands-off” approach to the defense industry and instead “be prepared to intervene when absolutely necessary to create and or sustain competition, innovation, and essential industrial capabilities.”

International Labor Comparisons Program May Be Eliminated

The Obama Administration is proposing to eliminate the International Labor Comparisons (ILC) program as part of the 2011 federal budget reductions. The ILC provides international comparisons of hourly compensation costs; productivity and unit labor costs; labor force, employment, and unemployment rates; and consumer prices. The comparisons relate primarily to the major industrial countries, but other countries are included in certain measures.

If this occurs, the Bureau of Labor Standards annual study International Comparisons of Hourly Compensation Costs in Manufacturing will cease publication. There are other sources of foreign compensation and related data, such as the Organization for Economic Cooperation and Development and the International Labor Organization, but the ILC is considered the most authoritative because of how it vets and adjusts the data to ensure consistent comparisons, particularly with respect to wages and productivity.

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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Southern Co. Obtains DOE Support for Nation’s First Nuclear Units in 30 Years

Southern Co., Atlanta, Ga., recently announced the U.S. Department of Energy (DOE) has offered its subsidiary, Georgia Power, a conditional commitment for loan guarantees to construct the nation’s first nuclear power units in more than 30 years.

“We are honored by the administration’s confidence in our ability to build the nation’s first new nuclear power plant in more than three decades,” said Southern Co. CEO David Ratcliffe following an event where President Obama and Secretary of Energy Steven Chu announced this award. “It’s an important endorsement in the role nuclear power must play in diversifying our nation’s energy mix and helping to curb greenhouse gas emissions.”

The new units will be located at Plant Vogtle near Waynesboro, Ga. The conditional commitment is for loan guarantees that would apply to future borrowings related to the construction of Vogtle Units 3 and 4, which are expected to begin commercial operation in 2016 and 2017, respectively. Total guaranteed borrowings would not exceed 70% of the company’s eligible projected costs and are expected to be funded by Federal Financing Bank. Adding these units is expected to create approximately 3500 jobs during construction and an additional 800 permanent jobs once operations begin.

Georgia Power has 90 days to accept the conditional commitment, including obtaining any necessary regulatory approvals. The company will work with the DOE to finalize loan guarantees; also, final approval and issuance of these are subject to receipt of the Combined Operating License from the U.S. Nuclear Regulatory Commission, completion of final agreements, receipt of any other required regulatory approvals, and satisfaction of other conditions.

Along with Georgia Power’s portion of the two 1100-MW reactors, remaining ownership is divided among Oglethorpe Power Corp., Municipal Electric Authority of Georgia, and Dalton Utilities. Currently, total cost of the new units is projected to be approximately $14 billion. Southern Nuclear, a subsidiary of Southern Co., will oversee construction and operate the two new units for Georgia Power and the other owners.

AirgasRejects Acquisition Offers from Air Products

Airgas, Inc., Radnor, Pa., announced Feb. 22 its board of directors had voted unanimously to reject the unsolicited tender offer from Air Products & Chemicals, Inc., Lehigh Valley, Pa., to acquire all outstanding common shares of the company at a price of $60/share in cash. The board noted this value is unchanged from the unsolicited proposal made Feb. 4, which it rejected Feb. 9.

The basis for this recommendation is provided in Airgas’s Schedule 14D-9 filed with the Securities and Exchange Commission. “The Airgas Board of Directors is unanimous in its belief that the Air Products offer significantly undervalues Airgas and fails to reflect the value of our industry-leading position and future growth prospects,” said Airgas Chairman and CEO Peter McCausland.

Additional reasons for the board’s decision, detailed in its 14D-9 filing, include the following: The offer is highly uncertain and any payments made to Airgas stockholders would be considerably deferred; the offer’s extraordinarily broad conditions render it illusory; and Air Products’s acquisition of Airgas will likely reduce value. For more information on these unsolicited proposals, go to the Investor Information section of the company’s Web site at www.airgas.com.

National Standard Partners with Flux Cored Welding Wire Manufacturer

National Standard, Niles, Mich., a Heico Wire Group company and supplier of solid carbon steel and stainless steel wires to the North American welding industry, has formed a strategic alliance with RevWires LLC, a new cored wire manufacturing company located in Troy, Ohio. This partnership provides National Standard with flux cored wires.

“The addition of these unique new products will help us better serve our customers, and we look forward to making these industry-leading products available to them,” said Jim Hillebrand, president and CEO of Heico Wire Group.

In addition, this cored wire product line will provide new sales and market opportunities to National Standard’s existing distributors.
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Kia Celebrates Grand Opening of $1 Billion Automobile Manufacturing Plant in Georgia

Officials with Kia Motors Manufacturing Georgia (KMMG), Inc., were recently joined by dignitaries from the Hyundai-Kia Automotive Group, the state of Georgia, and local city and county officials to celebrate the official grand opening of Kia’s first U.S. automobile manufacturing plant in West Point, Ga. It’s capable of producing 300,000 cars annually for the North American and global markets.

This event attracted approximately 500 VIPs from Korea and the U.S., including Chairman of the Hyundai-Kia Automotive Group Mong-Koo Chung; Group President and CEO of KMMG and Kia Motors America Byung-Mo Ahn; Georgia Governor Sonny Perdue; and a number of other high-ranking Korean government and state of Georgia officials.

“The first U.S. Kia Motors plant, located in West Point, Ga., encompasses 2.2-million sq ft and covers more than 2200 acres. The four main shops in the complex include welding, stamping, paint, and assembly. A second wave of hiring has also been started; visit www.KiaJobsInGeorgia.com for more details.

“Kia is proud to call West Point, Georgia, home, and we look forward to many years of growing together,” said Ahn. “Continued diligent work has helped elevate Kia to one of the fastest-growing automobile brands around the globe. With the successful launch of the 2011 Kia Sorento CUV (crossover utility vehicle) and establishment of our first manufacturing plant in the United States, the Kia brand is well positioned for further growth and to become a worldwide leader in quality and innovation.”

The 2011 Kia Sorento CUV is built at this new facility. Mass production of the vehicle began late last year, and it went on sale in the United States this past January.

Mass production of the 2011 Kia Sorento CUV began Nov. 16, 2009, with the product officially going on sale in the U.S. in January of this year.
SPARX Opens Welder Training Facility to Strengthen Louisiana Workforce

SPARX Welding & Technology Institute, LLC, has opened its first American Welding Society (AWS) accredited welder training facility in Houma, La. It serves to fill demands in the fabrication, shipbuilding, and oilfield industries.

“Welding’s still a great paying job,” said Philip Strother, the institute’s operations manager. He wanted to open up this school to give back to younger generations and now enjoys teaching. Strother also comes from a welding background and is an AWS Certified Welding Educator and Certified Welding Inspector.

“The company will participate in the much needed welding training field to meet the needs to fill the major welder shortage that is expected to intensify as baby boomers age and the need for skilled labor grows,” added CEO Derrick Prentice.

Day and evening classes are available. “We start with the very basics,” said instructor Billy Fields. The seven-week basic course begins with shielded metal arc followed by flux cored arc and gas tungsten arc welding. Plus, the Schools Excelling through National Skills Education (SENSE) program is followed, and students receive training in safety and blueprint/symbol reading. Advanced welding technique training and special classes can even be coordinated on a particular topic.

The institute accommodates up to 36 students, providing a low student-teacher ratio. Steve Parker, Mike Carrere, and Miranda Folse serve as instructors; additional employees are expected to be hired as well. Upon finishing the basic course, students can take the AWS qualification tests for the 3G and 4G positions on carbon steel.

“We have hopes of expanding into different towns,” Strother said regarding future plans. For more information about SPARX, visit www.sparxwelding.net.

The SPARX Welding & Technology Institute in Houma, La., offers students day and evening classes for advanced welding technique training. The facility features 36 welding booths.

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Visit www.welding.org for course dates or call 1-800-332-9448 for more information.

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For info go to www.aws.org/ad-index
An external tank is three components in one. The bottom component is the LH2 tank that carries the liquid hydrogen propellant. In this photo, two LH2 barrels have already been welded together and are awaiting the 3rd and 4th barrels to form the final assembly. When completed, the external tank will be 154 ft long. (Photo courtesy of Lockheed Martin.)

When Space Shuttle Endeavour recently lifted off at NASA’s Kennedy Space Center, Fla., it marked the first flight of an external tank manufactured using longitudinal friction stir welds on all four liquid hydrogen tank barrels and the single liquid oxygen tank barrel. Previously, fusion welding was used.

Three of ET-134’s liquid hydrogen tank barrels are about 20 ft in length; one is about 14 ft long. Together with the forward and aft dome sections, they form the 96-ft liquid hydrogen tank. Just more than 54 ft long, the liquid oxygen tank holds almost 1.4-million lb of oxidizer that mixes with the 226,237 lb of liquid hydrogen to fuel the Space Shuttle’s main engines.

Also, the flight of ET-134 debuted an improvement to the intertank. Thrust panels were constructed with aluminum-lithium Al-Li 2297, lighter in weight than Al-Li 2219. The unpressurized intertank is a cylindrical structure with flanges on each end for joining the liquid oxygen and liquid hydrogen tanks. The external tank is manufactured at NASA’s Michoud Assembly Facility in New Orleans, La., by Lockheed Martin Space Systems, Littleton, Colo.

Robert C. Byrd Institute Addresses West Virginia Welder Shortage

The Robert C. Byrd Institute for Advanced Flexible Manufacturing (RCBI) is joining forces with Cabell County Career Technology Center (CCCTC) to offer evening welding classes in the West Virginia Tri-State Area. Under a memorandum of understanding, RCBI will supply the instructor and enroll students while CCCTC will provide equipment and facilities for these classes.

“There is an identified shortage of welders — not just in West Virginia but nationwide — and we are continuing to work to prepare individuals with proper skills so they are positioned to earn state welding certification and join the work force,” said RCBI Director and CEO Charlotte Weber.

The first 16-week welding class is scheduled to begin April 19.
Starting this month, evening welding classes will be provided to the Tri-State Area through the Robert C. Byrd Institute for Advanced Flexible Manufacturing in conjunction with Cabell County Career Technology Center.

at CCCTC, Huntington, W.Va. It will meet for four hours each Monday, Tuesday, and Wednesday evening; includes classroom instruction and hands-on training on the shop floor with intensive student-instructor interaction; and can be taken independently to prepare students to test for state certification in shielded metal arc welding or as part of RCBI's comprehensive welding program. For more information or to register, send an e-mail to register@rcbi.org. Enrollment is limited, and financial assistance is available to individuals who qualify.

The RCBI has a similar agreement to provide evening welding classes in Clarksburg, W.Va., at United Technical Center. The first class of 13 students began the first week of January.

North American Die Casting Association’s HyperCAST Project to Create Jobs

Shown above, an aluminum-based metal matrix composite is poured into a graphite mold. Funds totaling $1.5 million have been awarded to the North American Die Casting Association for the HyperCAST project. (Photo courtesy of the Colorado School of Mines.)

The North American Die Casting Association (NADCA), Wheeling, Ill., has received $1.5 million to fund the HyperCAST project, whose purpose is to develop materials and processes for cast high-strength lightweight frame, body, chassis, and power... continued on page 96
Q: We are torch brazing 304 stainless steel “u” tubes to flared socket joints of the same base material. We are brazing with a black flux and a filler metal ring made from a 50% silver filler metal recommended for stainless steel. We do not seem to have any problems with wetting the stainless steel, and leaks are no problem as the filler metal is quite fluid and does a good job filling the tight joint. If anything, the alloy is too fluid as it travels out of the joint and well onto the surface of the “u” tube. From a process perspective, the only issue we have is that the fit-ups are very tight, we get inconsistent tube size, and we sometimes need to force the parts together. It can prove difficult from time to time. The problem is that, fairly often, we get a “u” tube that cracks wide open during heating. It’s not a hairline crack or a leak in the joint, but rather, a catastrophic tube failure. We have been in contact with our tube supplier and can find no issues with tube quality. What may be causing this, and what can we do about it?

A: There are a number of mechanisms that can cause the base metal failure as you are describing. Some are related to the service conditions the brazed joint is subjected to and some are caused by the brazing process. Yours, obviously, is the latter. There is detailed information about these and other joint failure mechanisms in the AWS Brazing Handbook, Fifth Edition, Chapter 7, Corrosion of Brazed Joints.

In cases where normally sound base metal fails with catastrophic cracking during the brazing process, tensile stresses in the material are normally blamed. There is, however, almost always a corrosion component that goes along with it. If you were to heat these assemblies without brazing alloy being added, you would most likely not see this cracking occur. The parts would be stress relieved and no failure would occur. It is the combination of stress and corrosive material that causes the failure. The corrosive agent may be the flux, the filler metal, or both. Because you need flux and filler metal to make your brazed joints, the things you need to eliminate are the causes of stress.

The two most common mechanisms we see in this regard are stress corrosion cracking and liquid metal embrittlement. They both involve tensile stresses in the base metal and a corrosive environment.

Stress corrosion cracking normally refers to failure in service after a brazed assembly is exposed to service conditions. The phenomenon you are experiencing is most likely liquid metal embrittlement. The flow of the molten filler metal on the stainless steel disrupts the equilibrium of stresses on the surface, initiating the catastrophic cracking.

We saw this problem many years ago with similar types of parts. A quick test we did to get a fix on the problem was to heat the parts without brazing alloy being added. We assembled and fluxed the components as usual, then ran them through the heating process. No cracking was observed. On some joints we overstressed them by excessively bending them before assembly. There was still no cracking when only flux was applied. After running a significant number of joints in this fashion, we began adding brazing alloy in our testing. On the parts that were overstressed, the tubing split wide open when the molten brazing filler metal was applied to the areas of highest stress.

There is a significant number of ways stress can be found in your base metal tubing during the brazing process. Some are inherent in the process used to fabricate the parts and some may be introduced during the assembly and brazing process. Identifying and eliminating them will be keys to overcoming the cracking issue.

Liquid metal embrittlement is found most commonly in high-strength materials such as the stainless steel you are using. You have chosen it for a reason, but if you could change to a base metal with less susceptibility to this failure mechanism, it would help. In most cases, this is not an acceptable solution. Looking for an alternative brazing filler metal might also be an option, but it’s doubtful that enough research could be uncovered to help in the search, leaving you most likely to a frustrating trial-and-error process.

The first place to look is in the tube fabrication. Any mechanical working of the tubing will put stress into the metal. Bending and end forming are the most common processes. You do not mention in your question whether or not you use annealed parts, but annealing the parts would eliminate residual stresses built up during the fabrication processes and may help.

Using annealed material would be a good start but there are several ways that stress can be induced during the brazing process. These could counter the positive effects of annealing. You mention that the part fitups are not ideal. Forcing these parts together is an obvious source of stress. Improving part dimensional consistency would seem to be in order. Parts can also be constricted by fixturing. When heated, brazed assemblies grow, and the fixtures need to allow for this growth. Otherwise, stress can be induced during heating.

There is another component that adds to the problem — heat. The cracking would not occur if heat was not applied. The heat is where the cracking and embrittlement would take place. In many cases, the parts would be stress relieved prior to brazing alloy being added. If a high enough temperature was reached prior to filler metal flow, fast heating rates may not allow enough time for the parts to stress relieve before the filler metal melts. You can also look at a higher-temperature brazing filler metal. It is possible that the parts would be stress relieved prior to brazing filler metal flow if a high enough temperature was reached prior to filler metal flow. Nonuniform heating can also be a factor if it contributes to a buildup of stress across the assembly. The down side to some of these heating-related ideas is that they cause you to take longer to heat the parts and take you to higher temperatures. Production rate goes down while energy and other process costs go up.

While there are many ways to approach this, the main objective is to use stress-free parts to start with then keep them as stress-free as possible during the brazing process. In your situation, this may mean annealing the parts before brazing and improving part fitup. The rest of the process may be fine. The details of your situation will dictate the optimum implementation of these ideas.

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, A5H 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.

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

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

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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Custom programs are also available.

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www.aws.org/CWSR
Friends and Colleagues:

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

For specifics on the nomination requirements, please contact Wendy Sue Reeve at AWS headquarters in Miami, or simply follow the instructions on the Fellow nomination form in this issue of the Welding Journal. Please remember, we all benefit in the honoring of those who have made major contributions to our chosen profession and livelihood. The deadline for submission is July 1, 2010. The Committee looks forward to receiving numerous Fellow nominations for 2011 consideration.

Sincerely,

Nancy C. Cole
Chair, AWS Fellows Selection Committee
Fellow Description

DEFINITION AND HISTORY
The American Welding Society, in 1990, established the honor of Fellow of the Society to recognize members for distinguished contributions to the field of welding science and technology, and for promoting and sustaining the professional stature of the field. Election as a Fellow of the Society is based on the outstanding accomplishments and technical impact of the individual. Such accomplishments will have advanced the science, technology and application of welding, as evidenced by:

- Sustained service and performance in the advancement of welding science and technology
- Publication of papers, articles and books which enhance knowledge of welding
- Innovative development of welding technology
- Society and chapter contributions
- Professional recognition

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

NUMBER OF FELLOWS
Maximum of 10 Fellows selected each year.

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

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

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

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

Return completed Fellow nomination package to:
Wendy S. Reeve
American Welding Society
Senior Manager
Award Programs and Administrative Support
550 N.W. Lejeune Road
Miami, Fl. 33126
Telephone: 800-443-9333, extension 293

SUBMISSION DEADLINE: July 1, 2010
CLASS OF 2011
FELLOWSHIP NOMINATION FORM

DATE ___________________ NAME OF CANDIDATE ___________________

AWS MEMBER NO. ___________________ YEARS OF AWS MEMBERSHIP ___________________

HOME ADDRESS ____________________________________________________________

CITY ___________________ STATE _____ ZIP CODE __________ PHONE __________

PRESENT COMPANY/INSTITUTION AFFILIATION ___________________________________

TITLE/POSITION ____________________________________________________________

BUSINESS ADDRESS __________________________________________________________

CITY ___________________ STATE _____ ZIP CODE __________ PHONE __________

ACADEMIC BACKGROUND, AS APPLICABLE:

INSTITUTION ________________________________________________________________

MAJOR & MINOR ____________________________________________________________

DEGREES OR CERTIFICATES/YEAR ____________________________________________

LICENSED PROFESSIONAL ENGINEER: YES ______ NO ______ STATE __________

SIGNIFICANT WORK EXPERIENCE:

COMPANY/CITY/STATE ______________________________________________________

POSITION ___________________ YEARS ________________________________

COMPANY/CITY/STATE ______________________________________________________

POSITION ___________________ YEARS ________________________________

SUMMARIZE MAJOR CONTRIBUTIONS IN THESE POSITIONS:

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

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

SEE GUIDELINES ON REVERSE SIDE

SUBMITTED BY: PROPOSER ___________ AWS Member No. ___________

Print Name ___________

The Proposer will serve as the contact if the Selection Committee requires further information. Signatures on this nominating form, or supporting letters from each nominator, are required from four AWS members in addition to the Proposer. Signatures may be acquired by photocopying the original and transmitting to each nominating member. Once the signatures are secured, the total package should be submitted.

NOMINATING MEMBER: ___________ NOMINATING MEMBER: ___________

Print Name ___________ Print Name ___________

AWS Member No. ___________ AWS Member No. ___________

NOMINATING MEMBER: ___________ NOMINATING MEMBER: ___________

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SUBMISSION DEADLINE July 1, 2010
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Q: How do I choose the most suitable filler metal for welding a particular aluminum base material? There are many aluminum base materials used in industry, and there are many aluminum filler metals available. It also appears that some base materials can be welded with a number of different filler metals. What are the rules for selecting the most appropriate filler metal?

A: A fundamental difference between arc welding of steel and aluminum is the evaluation method used during the filler metal selection process. There are many aluminum base materials that can be welded successfully with any number of different filler metals. The base Alloy 6061-T6, for instance, is commonly welded with at least four different filler metals and can be welded successfully with even more.

So how do we choose the filler metal that will work best for each individual situation or project? The answer to this question is that we are unable to select, with any certainty, the most appropriate filler material without a complete understanding of the welded component application and expected performance in service. When we choose an aluminum filler metal, we need to ask ourselves which of the variables associated with weld performance are of the highest importance. Also, we must realize that selection of a filler metal that is not recommended for our specific application may result in inadequate service performance and possibly premature failure of the welded joint. Filler metals for arc welding aluminum are evaluated against the following variables — Fig. 1.

- **Weldability or Freedom from Cracking.** By use of hot cracking sensitivity curves for the various aluminum alloys, and through the consideration of dilution between filler metal and base alloy, we can establish the filler metal/base alloy crack sensitivity rating.

- **Strength of Weld — Tensile or Shear.** Consideration of the transverse tensile strength of groove welds and shear strength of fillet welds, when welded with different filler metals, can prove to be extremely important during welding design and testing. Different filler metals, which may both exceed the as-welded tensile strength of the base material, can be significantly different in shear strength performance.

- **Ductility.** This characteristic of the completed weld may be of consideration if forming operations are to be used during fabrication; they may also be a design consideration for service if fatigue and/or shock loading will be factors directly associated with the weld.

- **Corrosion Resistance.** May be a consideration for some environmental conditions, and the rating is typically based on exposure to fresh and salt water environments.

- **Temperature Services.** The reaction of some filler metals at sustained elevated temperature, above 150°F (65°C) may promote premature component failure due to stress corrosion cracking. Some filler metals are suitable for service that sustains elevated temperatures, and some are not.

- **Match in Color after Anodizing.** Base alloy and filler metal color match after anodizing can be of major concern in some cosmetic applications. Some filler metals will closely match the base alloy’s color after anodizing, and others will react badly to the anodizing process and change to a color very different from that of the base.

- **Postweld Heat Treatment.** The ability of the filler metal to respond to postweld heat treatment associated with filler metal chemistry and joint design.

### Filler Metal Selection

As an example of the filler metal selection process, we will discuss three different base alloys that are to be used in specifically defined applications. We will then ask the question, “What is the most suitable filler metal to use for joining each particular base alloy within that specified application?”

We will use an extract from a typical aluminum filler metal selection chart that will show the numerous filler metals available for joining each base alloy. We will then discuss why we would choose one specific filler metal based on the welded components’ application.

In Fig. 2, we have an extruded 6061-T6 tubing that is being used as a hand railing, and the finished fabrication is to be postweld anodized.

If we examine the selection chart, in...
we have four “B” ratings and one “A” rating for the variables W, S, D, C, T, and M (see Fig. 1) that appear in the small yellow boxes along the top of the white box. The seven horizontal rows of black letters on the white background show there are seven different filler metals that can be used to weld 6061 to 6061. Each horizontal row of letters represents the filler metal aligned horizontally to its left. The top row of black letters on the white background reading from left to right is A, B, C, A, A, and blank (the blank rating is important and indicates that that filler metal should not be used if the variable for which it represents, the letter in the yellow box vertically above, is an important variable). This top line of black letters on the white background are the six ratings for filler metal 4043, which can be seen to align horizontally in the white box on the left-hand side of the chart.

In order for us to select the most suitable filler metal from the seven that are shown on the chart, we must first evaluate the application. Postweld anodizing is the principal issue to be considered when selecting a filler alloy for this application; this equates to match in color, which is the “M” variable. As can be seen, the top filler metal 4043 and the second filler metal 4643 both have a blank rating for the “M” variable and should therefore not be used for this application.

If we examine the other ratings available for the “M” variable, we will see that we have four “B” ratings and one “A” rating. The “A” rating appears against the 5356 filler metal and thereby indicates that the 5356 filler metal will provide the best match in color after anodizing; the 5356 filler metal is therefore the most suitable choice.

In Fig. 3, there is a 5454 base alloy that is going to be used at an elevated service temperature. As can be seen in the filler metal chart above, there are five filler metals that may be suitable for welding the 5454 base alloy. The most important variable to be considered in this application is temperature service (the “T” variable). Aluminum alloys with more than 3% magnesium content should not be used for service that provides prolonged exposure to temperatures exceeding 150°F (65°C) because of the risk of sensitization and the resulting susceptibility to intergranular corrosion and stress corrosion cracking. The 5454 base alloy has less than 3% magnesium content, and for this reason, is suitable for the application. If we examine the filler metal chart in Fig. 3, we will see that of all five filler metals shown as being suitable for welding 5454 base alloy, only one of them has a rating for temperature service (the “T” variable). The 5554 filler metal has an “A” rating for temperature service and is therefore the only filler metal available for this application. The other four filler metals would be acceptable for a 5454 base alloy application at room temperature, but because they all have magnesium content in excess of 3%, they are unsuitable for this particular application.

In Fig. 4, we have a typical shipbuilding application using a 5083 base alloy for the hull of a ship. The welding procedure specification is required to be qualified and groove weld transverse tensile strength must meet the minimum requirements of the welding code. The most important variable to be considered here is strength (the “S” variable). The filler metal chart shows three possible filler metals — 5183, 5356, and 5556 — as being suitable for welding the 5083 base alloy. If we consider strength (the “S” variable), we see that 5183 and 5556 both have “A” ratings, and 5356 has no rating. When we consider strength in aluminum welds, we need to recognize the difference between tensile strength, which is used to evaluate groove welds, and shear strength, which is used to determine the strength of fillet welds. In this application, tensile strength is the important issue. The 5356 filler metal will not consistently meet the minimum tensile strength requirements for the 5083 base alloy. The 5183 filler metal is the usual choice for the 5083 base alloy; however, the 5556 filler metal would also meet the strength requirement.

**Conclusion**

The most important rule for selecting a suitable filler metal for aluminum is to evaluate, in great detail, all of the variables specific to the welding application. Fortunately, there are aluminum filler metal selection charts available that have been developed to assist with the appropriate choice of filler metals. These charts have been developed through careful consideration of all the variables and often provide a rating system for each variable to help with the selection process. If there is ever any uncertainty as to the most suitable filler metal, always consult an expert.

If you would like a filler metal selection chart, you can contact me with your mailing address, and I will send you one free of charge.

Tony Anderson is corporate technical training manager for ESAB North America. He is a Fellow of the British Welding Institute (TWI), a Registered Chartered Engineer with the British Engineering Council, and holds numerous positions on AWS technical committees. He is chairman of the Aluminum Association Technical Advisory Committee for Welding and author of the book Welding Aluminum Questions and Answers currently available from the AWS. Questions may be sent to Mr. Anderson c/o Welding Journal, 550 NW LeJeune Rd., Miami, FL 33126, or via e-mail at tanderson@esab.com.
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R. Sarrafi and R. Kovacevic

References


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The author of this book is a Fellow of the American Welding Society. He developed, implemented, and managed innovative manufacturing processes based on advanced welding (electron and laser beam), brazing, and inspection technologies first for critical aerospace turbine engine components and then for other transportation products.

This book presents the author’s thesis that inappropriate application of modern management techniques destroyed a respected American manufacturing firm. He does this with ten chapters of details on how the firm, which is not identified but is referred to as “The Division,” was slowly destroyed by inept management.

He contends that it was modern business management practices that destroyed The Division because management failed to recognize the importance of maintaining the quality and safety of its products. Early on, The Division manufactured helicopter aircraft engines that were known as “the best and most dependable” that were used in Vietnam. Later, via mergers and acquisitions, The Division management implemented practices that emphasized cost reductions and profit, instead of quality and safety. These practices changed to ones that slowly, but inexorably, lost The Division’s ability to produce reliable engines. Its reputation was slowly destroyed as the quality and safety were sacrificed in pursuit of profits.

The author writes in a conversational tone and does not mince words. He uses very colorful language. Words like “hooligan,” “stooges,” “nincompoops,” and “useless” abound. The first nine chapters describe how The Division slowly deteriorates and is finally destroyed. In the tenth (and last) chapter, he outlines eight steps that summarize how he believes others can avoid the management mistakes made by The Division.

In Chapter 1, “The Inventors,” the author describes how The Division began its existence making large radial engines for the U.S. government. After WWII, German and American engineers, together, developed the first turboshaft aircraft engines. One of these helicopter engines became “the most numerous gas turbine aircraft engine in the world and one of the most dependable and respected.”

Chapter 2, “The Engines,” describes the beginning of The Division’s downfall due to its failure to correct part failures, such as turbine disk cracking and rupture.

Chapter 3, “Transitions,” describes some of the many organizational changes that were made. These changes led to aggravated hostility and finger pointing among the various departments. Because of the hostility, “what were often simple technical problems had become impossible political ones.”

Chapter 4, “Money,” points out, with great detail, that “nothing escalates costs like panic-driven expediency.”

Chapter 5, “The Shop,” discusses how pressure to reduce costs affects quality and development. It points out that “lousy quality had undermined employee pride and morale, was costing barrels of money, and, what was even more important, was costing the respect and trust of customers.”

The following chapters (Chapter 6, “Junk”; Chapter 7, “People”; Chapter 8, “Downfall”; and Chapter 9,”Reminiscences”) complete the description of The Division’s disintegration. The lessons learned, and described in Chapter 10, may be of help to practitioners of modern management theories. There is no doubt left, after reading this book, that the author believes that “contemporary management practices and attitudes are destroying America’s manufacturing capability and jeopardizing her future.”

This was an enjoyable read, almost like reading a novel. For that reason alone, I can recommend it to AWS members.♦

A. F. MANZ is a Fellow of the American Welding Society, Miami, Fla.
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The Fastcam SA4 provides 3600 frames/s operation at full pixel resolution — continued on page 95

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Welding and Postweld Heat Treatment of P91 Steels

These advanced steels are quite different from and require significantly more attention than traditional chrome-moly alloys

BY WILLIAM F. NEWELL JR.

The P(T)91 and other creep strength-enhanced ferritic (CSEF) steels are experiencing increased use around the world. There are various sources for base materials, welding consumables, and fabrication of components. The art is such that few welding problems are encountered. However, premature failures are being encountered due to design, improper heat treatment, inadequate experience, or failing to observe procedures. Heat treatment in both original component manufacture and completed welds during final installation appears to be the primary cause of premature failure. Improper design and inexperienced personnel also follow as important causes.

Welding

Provided that proper welding filler metals, welding procedures, and preheat are implemented by personnel with adequate skill, welding P(T)91 or any of the other creep strength-enhanced ferritic steels (see boxed item) is rather straightforward. In fact, if engineering and supervision have done an adequate job, welding these alloys is the easy part (Ref. 1).

Design

Designers choose CSEF steels, particularly for heavy-walled components, because of their attractive thermal, physical, and elevated-temperature mechanical properties. In addition to P(T)91, other alloys in this family include Grades 911, 92, 23, and 24 (Table 1). All of the CSEF steels are designed for use in high-temperature applications where maintaining strength and creep resistance is required. Properly manufactured CSEF components and systems exhibit significantly more strength — up to almost double — than that of their unenhanced counterparts with similar chrome and molybdenum contents. Elevated thermal conductivity offers the designer additional opportunities.

The weld metals used to join the CSEF steels are stronger, oftentimes stronger and more resistant to tempering than the base metals. Satisfactory service is obtained when weldments receive a proper postweld heat treatment (PWHT).

Many challenges and premature failures have risen because of the strength mismatch between the superior strength CSEF steel and material of lower strength. Even weldments involving P(T)91 and P(T)22 can be challenging if adequate section thickness is not present in the lower-strength material. It is even more challenging when a larger mismatch in strength or lower critical transformation temperatures exist between the two steels.

Creep strength-enhanced steels should not be used unless needed. Where required, transitions between dissimilar materials must be made in regions of the system where operating temperatures and design stresses have descended to levels within the ability of the lower-strength material to provide adequate performance. The use of machined transition or

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Based on a presentation made during the Chrome-Moly Steels Conference held Nov. 17 during the 2009 FABTECH International & AWS Welding Show, Chicago, Ill.
“pup” pieces of similar or even intermediate strength alloys is popular for mitigating such challenges.

The designer, fabricator, installer, and owner-operator all normally assume that the material is as it is marked or stamped and will perform as shown on the material test report(s). However, many instances have surfaced where “soft spots” (not decarburized surface material) or even entire components (fittings) have been identified where the material was degraded and not P(T)91 or other CSEF steels anymore. This issue was originally discovered in the course of checking (using hardness tests) to see that welds received PWHT. Now it is routine to check new base material before it is used or installed. Where this condition is discovered, two options normally exist: scrap the material or perform a normalize and temper heat treatment on the entire component.

Hardness is the means normally used to initially evaluate material. Most base material and components have code criteria for the maximum hardness. New criteria are being considered for P(T)91 and 92 to impose a 190 HBW minimum hardness level. A similar thought process may be extended to other CSEF steels. When values are discovered that are slightly less or much less than acceptable, it must be determined that measurements are not being taken in carburized surface material. Sometimes only a metallurgical examination of the microstructure will provide enough accurate information to make a proper determination (Refs. 1, 3).

**Heat Treatment**

By the very definition of a CSEF (see boxed item), these steels obtain their mechanical properties by exhibiting a specific microstructure. Assuming that the chemical composition is satisfactory, the enhanced properties or microstructure can only be achieved by proper heat treatment of components and product forms, including welds. These materials can be significantly altered by improper heat treatment to the point that they may perform significantly different than intended. For example, if P(T)91 is heated close to or above its lower critical transformation temperature, it can actually be turned into an alloy more closely resembling the significantly less strong Grade 9. Most problems are related to either not achieving adequate temperatures or exceeding permissible temperatures.

Those performing and monitoring preheat and PWHT activities must be trained, experienced, and follow formal procedures. The CSEF steels demand that heating-related tasks become a primary function and not be considered a secondary or unimportant activity. Use of AWS D10.10, Recommended Practices for Local Heating of Welds in Piping and Tubing, is becoming more common as a guide to better perform local PWHTs.

The base metals typically respond to tempering and at broader and lower temperature ranges than the weld metal. This is particularly true when P(T)91 is joined with the matching E/ER90XX-B9 compositions. The matching “-B9” filler metals do not temper as well. This is due, in part, to the fact that a narrow range exists between the minimum temperature required for tempering and the maximum permitted. This range may be as narrow as 50°F to 75°F (10°C to 24°C). The upper limit is dictated by the composition, especially the nickel plus manganese (Ni+Mn) content, which affects and depresses the lower critical transformation temperature as the sum of their weight-percent content increase. A maximum Ni+Mn content of 1.5 wt-% has been established in many domestic codes of construction. If the actual composition is unknown, the user is restricted to a tempering temperature range of 1350°F to 1425°F (730°C to 775°C). A Ni+Mn of less than 1.0 wt.-% permits the

---

**Table 1 — Nominal Compositions of CSEF Steels**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Cr</th>
<th>Mo</th>
<th>V</th>
<th>W</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>91</td>
<td>9</td>
<td>1</td>
<td>0.2</td>
<td>—</td>
<td>Nb, N</td>
</tr>
<tr>
<td>911</td>
<td>9</td>
<td>1</td>
<td>0.2</td>
<td>1.0</td>
<td>Nb, N</td>
</tr>
<tr>
<td>92</td>
<td>9</td>
<td>0.5</td>
<td>0.2</td>
<td>1.75</td>
<td>B</td>
</tr>
<tr>
<td>23</td>
<td>2.25</td>
<td>0.25</td>
<td>0.25</td>
<td>1.5</td>
<td>B, Nb, N</td>
</tr>
<tr>
<td>24</td>
<td>2.25</td>
<td>1</td>
<td>0.25</td>
<td>—</td>
<td>B, N, Ti</td>
</tr>
</tbody>
</table>

---

**Fig. 1 — Temperature gradient in heavy-wall pipe PWHT without increased heated band. Minimum ID temperature required to be 1350°F (730°C) (Ref. 5).**

**Fig. 2 — Temperature gradient in heavy-wall pipe PWHT with increased heated band. Entire ID is greater than 1350°F (730°C) minimum (Ref. 5).**

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range of 1350°F (730°C) to 1470°F (800°C). The actual code of construction must be consulted for specific rules (Refs. 1, 2).

**Thermal Gradients**

Recently, it has become apparent that due to the thermal conductivity, especially $P(T)_{91}$ and $P(T)_{92}$, the heated and soak bands need to be greater than those used (Ref. 4) on the traditional chrome-molybdenum steels and as outlined in AWS D10.10. This is especially true on heavy sections where the thermal gradient between the outside and inside of a component may be such that the inside may not be seeing the required PWHT temperatures. On a 2-in. (50-mm) or thicker section, thermal gradients of 70°F to 200°F (21°C to 93°C) are not unusual.

Therefore, verifying procedures with mock-ups or extensive monitoring of the weldment during PWHT becomes critical. Just because the outside or surface where the heaters are placed reaches temperature, it cannot be assumed that the inside or surface opposite the heaters has reached temperature. Normally on heavy or complex sections, the heated band must be increased and the maximum possible PWHT temperature used. This is illustrated in Fig. 1. The outside reached and maintained the 1400°F (760°C) target temperature, but the inside varied from 1340°F to 1360°F (727°C to 738°C). The minimum permitted temperature was 1350°F (730°C). When an extended heated and soak band is to be utilized, the required temperatures can be achieved — Fig. 2.

**Soft Spots**

Where soft spots have been found in CSEF components, most are not even near a weld. Their cause was initially a mystery; however, recent work by EPRI in a collaborative program with industry (Ref. 6) suggests such hot areas that resulted in soft spots may have initiated during heat treatment, even preheating. Figures 3 and 4 illustrate one arrangement for preheating and the resulting effect. These findings further substantiate the need for additional monitoring thermocouples, not just the minimum number recommended in AWS D10.10 or other sources.

**Weld Metal Composition — New Issue, Fabrication vs. Installation**

A new issue concerning Ni+Mn content of weld metal actually used during shop fabrication vs. the PWHT temperatures required for installation or repair has been identified. In certain parts of the world, fabrication has been conducted with weld metal with Ni+Mn contents as high as 2.4 wt-%. Weld metal with higher nickel content is used to satisfy some offshore toughness requirements. Such values will result in a lower critical transformation temperature as low as 1335°F (724°C), which would be less than that required by code or that necessary to temper “B9” weld metal. The problem arises when the installer or repair organization makes a weld near or repair of this weld metal and uses domestic (ASME) code criteria for PWHT. The PWHT could be conducted properly, but would exceed the lower critical transformation temperature of the adjacent high Ni+Mn weld metal, thus potentially degrading its properties.

It is being proposed that during manufacture of components (pipe, fittings, etc.), material specifications will limit the nickel plus manganese to 1.0 wt-% maximum to avoid this issue. Similar consideration, except a 1.5 wt-% maximum, is being given to code rule revisions. In the interim, many domestic owner-users are specifying a 1.0...
ASME and AWS

Due to the increased attention CSEF steels require, the AWS D10 Committee removed P(T)91 materials from its existing guideline publication on welding chromium-molybdenum piping and tubing (D10.8) and are preparing a new document (D10.21, which is still pending) for advanced chrome-molys and CSEF steels. Revision of D10.10 is also being considered to address thermal gradient issues being found between existing recommendations and CSEF issues. These documents are pending consensus with efforts underway to revise the appropriate sections and rules of the ASME code. Efforts at both ASME and AWS are an evolving process, and will continue to be so as more is learned about these materials (Refs. 1-3).

Supervision and Experience

Codes are rarely prescriptive and only provide what is required, not how to do it. This is intentional and appropriate — it would be impossible to cover all situations. Safety is the primary basis for our codes and standards. Attempting to displace blame for a problem or issue because “it’s not in the code” is technically indefensible. Contractually or legally it may be true, but from an engineering standpoint, such a defense is unacceptable. The problems and challenges surrounding the CSEF steels cannot be resolved with code rules alone. There is no substitute for sound engineering judgment, mock-ups, and experience. This also extends to material manufacturing and shop and project supervision for all aspects of the work. The best specification or procedure is relatively worthless unless it is followed.

These facts should be obvious, but given the frequency and nature of continued problems, the CSEF steels are not being given the respect and attention required. The CSEF steels are not like traditional chrome-molybdenum steels that are very forgiving. Too often, the root cause of observed technical problems with CSEF steels has its genesis from a commercial issue, such as lack of training (no budget), inexperienced engineering or supervision (no budget), overall budget constraints, unrealistic schedule, ignorance of the fact that CSEF steels require special attention, or the low bidder got the job. Sometimes problems arise from just plain ignorance of the rules and technical attributes required to successfully fabricate and install CSEF steels.

Summary

Base material development and code acceptance have preceded effort and research in the areas of weldment properties and welding consumables for the CSEF steels. Although the base metals can offer superior properties, these benefits can only be realized when the properties are maintained and not degraded during manufacture, fabrication, or installation. From a welder’s standpoint, the ability to weld the CSEF steels is rather straightforward. For the CSEF steels, proper preheat, PWHT, and monitoring are not optional; they are mandatory.

Lessons learned with P(T)91 weldments have truly demonstrated that these advanced chromium-molybdenum (Cr-Mo) steels are quite different and require significantly more attention than the P(T)22 and more traditional chromium-molybdenum alloys. Greater attention to weld metal selection, preheat, and demonstrated postweld heat treatment schedules are some of the reasons that the CSEF alloys must be treated differently.

Competent, experienced engineering and supervision are required to successfully obtain the mechanical properties that can be realized with the CSEF steels. All rules, technical requirements, and procedures must be followed, verbatim. Overlooking these facts will more than likely result in problems and/or premature failure.

References

5. Superheat FGH, Evans, Ga.
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Selecting an Engine-Driven Welding Machine

The applications you’ll use it for, the processes it must perform, and the environment where it will be used should be considered when choosing an engine drive

BY ERIC SNYDER

Engine-driven welding machines are typically used when electric power is unavailable for arc welding in outdoor applications. Before discussing product features for selecting equipment, you first want to ask yourself what type of applications will be performed. Consider the questions and application issues below so you can select a welding machine that is most suitable for your needs.

Construction or Repair Jobs

First ask yourself the following question: “Is this a major construction job that will last several months or longer?” If so, welding machines with industrial diesel engines may be the most appropriate choice. Diesel-powered units performing at 1800 rev/min have a longer engine life than commercial diesel engines running at 3600 rev/min due to the slower speed — Fig. 1.

Products with industrial diesel engines are higher priced, but have a longer engine life, so are considered more cost-effective over the long term. A lower price-point option is a more compact, commercial diesel machine. Both types will have longer engine life than commercial air-cooled gasoline engines.

For certain job sites such as refineries, diesel units are required because diesel fuel does not ignite as easily as gasoline. Another consideration for large projects is whether fuel is supplied at the job. If so, it is usually diesel, and the fuel cost savings can be a significant factor in choosing a diesel-powered product.

Commercial gasoline engines are typically better suited for quick repair jobs because of their portability. Gasoline welding machines can be easily transported by pushing or pulling the unit on an undercarriage. Gasoline-driven welding machines with smaller engines are often made with tube frames rather than enclosed cases. Tube frame welding machines are easy to transport short dis-

Fig. 1 — Diesel-driven, 1800 rev/min welding machines are usually the most appropriate choice for large-scale construction projects.

Fig. 2 — Extremely cold weather presents starting challenges for engine-driven welding machines.

tances with two people lifting the power source, but also can be mounted on an undercarriage for longer distances.

Gasoline-powered welding machines are lower in cost than diesel-powered products and are ideal for short-duration jobs. These machines are often preferred over diesel engines in cold weather because they start easily without the aid of ether start kits or winterized diesel fuel — Fig. 2.

Liquid propane gas (LPG) is less common, but is required when operating in areas where gasoline and diesel engines are not permitted — Fig. 3. This is typically the result of company policy limiting the type of engine that can be powered at a work environment. Liquid propane gas engine-driven welding machines are portable machines ideal for small repairs. Always operate any engine-driven equipment in open spaces with adequate ventilation.

Any of the previously mentioned types of engines may require a spark arrestor attached to the muffler exhaust tube in forest and oil service areas — Fig. 4.

**Welding Processes**

For simple repairs that require minimal setup and teardown, such as construction applications, direct current (DC) shielded metal arc welding (SMAW) is the most common choice. Because of this, all engine-driven welding machines have SMAW capabilities.

For SMAW on pipe, choose a machine specifically designed for this application — Fig. 5. A high level of operator skill is required to meet pipe welding requirements, so engine-driven machines designed specifically for pipe welding make those applications easier.

While SMAW is often the choice for short-duration jobs, wire welding is ideal for larger jobs when productivity is important. Look for engine-driven welding machines that have a constant voltage (CV) wire capability. While CV wire welding requires additional setup time and a wire feeder, it is better suited for construction projects when a significant amount of welding will be done in a stationary location — Fig. 6.

Wire welding is also appropriate for large field repair jobs to minimize downtime, such as in the mining industry, where the equipment cannot easily be taken to a maintenance shop.

Most of these welding machines have DC welding output, and scratch-start DC gas tungsten arc welding (GTAW) can normally be done with a wide variety of products. A high-frequency DC start is possible with the addition of a high-frequency generator. This is a small, portable unit often mounted to the roof of an engine-driven equipment — Fig. 7.

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Fig. 3 — Liquid propane gas-fueled welding machines may be permitted in areas where diesel- and gasoline-fueled machines are not allowed.

Fig. 4 — Spark arrestors can be added as required to protect forest and other sensitive environments.

Fig. 5 — Cross-country pipe welders demand a welding arc specifically designed for that type of work.
driven welding machine. It can also be used at the work site with a control cable extension and longer lengths of welding cable connected between the welding machine and the high-frequency generator. (For AC GTAW, see the section titled Welding with Different Materials.)

While arc gouging may not be considered a welding process, it is a common process used for repairs using engine-driven welding machines. Repair work that requires a lot of arc gouging is often performed in the 400- to 600-A range. This amperage increases productivity and minimizes downtime.

High output arc gouging requires a machine with higher output capabilities. The compressed air for arc gouging can be supplied by a separate compressor or by using a more specialized engine drive with a built-in compressor — Fig. 7 (see the section titled Special Applications).

Most of these machines can handle more than one welding process and some can handle several processes — Fig. 8.

**Welding with Different Materials**

Typically, the materials being welded are mild steel plate or pipe. For aluminum applications, an AC welding output along with a high-frequency generator is necessary to start and sustain the arc.

Most often, welding machines have DC output only and 8000 W or more of single-phase AC generator power. When attempting to tackle aluminum welding in the field with these models, it is often recommended to add a plug-in or factory-type welding machine with AC GTAW capability, powered by the engine-driven machine.

**Metal Cutting**

Engine drives with 8000 W or more (recommended) of AC generator power can be used for metal cutting. A portable plasma arc cutting machine can be powered from the AC generator. Many plasma arc cutting machines are designed to run on single-phase or three-phase power. Running a plasma arc cutting machine on three-phase power for maximum output is preferred, as plasma cutting output is often reduced for operation from single-phase power. A plasma arc cutting machine will require a source of compressed air.

**AC Generator Power**

Most engine-driven welding machines have some single-phase AC generator power and many have three-phase power as well. As previously mentioned, an engine-driven welding machine should have 8000 W or more of generator power for AC GTAW and plasma arc cutting equip-
To run a grinding machine, work lights, or other common tools, 3000 W of AC generator power is sufficient.

**Fig. 9**

Voltage Reduction Device™ systems maintain open circuit voltage below a specified level as required in some parts of the world or for use in electrically hazardous areas.

**Fig. 10**

While single-phase power is needed for AC GTAW equipment, three-phase power is the best choice for cutting thicker materials. For common welding-related applications such as grinding or powering a light, 3000 W is sufficient — Fig. 9.

**Machines Designed for Special Applications**

A variety of engine drives are specifically designed for special applications. This is particularly true for extreme environments ranging from the jungle and the desert to the salty air on oil rig platforms.

In the railroad and mining industries, the ideal choice is typically a heavy-duty engine drive that is a combination welding machine, generator, and air compressor. These units are best for arc gouging, plasma arc cutting, or powering almost any air tool. These machines include a very compact lighter weight compressor and are preferred for mounting on service trucks to save space.

For offshore oil rigs, you’ll need an engine drive for maintenance work that is rugged enough to endure the corrosive salt air. A model designed to handle this environment uses stainless steel and hot-dipped galvanized steel for the case. You’ll want a unit that also delivers great arc performance, especially for pipe welding, with 500 A of DC arc welding power.

When using equipment in remote locations such as a jungle, desert, or other high-temperature environments, you’ll want a machine designed to operate in these extreme environments. For example, Lincoln’s Big Red™ 500 and Vantage® 500-I feature a Desert Duty™ rating. This rating means the welding machine and generator can operate in temperatures up to 55°C (131°F).

Low open circuit voltage (OCV) for SMAW is an additional safety feature for some applications to reduce the risk of electric shock to the operator when welding is performed in electrically hazardous areas. Open circuit voltage has been limited to less than 32 V by countries such as Australia and South Africa. When using engine-driven welding machines in these countries, or when welding in electrically hazardous environments, consider a product that includes a device that keeps the OCV below 30 V for SMAW applications — Fig. 10. Indicator lights on the control panel show when the feature is active and when the OCV is above or below this level.

For info go to www.aws.org/ad-index
Best Practices for GTAW 4130 Chrome-Moly Tubing

Here’s a guide for welding this type of steel in general motorsports and aerospace applications

BY TODD BEVIS AND ANDY WEYENBERG

Just as a National Hot Rod Association (NHRA) drag racing team depends on a blend of team talent to win races, the material selected for a particular application requires a blend of properties to withstand the stresses involved. For a drag racing chassis, and for many other motorsports and aerospace applications, that material is 4130 chromium-molybdenum, or chrome-moly, which is selected for its blend of ductility, strength, weight, and fabrication advantages.

Advantages of 4130 Chrome-Moly Steel

The 4130 grade of chrome-moly is a high-strength low-alloy (HSLA) steel that contains molybdenum (0.15–0.25% by weight) and chromium (0.8–1.1% by weight) as strengthening agents. However, it has relatively low carbon content (nominally 0.30%).

TODD BEVIS (tb@vjcr.com) is a chassis engineer with Cagnazzi Racing, Mooresville, N.C., and ANDY WEYENBERG (andy.weyenberg@millerwelds.com) is a motorsports coordinator for Miller Electric Mfg. Co., Appleton, Wis.
When someone’s life literally depends on your welds, almost perfect isn’t good enough. Above, author Todd Bevis uses a dragster’s chassis tubing to brace himself and gain more control over weld bead placement.

so it welds, machines, and bends almost as easily as 1018 drawn over mandrel (DOM) mild steel tubing, which has an 0.18% carbon content.

Chrome-moly is not lighter than steel, a common misconception. Both weigh about 491 lb/ft³. However, as Table 1 shows, chrome-moly offers a better strength-to-weight ratio and better elongation (a measure of ductility), which enables designers to use thinner-wall and/or smaller-diameter tubing to reduce weight.

Because many motorsports, aerospace, and sporting goods applications involve welding normalized 4130 chrome-moly tubing with wall thicknesses < 0.125 in., this article focuses on best practices for these applications.

Welding Consumables and Variables

Table 2 summarizes the welding procedures, consumables, and variables required for most tubing applications. The images and text that follow expand on this information to provide further clarification and guidance.

Perfect Fitup

When welding thin-wall tubing, whether chrome-moly or other metals, the welders at Cagnazzi Racing in Mooresville, N.C., joke that their tolerances range from perfect to almost not perfect. That is, if the parts don’t fit perfectly, they start over because thin-wall tubing does not have sufficient mass to absorb excess heat.

The usual trick to filling root openings with gas tungsten arc welding (GTAW) is to use a larger-diameter filler rod. However, larger rods require more heat, and excess heat promotes melt-through, warping, carbide precipitation, and embrittlement. Using a larger rod might be an acceptable solution in a noncritical application, but it’s a poor practice when welding chrome-moly. An example of perfect fitup, with the proper diameter filler rod shown for perspective, is displayed in Fig. 1.

Consistency

The company uses hundreds of jigs and fixtures bolted to a surface that is flat to within a few thousandths of an inch for fabricating even the smallest items to help ensure tight fitup and consistent tube placement, which provides repeatability — Fig. 2.

By producing a new chassis nearly identical to the previous one, the crew chief can hone his craft of gear ratio and clutch management without worrying about a new chassis introducing unknown variables. Many fabricators believe that they cannot afford to build fixtures for all of their components or larger weldments. However, if repeatability and accuracy are important, good fixturing is mandatory.

Coping Mechanism

Most of Cagnazzi Racing’s jigs have a go/no-go type fit, which enables small incremental adjustments to get an exact fit.

After cutting to approximate length with a band saw, a tube notcher is used for rough coping — Fig. 3. The fabricator then checks the length and uses a drum sander to create a perfect fit by slowly sanding away excess metal from the mouth of the tube — Fig. 4. Before welding, the fabricator deburrs the edge, cleaning back 1 in. from the edge using Scotch-Brite™ or 120-grit sandpaper, then removes oils or other contaminants with a solvent — Fig. 5. It is necessary to wear nitrile gloves, as the natural oils from your fingers can ruin a weld just like grease or cutting fluid. Likewise, use sandpaper and solvent on the filler rod, too.

Filler Metal Selection

In many motorsports and aerospace applications, engineers want some degree of ductility in the weld to help absorb impacts and prevent cracking. For this reason, most NHRA fabricators intentionally dilute the strength of the base material by selecting an ER70S-2 filler metal for roll cages, chassis, and other applications re-
Chrome-moly requires a perfect fitup. An appropriate diameter filler rod is shown for perspective.

Jigs such as this ensure consistency and repeatability.

Fig. 2 — Jigs such as this ensure consistency and repeatability.

Diameter filler rod is shown for perspective.

Good fit.

Fig. 3 — Demonstrating the process of notching a tube.

Using a drum sander to create a good fit.

Fig. 4 — Using a drum sander to create a good fit.

Before welding, a solvent can be utilized to remove oils.

Fig. 5 — Before welding, a solvent can be utilized to remove oils.

Filler rod diameters should match the thickness of the base metal. Displayed are those featuring small diameters.

Fig. 6 — Filler rod diameters should match the thickness of the base metal. Displayed are those featuring small diameters.

Successfully welding 4130 requires preserving its mechanical properties by heating and cooling the weld in a controlled manner. Excess heat causes carbide pre-

Heat Control

As for the filler rod diameter, use a rod diameter that matches the thickness of the base metal. Trying to weld 0.035-in. tubing with a ¾-in. (0.063-in.) rod is a bad idea because the tubing wall will melt before the filler rod is up to temperature. Predominantly, the company uses 0.030-, 0.045-, and 0.063-in. (¾”) filler rods, with 0.045 and 0.063 being the most common — Fig. 6. For thicker, larger-diameter tubing, it uses ½- and ¾-in. rods.

Fig. 7 — Welders should hold an arc length to ½ in. or less.
Pool Size and Arc Length

While welding too slowly increases overall heat input, operators should not necessarily focus on welding travel speed. Rather, they should focus on controlling their body (see lead photo) as well as the pool size by making it only as wide as necessary, and holding a tight arc length of ⅛ in. or less — Fig. 7.

No Slacking Allowed — Ever

The authors of this article weld 4130 tubing in critical applications, and they have a combined 50 years of welding experience. As such, they take every step of the fabrication process seriously. Close enough is simply not good enough for NHRA or aerospace work, nor should it be for even a child’s go-kart or bicycle.

While professionals weld most chrome-moly tubing, the aspiring chassis fabricator or experimental aircraft enthusiast can weld it at home. In any circumstance, follow proper procedures and any applicable codes and standards.

Table 1 — A Comparison of 4130 Chrome-Moly to 1018 Drawn over Mandrel (DOM) Tubing (Cold Drawn, Normalized State)

<table>
<thead>
<tr>
<th>Material</th>
<th>Tensile Strength</th>
<th>Yield Strength</th>
<th>Hardness, Rockwell B</th>
<th>Elongation</th>
</tr>
</thead>
<tbody>
<tr>
<td>4130 Chrome-Moly</td>
<td>97,200 lb/in.²</td>
<td>63,100 lb/in.²</td>
<td>92</td>
<td>25.5%</td>
</tr>
<tr>
<td>1018 DOM</td>
<td>63,800 lb/in.²</td>
<td>58,700 lb/in.²</td>
<td>71</td>
<td>15%</td>
</tr>
</tbody>
</table>

Table 2 — Summary Advice for Welding 4130 Chrome-Moly

<table>
<thead>
<tr>
<th>Material</th>
<th>4130 chrome-moly tubing (normalized).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness</td>
<td>&lt;0.125 in. Most chassis tubing has a wall thickness ranging from 0.035 to 0.083 in. and diameters from ¼ to ½ in.</td>
</tr>
<tr>
<td>Amperage</td>
<td>1 A/0.001 in. of wall thickness.</td>
</tr>
<tr>
<td>Polarity</td>
<td>DC electrode negative. HF for arc starts only.</td>
</tr>
<tr>
<td>Filler Material</td>
<td>ER70S-2 or ER80S-D2.</td>
</tr>
<tr>
<td>Filler Diameter</td>
<td>0.030–⅛ in. Generally, do not use a rod larger than the thickness of the base metal.</td>
</tr>
<tr>
<td>Tungsten Type</td>
<td>2% type (ceriated is first choice, then thoriated).</td>
</tr>
<tr>
<td>Tungsten Diameter</td>
<td>⅛–½ in. (smaller diameter for thinner wall).</td>
</tr>
<tr>
<td>Arc Length</td>
<td>Less than or equal to the electrode diameter. Generally, the tighter the better, as shorter arc lengths reduce heat input.</td>
</tr>
<tr>
<td>Electode Extension</td>
<td>No farther than the distance of the inside diameter of the cup being used. However, using a gas lens can extend this distance.</td>
</tr>
<tr>
<td>Gas Lens</td>
<td>Not required, but helpful if a tight joint configuration demands a longer electrode extension or involves multiple tubes. Keep the screen free of debris and spatter.</td>
</tr>
<tr>
<td>Shielding Gas</td>
<td>100% argon, 15–20 l/h. More is not better, as turbulence could suck atmosphere into the weld.</td>
</tr>
<tr>
<td>Preflow</td>
<td>0.4 to 0.6 s.</td>
</tr>
<tr>
<td>Postflow</td>
<td>10–15 s.</td>
</tr>
<tr>
<td>Backing Gas</td>
<td>Follow applicable codes/standards, if any; not required for NHRA applications.</td>
</tr>
<tr>
<td>Preheat</td>
<td>Not required as long as tubing is above 60°F.</td>
</tr>
<tr>
<td>Tack Welds</td>
<td>Four tacks made 90 deg apart; tacks ideally should be longer than wide.</td>
</tr>
<tr>
<td>Joint Preparation</td>
<td>Tubing notcher for coping, drum sander for final fitup, deburring for edge preparation, Scotch Britte ™ or 120-grit sandpaper to clean about 1 in. back from the joint, and final clean with acetone, laquer thinner, or similar solvent to remove oil.</td>
</tr>
<tr>
<td>Joint Opening</td>
<td>None! Realistically, openings smaller than 0.010 are permissible; large openings promote poor quality.</td>
</tr>
<tr>
<td>Weld Size</td>
<td>Keep welds to within their specified size: A weld needs to be no larger than its thinnest section, which will be the “weakest link” in the chain. Larger-than-necessary welds add excess heat and waste gas, filler rod, and time.</td>
</tr>
<tr>
<td>Weld Technique</td>
<td>Weld in one continuous motion, pulsing the foot control and adding filler rod to create the “stack of dimes” appearance (or use the machine’s pulsing controls). Do not stack separate pools on top of each other, as this may lead to incomplete fusion.</td>
</tr>
<tr>
<td>End-of-Weld Procedure</td>
<td>Avoid pinholes by tapering off heat input at the end of the weld maintaining a constant distance between the tungsten and the weldment.</td>
</tr>
<tr>
<td>Weld Appearance</td>
<td>A good weld looks shiny and has a bluish tint. A dirty, gray-looking weld may indicate poor shielding gas coverage or excess heat.</td>
</tr>
</tbody>
</table>
Examples are presented that simplify the complex welding of Cr-Mo steels

Successful welding of Cr-Mo steels requires proper design, material selection, and quality control throughout all phases of engineering and construction. Early welding of Cr-Mo materials, pre-1950s, varied little in technique from low-carbon steel welding. Producing high-quality welds was difficult and quickly generated research into the effects of hydrogen, material chemistry, vessel design, and post-weld heat treatment (PWHT). The past half-century yielded significant advancements in consumables and methods to reduce hydrogen effects in welding. Modern welding techniques, including pre-heat, postheat, and PWHT, provide a repeatable methodology producing high-quality welds in both the shop and field construction. The lessons learned throughout the industry provide the base knowledge for construction codes and

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standard practices such as API 934-C, Materials and Fabrication of 1/4 Cr-1/2 Mo Steel Heavy Wall Pressure Vessels for High-Pressure Hydrogen Service Operating at or below 825°F (441°C).

Applications

ASTM SA-387, Grade 11 defines the 1/4 Cr-1/2 Mo steels. Minor additions of the elements Cr and Mo, to standard carbon steels, provide creep resistance at elevated service temperatures. Typical plate structures, utilizing SA-387, Grade 11 material, include reactor vessels and coke drums for refinery operations (Fig. 1), and basic oxygen furnaces for steel mills. These large structures have wall thicknesses from 1 to 3 in. (25 to 75 mm), are 22–36 ft (6.7–11 m) in diameter, and between 80 and 120 ft (24 and 36 m) high. Coke drums endure the most severe cyclical thermal service with temperatures reaching as high as 1000°F (538°C) followed by a water quench. Typical service allows for two thermal cycles per day and an estimated vessel lifespan of 3000 cycles. Figure 2 shows an extreme example of a coke drum replaced after seven years in service. Bulging of the vessel was caused by thermal fatigue exacerbated by the differential yield strength between the base metal and weld. Higher-strength weld metal has a stiffening effect, resulting in stress concentrations, and ultimately leads to distortion and later cracking (Ref. 1). The lifespan can be prolonged, without changing the base material, by lowering the quench rate, matching the weld metal yield strength to the base material, and minimizing residual stresses. Current standards for vessel design, fabrication, and construction have developed from more than 60 years of experience.

Early Welding

Early Cr-Mo vessels, including stainless steel clad vessels, were welded and placed into service beginning in the mid-1940s. Plate material was not standardized, but was typically designated as SA-301 material, which later evolved into the SA-387 grade. Low-hydrogen shielded metal arc welding (SMAW) electrodes were not manufactured at that time; therefore, cellulose-covered electrodes such as E7010, E8010, and E9011 containing additions of Cr and Mo were used. Clearly, weldability was poor compared with modern standards, but quality welds were still possible with highly trained welders. Radiography, still in its infancy, was used extensively on Cr-Mo vessels. Some of the first vessels with 100% radiography were coke drums and reactors. Notable vessels from CB&I history include a large Houdriflow Reactor built in El Segundo, Calif., in 1950. The plates were SA301 Grade B and welded using E8010 with additions of 1% Cr-0.5% Mo. Historical construction documents show that obtaining uniform preheat was difficult, but an important factor in producing acceptable welds. Repairs were especially prone to cracking, due to the localized heating and the relatively high hydrogen content of the cellulose-coated electrodes. By 1954, low-hydrogen electrodes were introduced that vastly improved the weldability and crack resistance of these materials. After the first decade of Cr-Mo welding, three major considerations were identified:

- Hydrogen contamination
- Temper embrittlement
- Stress concentrations

Recognition of these common factors, which often led to cracking during construction and a shorter, usable vessel lifespan, prompted research to improve the welding processes.

Limiting Hydrogen Contamination

Hydrogen control begins with the consumable manufacturer. The SMAW consumables are supplied in hermetically sealed containers with tested hydrogen levels. Once opened, proper electrode storage must be followed per the manufacturer’s guidelines. Uncontrolled exposure to the atmosphere can lead to hydrogen absorption by the flux that could be introduced into the weld. The now common E8018-B2 electrodes, used in conjunction with ovens, introduce minimal hydrogen into a weld. By 1960, field construction organizations were using elec-
Controlling Temper Embrittlement

Base material and electrode chemistry play a major role in both vessel constructibility and its service application. Temper embrittlement is defined as a decrease in toughness when the material is heated or cooled through the 570°-1110°F (300°-600°C) temperature range (Ref. 2). This temperature range coincides with the thermal cycling that a coke drum experiences in service. In addition, the unintentional additions of silicon, phosphorus, tin, antimony, and arsenic can increase the susceptibility to temper embrittlement.

In the late 1960s, CB&I researcher Robert Bruscato examined Cr-Mo weld deposits and quantified the relationship between these trace impurities and their effects on temper embrittlement. The now common Bruscato temper embrittlement factor, $\bar{X}$, can be calculated using the following formula, where elements are given in parts per million (ppm) (Ref. 3).

$$\bar{X} = \frac{10 \cdot P + 5 \cdot Sb + 4 \cdot Sn + As}{100}$$

The accepted limits are $\bar{X} \leq 15$ for coke drums; however, critical applications of higher-alloyed Cr-Mo materials may require $\bar{X} \leq 12$. Modern material processing facilitates the production of base materials and consumables with low levels of these undesirable “tramp” elements. Fabricators and end-users must be vigilant in defining material limits for proper procurement of high-quality products.

Minimizing Stress Concentrations

Stress concentrations are responsible for a variety of crack-related failures and must be minimized by design. Elimination of circumferential or girth seams in the vessel shell of the coke drum eliminates the strength mismatch between weld and base metal, thereby lessening the effects of thermal fatigue. Vertical Plate Coke Drum ™ technology, a proprietary design from CB&I, allows for shell sections up to 46 ft (14 m) in height — Fig. 3. Vertical plate design, whether applied to vessel replacement or a new process unit, will outlast conventional “can section” designs due to the elimination of stress concentrations at the girth seams.

A weld profile can also affect local stress concentrations. All welds must be profiled to eliminate sharp transitions and excessive reinforcement. Grinding inte-
rior weld joints, especially girth joints, to a flush, smooth and blended finish is common practice in coke drum fabrication.

1¼ Cr-½ Mo Welding Challenges

Advancements in the processes used for manufacturing welding consumables, driven by the need to limit trace elements and lower diffusible hydrogen, have given the industry many good options for welding Cr-Mo materials. Most SMAW consumables can easily meet the X < 15 requirements, while providing excellent weldability. Modern submerged arc welding (SAW) electrodes also have excellent chemical makeup. When used in conjunction with significantly improved SAW fluxes, these consumables result in minimal cracking, smooth weld beads, and good operator appeal. The AC waveform control used in SAW is a recent modification to the process. This AC waveform technology allows greater control of the depth of penetration and deposition rates, while using the same consumable/flux combination. These techniques are easily applied to shop-built vessels decreasing production time. While significant improvements have already created good consumables for SMAW and SAW, flux cored arc welding (FCAW) remains a new product to the market. History shows that careful material evaluations are required to ensure that all design requirements are met by any new product.

Preheat and postheat methods are always being pushed for faster application while providing improved energy efficiency. Heating rates and temperature control can be improved with modern gas burners and electric resistance heaters formed to fit the vessel shell — Fig. 4. As previously noted, PWHT must consider the temper of the plate material, as surpassing this temperature may have detrimental effects on the mechanical properties. Owners and end users often require multiple thermal cycles, allowing for subsequent repairs followed by PWHT, thereby increasing the life of the vessel. Retaining mechanical properties after several PWHT operations is difficult for both the base materials and the welds. Ultimately, the vessel is limited by the material to which it was designed and the conditions of its operation.

Summary

Significant advancements over the past half-century have made 1¼ Cr-½Mo steels readily weldable. Ongoing research is pushing to increase productivity by enhancing the deposition in AC waveform-controlled SAW and new FCAW consumables. Material and design improvements are continually pushed by the desire for steel plate structures with longer lifespans. Innovative designs, such as the vertical plate coke drum, provide fundamental engineering improvements, while quality consumables limit the introduction of detrimental elements. Whatever the future holds, three basic factors must be controlled to produce quality products: hydrogen contamination, temper embrittlement, and stress concentrations.

References

Liebherr tower cranes dominated the landscape of building sites in Germany during the boom construction years after 1949. Nowadays, the globally active family-owned company also supplies maritime customers from its facilities in Nenzing in Austria, Rostock in Germany, Killarney in Ireland, and Sunderland in England. Its customers include shipyards, shipbuilders, operators of offshore platforms, and consulting engineers.

The Sunderland plant is located on the site of a former shipyard whose industrial history dates back to 1793. The Liebherr Group acquired the factory and equipment in 1989. With 200 employees, 150 of whom work in production, the site is the smallest of the four production sites. A total of 3000 people work for Liebherr’s maritime division.

Manfred Fiedler, welding manager at the parent site in Nenzing, explains: “Welding is our key technology.” Investing in the recruitment of more well-qualified young welders highlights the importance of the role that welding plays in Sunderland.

**Welding and Testing Requirements**

The crane boom is subject to extreme loads. Pipes and structural shapes that make up the crane must have both structural stability and flexibility.

Weld discontinuities that could lead to the failure of a component are not acceptable. The cranes, made of high-strength, fine-grained structural steel, are often exposed to harsh weather conditions at sea and operate at maximum dynamic stress levels. The strength of the weld is central to the quality of the products.

Safety is of top concern, and for this reason, virtually every welded joint is tested using nondestructive testing methods — visual checks, ultrasound, and X-ray. The customer’s personnel also approve welds.

*GERD TROMMER is an editor in Gernsheim, Germany. Additional information is available from Fronius International GmbH (www.fronius.com).*
that have a key function on the cranes.

Gas metal arc welding (GMAW) is the main process employed at Sunderland, although submerged arc is also used. Pulsed gas metal arc welding is a favored process. High-quality welding power sources are required to join the steel plate.

The plates are made of a special high-strength steel (S690 QL), and the various components are between 15 and 130 mm thick — Fig. 1. Following preheating to a temperature of 150°C (302°F), the joining process uses a welding current of up to 300 A — Fig. 2. Multipass welding in V grooves is used for components up to 130 mm. Mainly digital power sources, such as those used for pulsed arc welding are used, although a few robust analog machines, some of them 20 years old, are still in use. However, the welding machinery and equipment are subject to heavy work loads and are replaced regularly.

Selecting Equipment

When it came time to replace existing welding equipment, the technical team paid particular attention to the welding systems from Fronius, a company based in Wels in Upper Austria. The workers inspected the company's systems thoroughly and critically. Initial tests showed that they worked well, and the decision was made to go with them. The focus was on acquiring multipurpose machines.

The systems had to be, as far as possible, suitable for all the processes used by the department. The pulsed-arc welding process is particularly important. Controlled droplet detachment is part of the pulsed arc welding process, and it is adjusted to suit parameters such as base and filler metal and the type of shielding gas used. This results in optimized current waveforms that produce a better weld quality and less spatter, reducing the cost of finishing or rework. Currently, the Liebherr facility in Sunderland includes seven TransPuls Synergic 5000 water-cooled systems. These power sources are digitized, microprocessor-controlled inverter power sources. They form the central unit of the welding system and its peripherals.

As a result of their positive experiences, it has been decided to launch a project to research an automated robotic system.
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American Welding Society
Using Competency Models to Build a Career Ladder in Welding

Tools are presented that can help schools prepare students for the skilled welding jobs industry will need filled in the future

BY DAVID W. DICKINSON

Most of us believe that continuing education leads to career advancement and that leads to the increased strength and health of our technical/manufacturing society. However, how do you determine the knowledge, skills, and abilities a person needs to succeed first in school and then later on the job?

The Problem

In 2007, Harry Holzer (Ref. 1) headed a group that conducted a survey to determine the future job distribution between low, middle, and high skill level applicants. Figure 1 shows that only 22% of the jobs will go to those trained at a lower skill level while the remaining 78% will go to applicants trained to a higher skill level. An additional survey (Ref. 2) examined workers over 25 having more than a high school education beginning in the 1970s and projected through 2020. These results showed a 19% increase in high school graduates between 1980 and 2000, but the number of high school graduates has leveled off with only a 4% increase between 2000 and projected to 2020. With the leveling off of high school graduates coupled with the increased demand for higher skill-level job applicants, the problem we will face in the next decade is a shortage of workers trained for the challenging jobs of the future.

A second survey conducted last year in Ohio (Ref. 3) further confirmed these findings — Fig. 2. In Ohio, 72% of the urgent job-filling priorities are related to manufacturing technician level positions. These also represent the medium to high skill training levels. The problem is clear: Where are we going to find entry-level applicants with the required skill levels to fill these most urgently needed jobs?

Over the last decade, some efforts have been initiated to help recruit and train high school students in preengineering courses. High schools in all 50 states are using Project Lead the Way (Ref. 4) courses. Students who complete this series of courses actually earn college credits. Organizations like the National Academy Foundation (Ref. 5) have accepted the courses as the basis for their high school engineering academies.

Industry’s View of Workforce Needs

The U.S. Department of Labor (DoL) has established a template to represent industry’s view of workforce needs (Refs. 6, 7). This template is called a “competency model.” These models were originally introduced by David McClelland in 1973 (Ref. 7), and their basic design is presented in Fig. 3. As can be seen, these competency models graphically display the knowledge, skills, and abilities needed to successfully perform at work, in school, and in everyday life (Ref. 6).

The model consists of nine tiers of competencies as shown in Fig. 4. The lower tiers represent foundational characteristics; the middle tiers are industry-related competencies; and the top tiers are occupation-related competencies.

We’ll look at typical characteristics contained in each of these levels.

As illustrated in Fig. 5, the Foundational level of personal effectiveness learning objectives include interpersonal skills, integrity, professionalism, initiative and motivation, dependability and reliability, and willingness to learn.

In the first Academic competency level characteristics such as reading, writing, mathematics, science and technology, critical and analytical thinking, active learning, and communication are present.

Continuing to the Workplace competency level (Fig. 6), we find learning objectives like teamwork, adaptability, flexibility, customer focus, planning and organization, creative thinking, problem solving and decision making, working with tools and technology, using computers, keyboarding and word processing, scheduling and coordinating, checking, examining and recording, and accessing and updating computer files.

In the Industry-Wide Technology competencies (Fig. 6), we find production, maintenance, installation and repair, manufacturing process development/design, supply chain management, quality assurance/continuous improvement, and health and safety.

All the learning objectives up to this point are needed by workers across the entire advanced manufacturing industries and so are of great interest to the Dept. of Labor and all industry specialists interested in preparing students for tomorrow's advanced technology jobs. The DoL
The Problem

Fig. 1 — Surveys indicating the need for high skill-level employees and the lack of educational training.

Fig. 2 — An Ohio survey confirming the need for manufacturing technicians.

Industry’s View of Workforce Needs

Competency Model Definition

Competency models graphically display the knowledge, skills and abilities needed to successfully perform at work, in schools and in everyday life.

Fig. 3 — The competency model definition.

Fig. 4 — The foundational, industry, and occupational levels of the competency model.

has set up a committee from the advanced manufacturing sector to review these learning objects every year in order to integrate any new advances into these fundamental objectives.

This brings us to the upper level tiers in Fig. 7, which are unique to each specific industry. In the welding industry there should be at least three different competency models: one for the welder, one for the welding technician, and one for the welding engineer. In actuality, there may be several other competency models for other specific job functions within welding.

Weld-Ed is a National Science Foundation Advanced Technological Education Center for the advancement of materials joining technology. Weld-Ed Center partners in cooperation with the American Welding Society (AWS) undertook the process of developing these three basic models. As a starting point, it was determined that the content of the upper level tiers in each case should follow exactly the educational codes and standards AWS has already developed.

Three models were produced, and a series of learning objectives was developed and included on a spreadsheet for each of them. The spreadsheets were then sent to approximately 20 experts in each of the job functions for verification purposes. Those experts then ranked each learning objective.

The validated models are now being added to the DoL Competency Model Clearinghouse Web site (Ref. 6).

Workforce Training as Seen by Educators

The educator’s view of the problem is somewhat different from that of industry. Educators use a scheme called Bloom’s Taxonomy to describe the teaching and learning effort (Ref. 9). Bloom described three types of learning growth or learning domains, which are as follows:

1. Cognitive: mental skills (knowledge)
2. Affective: growth in feelings or emotional areas (attitude)
3. Psychomotor: manual or physical skills (skills).

Although the growth in attitude is extremely important, for the training of welding professionals, let us look more closely at the cognitive and psychomotor domains — Fig. 8.

The first three steps in the Cognitive Domain are often referred to as the entry...
level of knowledge attainment. They include the following:
• Knowledge in which the student is asked to list or recite facts
• Comprehension in which students are expected to explain in their own words or paraphrase the facts they just learned
• Application in which the student is expected to calculate or solve a problem using the comprehended facts, or determine how to apply those facts to making a better product or process.

The psychomotor domain is related to learned skills or dexterity, and consists of a series of learned skills. These start with “Perception” where the student selects an action or a procedure, continues to “Set” where the student sets up the manual skill task or laboratory, continuing to a “Guided Response” where the student performs the skill under guidance, followed by “Mechanism” where the student routinely performs the task smoothly and competently.

A student’s comprehensive learning is actually a balance between the domains. A student who concentrates on the psychomotor domain skills becomes expert in performing manual skills. Many companies like to hire these students because, when given an assignment, they are competent and get the job done with little on-the-job training. However, in a changing world with ever-developing technology, these students may require retraining on new products or processes within a few years.

On the other hand, students who concentrate on the cognitive domain become very useful in a changing world as they have developed knowledge that follows along as technology changes. However, at startup they may require more on-the-job training to get up to speed.

**Link between Industry’s and Educator’s Views**

Let us see if there is a link between these two views, especially as related to the welding industry. When we look at the three competency models previously developed, i.e., welder, welding technician, and welding engineer, and compare them with the balance in Bloom’s Taxonomy, we find an interesting link — Fig. 9. The welder, who has concentrated on psychomotor- or skills-based learning, represents the person who can immediately contribute to getting the joining task done. This doesn’t presuppose that this person has little or no cognitive knowledge, but only that the concentration of learning was on the motor skills with the cognitive contribution added where needed to make this person a good welder.

The welding engineer, on the other hand, has had some skills training in supervised laboratories, but the bulk of the training has been in the cognitive knowledge area. This is the person who will be developing our new products and processes by applying his or her knowledge to invent, design, and improve.

The welding technician stands between these two levels. This person strives to balance skills- and knowledge-based learning. The technician will be capable of developing welding procedures and supervising welders while interpreting the new developments of the engineer.

The bottom line is that within the welding industry there exists a need for all three types of individuals, and it is up to us to understand how to best train each and to provide an educational career path for our most promising students.

**Using the Models**

Understanding the three different competency models and their relationship to Bloom’s Taxonomy, the educator and industry representative can form a bond to check out the curriculum being offered at each institution or develop new curricula to better meet the needs of industry.
Referring to each competency model as illustrated on the DoL clearinghouse Web page, you can examine the full list of learning objectives for each tier level (these are also available from the spreadsheets mentioned previously at the Weld-Ed Web site www.weld-ed.org).

**Developing a Career Path: The Gap Analysis**

Using the learning objectives and thus developing curricula for the welder, technician, and engineer, we can begin to compare the competency models with one another to determine the additional learning needed to progress between job functions. This is called a gap analysis and is represented schematically in Fig. 10. In this particular figure, we are looking at the gap between the welding technician and welding engineer. We see that in the lower tiers, the advancing student would have to study some advanced mathematics, some technical writing topics, and perhaps some additional basic education requirements such as English and history. In tier 5, the first of the welding-industry-specific tiers, the student would need additional graphics and computer applications and some advanced studies in chemistry and physics (these will most likely be calculus based). Moving up to tier 6, we see some topics on strength of materials, heat transfer, heat sources, arc physics, fluid mechanics, metallurgy, electricity, and non-destructive evaluation. Finally, in the top tiers, some topics related to training of others and research and development may be needed.

Weld-Ed has examined the gap analysis between the AWS-recommended codes and standards for the entire range of welding industry job functions and has presented these in tabular form. A brief part of that table is presented in Fig. 11. The columns in the table labeled W1 through W3 represent the AWS SENSE program Levels 1–3 (entry, advanced, and expert welder). The AWI, WI, and SWI columns represent, respectively, learning objectives needed for the Certified Associate Welding Inspector, Certified Welding Inspector, and Senior Certified Welding Inspector. WT represents the welding technician, and WE represents the welding engineer.

**Assessing Outcomes**

Now that we have the learning objectives outlined and are working on development of courses, laboratories, and skills exercises to train the student toward industry’s needs, we must be able to assess the students’ outcomes to be sure they are meeting the objectives. First, however, we need to define the objectives we wish to meet. There are three levels of outcomes.
The most overreaching outcome is the Program Educational Goal. These are broad statements describing career and professional accomplishments graduates achieve upon completing all the required courses in the curriculum. An example of one of these goal statements might be, “The student can weld safely in shop and field operations.”

Next is the Course Outcome. These are narrower statements describing what students can do by course completion. An example: “To apply safety procedures to shop, occupational, and personal safety.” These are sometimes called “summative” assessments because they sum up the learning outcomes in an entire course. Well-planned and delivered courses have these summative assessments in the form of a final exam for cognitive learning or a certification for psychomotor skills learning.

The third outcome is narrower yet and describes a minimum level for a student to be considered proficient every day. For example, “On a daily basis demonstrate the ten rules of shop safety with 100% accuracy.” This type of assessment is often called a “formative” assessment.

As illustrated in Fig. 12, in order to completely assess the effectiveness of each course offering, one needs to have a document of competencies or outcomes that the course is designed to obtain for every subject taught, and the assessment techniques to be used must be enumerated. In addition, this needs to be done for both domains (the cognitive and the psychomotor).

An example of part of a course competency document is presented in Fig. 13. This document is for a Weld-Ed course titled Introduction to Materials Joining under consideration for a welding engineering curriculum. The entire document can be found at www.weld-ed.org and then clicking on the curriculum folder.

Note that this section of the document describes one of the many competencies to be taught in the course, in this case competency 2.1, which is “Contrast the classification of arc welding processes and describe how they fit in all fusion welding processes.” Note also that the active verbs “contrast” and “describe” in this particular competency fit well within Bloom’s cognitive domain at the second step called “comprehension.” Thus the student completing this competency is well on the way to comprehending and explaining this bit of technology. Note that there are also some key indicators listed on this table that more fully describe activities that lead to the contrasting and describing in Competency 2.1. They include recognizing the fusion welding classification chart, describing different fluxes, and differentiating between consumable and nonconsumable electrodes.

Since this competency performance objective is part of a course to be used in an engineering curriculum, the first step is to be sure that it meets at least one of the full program educational curriculum goals. In this case, it is Goal 2A (highlighted in yellow) to “describe fundamental operating theory of the various materials joining processes including arc, resistance, solid-state, and high-energy-density welding” (Level 3).

In order to be sure that this competency 2.1 meets the needs of industry (highlighted in pink), it has been reviewed...
Putting It All Together

Having examined all the pieces for a full curriculum, it is time to look at ways of putting it all together. The first step is to determine for which job function training is needed: welder, welding technician, or welding engineer. Selecting the proper competency model is a good start, followed up by some assistance of the Weld-Ed Center.

The National Science Foundation established the Weld-Ed Center to be a national partnership of colleges, universities, professional societies, government, and private industry committed to increasing the number and quality of welding and materialsJoining technicians to meet industry demand. Over the past two years, the center has been collecting courses offered by its partners to be made available to other educational institutions. These courses have been divided into a number of categories, some basic core-type courses and some technical electives that might be used by institutions in different regions of the country to personalize the training students receive to meet the needs of that particular region. Several hundred courses have been collected and descriptions of these are available at www.weld-ed.org.

The Career Ladder

A career ladder is graphically illustrated in Fig. 14. One side of the ladder shows advancement through structured advanced educational degrees, while the other side shows advancement by way of industry or society certifications.

Weld-Ed and the American Welding Society stand ready to assist students, parents, and faculty to identify career paths through the use of the school locator on the AWS Web site at www.aws.org.

References

3. Central Ohio 2009 Skills Bank Survey, Columbus, Ohio.
REACH NEW MARKETS!

3 Great Shows Come Together in Mexico City, May 11-13, 2010

Manufacturing, construction and energy jobs are growing in Mexico, demanding new equipment, services and technologically advanced products. The co-located AWS Weldmex, Fabtech Mexico and Metalform Mexico trade shows provide an opportunity to reach new markets and buyers in the most important business region in Latin America.

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marcela.ordaz@tradeshowconsult.com
Static Loading of Welds

Welds are sized for their ability to withstand static or cyclic loading in accordance with AWS D1.1, Structural Welding Code — Steel, to ensure that a soundly welded joint is able to support the applied load for the expected service life. Design strengths of welds for various types of static loading are normally specified in the applicable standard for the job. These are usually based on a percentage of the tensile or yield strength of the filler or base metal. The allowable stress range for cyclic loading is also normally specified in the applicable standard for the job.

Static Loading

The various types of static loading are shown in Fig. 1. Complete joint penetration (CJP) groove welds, illustrated in Fig. 1A–D, are considered full-strength welds because they are capable of transferring the full strength of the connected elements. Providing matching strength weld metal is used, the design strength of such welds are the same as those in the base metal. In CJP groove welds, the mechanical properties of the filler metal selected must at least match those of the base metal. If two base metals of different strengths are welded together, the selected filler metal strength must match or exceed the strength of the weaker base metal.

Partial joint penetration groove welds, which are shown in Fig. 1B, C, E, and F, are widely used for the economical welding of thick sections. These welds not only lead to savings in weld metal and welding time, but they can also provide the required joint strength. To avoid cracking in the weld or the heat-affected zone, the minimum weld size should provide adequate process heat input to counteract the quenching effect of the base metal.

Various factors should be considered in determining the design strength of the throat of partial joint penetration groove welds. One factor is joint configuration. The effective throat of a prequalified partial joint penetration groove weld is the depth of the groove when the groove angle is 60 deg or greater at the root of the weld. For groove angles of less than 60 deg, the effective throat depends upon the welding process, welding position, and groove angle at the root. The provisions of AWS D1.1 should be consulted to determine if an allowance for uncertain penetration is required for the conditions of a particular weld.

Fig. 1 — Examples of welds with various types of loading. A — Complete joint penetration groove weld in tension; B — compression normal to the axis of weld; C — tension or compression parallel to weld axis; D — complete joint penetration groove weld in shear; E — partial joint penetration in groove welds; F — shear parallel to weld axis; G — fillet welds loaded in shear along weld throat.

By popular demand, The American Welding Society, in cooperation with C-spec, will publish a 2010 update to Filler Metal Comparison Charts listing trade names of thousands of products conforming to AWS filler metal classifications. Products are tabulated by filler metal classifications within the 30 individual specifications. Now you can update your product trade name listings online at fmc.weldoffice.net.

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### Suppliers listed in AWS FMC: 2000 Filler Metal Comparison Charts

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COMING EVENTS

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


Int’l Symposium on Surface Hardening of Corrosion-Resistant Alloys. May 25, 26, Case Western Reserve University, Cleveland, Ohio. Visit www.asminternational.org.


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LOT 2010, 9th Int’l Conf. on Brazing, High-Temperature Brazing, and Diffusion Bonding. June 15–17, Aachen, Germany. Spon-
sored by DVS (German Welding Society), cosponsored by AWS, ASM Int’l, and other societies. Visit www.dvs-ev.de/loet2010.

New Welding Technologies Conf., The Key to Higher Productivity. June 15, 16, Fort Lauderdale, Fla. Contact American Weld-
sing Society, (800/305) 443-9353, ext. 455; or visit www.aws.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. 455; or visit www.aws.org.


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, non-
members $245. Register online at www.sspc.org/training.


Brazing Course. May 11–13, Wall Colmonoy Brazing Engineering Center, Cincinnati, Ohio. Brazing design, furnace brazing, material selection, quality control, and hands-on experience provided. Call Lydia Lee (248) 585-6400, ext. 252; or visit www.wallcolmonoy.com/brazingschool.html.


Preparation and Exam for AWS Certified Welding Inspector/Educator. Two-week-long courses beginning April 12, May 17, June 21, 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 May 3, Oct. 18 in Troy, Ohio. Call Hobart Institute of Welding Technology (800) 332-9448; hiwt@welding.org; or visit www.welding.org.


Structural Welding: Design and Specification Seminars. April 13, Secaucus/ Meadowlands, N.J., and April 20, Los Angeles/Buena Park, Calif. Call Steel Structures Technology Center (734) 878-9560, or visit www.steelstructures.com.

Submerged Arc Welding. A one-week course offered weeks of June 1 and Sept. 7. Call Lincoln Electric Welding School (216) 383-8325, or visit www.lincolnelectric.com.

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AWS Certification Schedule

Certification Seminars, Code Clinics and Examinations

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

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<td>Los Angeles, CA</td>
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<td>Syracuse, NY</td>
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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.
Friends and Colleagues:

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

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

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

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

For specifics on the nomination requirements, please contact Wendy Sue Reeve at AWS headquarters in Miami, or simply follow the instructions on the Counselor nomination form in this issue of the Welding Journal. The deadline for submission is July 1, 2010. The committee looks forward to receiving these nominations for 2011 consideration.

Sincerely,

Alfred F. Fleury
Chair, Counselor Selection Committee
Nomination of AWS Counselor

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

To be eligible for appointment, an individual shall have demonstrated his or her leadership in the welding industry by one or more of the following:
- Leadership of or within an organization that has made a substantial contribution to the welding industry. (The individual’s organization shall have shown an ongoing commitment to the industry, as evidenced by support of participation of its employees in industry activities such as AWS, IIW, WRC, SkillsUSA, NEMA, NSRP SP7 or other similar groups.)
- Leadership of or within an organization that has made substantial contribution to training and vocational education in the welding industry. (The individual’s organization shall have shown an ongoing commitment to the industry, as evidenced by support of participation of its employees in industry activities such as AWS, IIW, WRC, SkillsUSA, NEMA, NSRP SP7 or other similar groups.)

II. RULES
A. Candidates for Counselor shall have at least 10 years of membership in AWS.
B. Each candidate for Counselor shall be nominated by at least five members of the Society.
C. Nominations shall be submitted on the official form available from AWS headquarters.
D. Nominations must be submitted to AWS headquarters no later than July 1 of the year prior to that in which the award is to be presented.
E. Nominations shall remain valid for three years.
F. All information on nominees will be held in strict confidence.
G. Candidates who have been elected as Fellows of AWS shall not be eligible for election as Counselors. Candidates may not be nominated for both of these awards at the same time.

III. NUMBER OF COUNSELORS TO BE SELECTED
Maximum of 10 Counselors selected each year.

Return completed Counselor nomination package to:

Wendy S. Reeve
American Welding Society
Senior Manager
Award Programs and Administrative Support
550 N.W. LeJeune Road
Miami, FL 33126
Telephone: 800-443-9353, extension 293

SUBMISSION DEADLINE: July 1, 2010
CLASS OF 2011
COUNSELOR NOMINATION FORM

DATE NAME OF CANDIDATE

AWS MEMBER NO. YEARS OF AWS MEMBERSHIP

HOME ADDRESS

CITY STATE ZIP CODE PHONE

PRESENT COMPANY/INSTITUTION AFFILIATION

TITLE/POSITION

BUSINESS ADDRESS

CITY STATE ZIP CODE PHONE

ACADEMIC BACKGROUND, AS APPLICABLE:

INSTITUTION

MAJOR & MINOR

DEGREES OR CERTIFICATES/YEAR

LICENSED PROFESSIONAL ENGINEER: YES NO STATE

SIGNIFICANT WORK EXPERIENCE:

COMPANY/CITY/STATE

POSITION YEARS

COMPANY/CITY/STATE

POSITION YEARS

SUMMARIZE MAJOR CONTRIBUTIONS IN THESE POSITIONS:

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

**MOST IMPORTANT**

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

SUBMITTED BY:
PROPOSER
AWS Member No.
The proposer will serve as the contact if the Selection Committee requires further information. The proposer is encouraged to include a detailed biography of the candidate and letters of recommendation from individuals describing the specific accomplishments of the candidate. Signatures on this nominating form, or supporting letters from each nominator, are required from four AWS members in addition to the proposer. Signatures may be acquired by photocopying the original and transmitting to each nominating member. Once the signatures are secured, the total package should be submitted.

NOMINATING MEMBER: Print Name

NOMINATING MEMBER: Print Name

NOMINATING MEMBER: Print Name

NOMINATING MEMBER: Print Name

SUBMISSION DEADLINE JULY 1, 2010
National Officers Transition in Miami

BY KRISTIN CAMPBELL

“I came up as a welder, and worked my way through all sorts of career changes to do what I do now, and I never dreamed that I would be in this position (as AWS president). I will do my best to represent you proudly,” said incoming AWS President John Bruskotter during the officers transition ceremony held Feb. 19 at AWS headquarters in Miami, Fla.

Victor Matthews reflected on his year as president in 2009. “When we started the year, we had four priorities — education, enhancing career development, technical committees, and membership,” Matthews noted. The AWS student membership is growing at 24%; 76 new standards or specifications were published; and AWS currently has 61,537 members — an all-time record. He noted that the public’s awareness of the importance of welding has improved significantly. “I can tell you that of the 11 countries and 22 states that I’ve been in during my year that we are a highly respected society throughout the world.”

Tomas Regalado, Miami mayor, presented a proclamation naming Feb. 19 American Welding Society Day in the city. Wayne Carter, assistant director of constituent services, office of Carlos Alvarez, Miami-Dade County mayor, did the same for Miami-Dade County.

Robert Pali, accompanied by his wife, Annette, was installed as treasurer. Others in attendance included Gerald Uttrachi, AWS Foundation chair, and wife, Christine; Ronald Pierce, a past AWS president, and wife, Joyce; Tully Parker, District 14 director, and wife, Sharon; David Landon, District 16 director; Don DeCorte, a director-at-large; Gene Lawson, a past AWS president; Dean Wilson, a director-at-large, and wife, Debi; Nancy Cole, vice president, and husband, Leon; William Rice Jr., vice president, and wife, Nora; Sally Matthews; Donna Bruskotter; Ray Shook, AWS executive director; and the AWS headquarters staff members.

Selvis Morales, a standards program manager in the Technical Services Department, earned the 2009 Michael A. Rowland Employee of the Year Award. This peer-nominated honor recognizes an AWS employee who has provided exemplary service and made notable contributions above the scope of normal duties, plus possesses an attitude and behavior contributing to teamwork and positive treatment of others in ways that exceeded job expectations.

Over the past year, Morales brought four D1 codes, including a new D1.7 code, Guide for Strengthening and Repairing Existing Structures, to publication or expected publication in early 2010. This will bring all nine D1 codes and the two non-code D1 publications to published dates of 2007, 2008, 2009, or 2010; the total page count for all 11 documents exceeds 2000 pages. Morales’s ability in handling the steps to guide these documents through a tough consensus process makes this accomplishment more remarkable. She also published the 250-page B2.1 code, Specification for Welding Procedure and Performance Qualification.

Selvis Morales receives the Michael A. Rowland Employee of the Year Award from Victor Matthews, 2009 AWS president.

Her nomination form states, “Despite lacking a technical background, Morales has developed her understanding of many code and technical aspects to a point where her supervisors are confident in her ability to address many general D1 code questions herself. This is quite an accomplishment considering how complex some of the simplest appearing code questions can really be.”

Supporting Morales’s nomination were Duane Miller, D1 Structural Welding Committee chair; Allen Sindel, D1 vice chair; and Don Rager, a former D1 chair. They appreciated Morales’s organization and administrative skill set, energy, willingness to help, ability to take care of various details, dedication, hard work, and professionalism.

Her citation concludes, “Selvis brings a positive attitude to work every day, which is inspirational to the other depart-

Incoming President John Bruskotter (right) receives the AWS president’s pin and ring from Victor Matthews, outgoing president.

Selvis Morales receives the Michael A. Rowland Employee of the Year Award from Victor Matthews, 2009 AWS president.
which means and methods will achieve weld smoke residues?

wire brushing?
weld after slag removal, or does it mean ASTM E 709, referenced in AWS D1.1

be accomplished by any cleaning tech-

Particle mobility in the area of interest. (See this result.
The contractor/fabricator determines visual inspection or other NDE required.

Inquiry:
1. Is “brushing” intended to sweep away loose slag particles lying on the weld after slag removal, or does it mean wire brushing?
2. Is there a requirement to remove weld smoke residues?
3. What “other suitable means” were considered when this wording was added in D1.1:2006?
4. Is complete removal of tightly adherent spatter required for RT?
5. Is complete removal of tightly adherent spatter required for MT?

Response:
1. Cleaning of completed welds is to be accomplished by any cleaning technique that prepares the surface for visual inspection or other NDE required. The contractor/fabricator determines which means and methods will achieve this result.
2. No.
3. See Response 1.
4. No.
5. No, unless it will interfere with particle mobility in the area of interest. (See ASTM E 709, referenced in AWS D1.1 Subclause 6.14.4.)

Technical Committee Meetings
April 14, SH1, Subcommittee on Fumes and Gases. Columbus, Ohio. Contact S. Hedrick, ext. 305.
April 21, D14B Subcommittee on General Design and Practice. Cincinnati, Ohio. Contact M. Rubin, ext. 215.
April 21, D14E Subcommittee on Welding of Presses and Industrial and Mill Cranes. Cincinnati, Ohio. Contact M. Rubin, ext. 215.
April 22, D14 Committee on Machinery and Equipment. Cincinnati, Ohio. Contact M. Rubin, ext. 215.

The contractor/fabricator determines visual inspection or other NDE required. (See Response 1.

No. unless it will interfere with particle mobility in the area of interest. (See ASTM E 709, referenced in AWS D1.1 Subclause 6.14.4.)
ing the approval process. The above standards were submitted for public review with the expiration dates shown. Draft copies may be obtained from R. O’Neill, ext. 451; roneill@aws.org.

New Standards Projects

Development work has begun on the following two revised standards. Affected individuals are invited to contribute to their development. Contact S. Morales, ext. 313. Participation on AWS Technical Committees and Subcommittees is open to all persons.

D1.1/D1.1M:2015, Structural Welding Code — Steel. This code covers the welding requirements for any type of welded structure made from the commonly used carbon- and low-alloy constructional steels. Clauses 1–8 constitute a body of rules for the regulation of welding in steel construction. Included are eight normative and 12 informative annexes, and a Commentary. Stakeholders: Structural engineers working with steel, designers, manufacturers, welders, qualiﬁers, inspectors, and fabricators.

D1.6/D1.6M:20XX, Structural Welding Code — Stainless Steel. This code covers the requirements for welding stainless steel structural assemblies. Stakeholders: Structural engineers working with stainless steel, manufacturers, welders, qualiﬁers, and inspectors.

Documents Approved by ANSI


B2.1-1-019-94-AMDI, Standard Welding Procedure Speciﬁcation (SWPS) for CO2 Shielded Flux Cored Arc Welding of Carbon Steel (M-1/P-1/S-1, Group 1 or 2), ¾ through 1½ Inch Thick, E70T-1 and E71T-1, As-Welded Condition. Approved 1/22/10.

B2.1-1-020-94-AMDI1, Standard Welding Procedure Speciﬁcation (SWPS) for 75%/Ar/25% CO2 Shielded Flux Core Arc Welding of Carbon Steel (M-1/P-1/S-1, Group 1 or 2), ¾ through 1½ Inch Thick, E70T-1 and E71T-1, As-Welded or PWHT Condition. Approved 1/22/10.

Technological Committee Volunteer Opportunities

Armament Systems Welding

The recently formed D14J Subcommittee on Armament Systems Welding seeks volunteers to help prepare welding standards for armament systems. Represented are members of the military, defense contractors, research institutes, heavy manufacturing, robotics, consulting and inspection ﬁrms, and others. It is the intent that D14J’s standards will supersede U.S. TACOM’s ground combat vehicle Welding Codes 12479550 and 12472301 for steel and aluminum. Contact Matt Rubin, mrubin@aws.org, (800/305) 443-9353, ext. 215, to contribute to this important work.

Surfacing Industrial Mill Rolls

Volunteers are sought to contribute to the D14H Subcommittee on Surfacing and Reconditioning of Industrial Mill Rolls to revise AWS D14.7, Recommended Practices for Surfacing and Reconditioning of Industrial Mill Rolls. Persons involved in this ﬁeld are asked to contact Matt Rubin, mrubin@aws.org; (800/305) 443-9353, ext. 215, or visit www.aws.org/IUQ4 to apply online.

Labeling and Safe Practices

Volunteers are needed to participate on the SH4 Subcommittee on Labeling and Safe Practices. Its documents include F2.2, Lens Shade Selector, F4.1, Safe Practices for the Preparation of Containers and Piping for Welding and Cutting, and the AWS Safety and Health Fact Sheets. For additional information about this committee’s work, contact Steve Hedrick, steveh@aws.org, (800/305) 443-9353, ext. 305; or submit a technical committee application online at www.aws.org/IUQ4.

Welding Sales Representatives

AWS established a new certiﬁcation program for welding sales representatives in 2009. Volunteers are invited to be part of the technical subcommittee responsible for setting the qualiﬁcation requirements, AWS B5.14, Speciﬁcation for the Qualiﬁcation of Welding Sales Representatives, that this program is based on. Contact John Gayler, gayler@aws.org, (800/305) 443-9353, ext. 472; or visit www.aws.org/IUQ4.

Robotic and Automatic Welding

Volunteers are sought to contribute their expertise to the D16 Committee on Robotic and Automatic Welding. Its documents include D16.1, Speciﬁcation for Robotic Arc Welding Safety; D16.2, Guide for Components of Robotic and Automatic Arc Welding Installations; D16.3, Risk Assessment Guide for Robotic Arc Welding; D16.4, Speciﬁcation for Qualiﬁcation of Robotic Arc Welding Personnel. Persons engaged in robotic welding operations and suppliers of equipment who want to contribute their expertise to the preparation of one or more of these documents are urged to contact Matt Rubin, mrubin@aws.org; (800/305) 443-9353, ext. 215, or apply online at www.aws.org/IUQ4.

Magnesium Alloy Filler Metals

Volunteers are invited to participate on the A5L 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. For complete information, contact Subcommittee Secretary Rakesh Gupta at gupta@aws.org, or call (800/305) 443-9353, ext. 301; or visit www.aws.org/IUQ4 to submit your member application online.

Thermal Spraying

Volunteers are invited to participate on the C2 Committee on Thermal Spraying. Several of its documents include C2.16, Guide for Thermal-Spray Operator Qualiﬁcation; C2.18, Guide for the Protection of Steel with Thermal Sprayed Coatings of Aluminum and Zinc and their Alloys and Composites; C2.19, Machine Element Repair; C2.23, Specification for the Application of Thermal Spray Coatings (Metallizing) of Aluminum, Zinc, and Their Alloys and Composites for the Corrosion Protection of Steel. Contact Reino Starks, starks@aws.org, (800/305) 443-9353, ext. 304, for information, or visit www.aws.org/IUQ4 to apply online.

Name Your Candidate for the Prof. 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. The award includes a $5000 honorarium. It is presented each year to one person who has made significant contributions to the advancement of materials joining through research and development. The candidate must be 40 years old or younger and need not be an AWS member.

The nomination should include the candidate’s résumé, plus at least three letters of recommendation from fellow researchers.

E-mail your nominations to Prof. John DuPont at jnd1@lehigh.edu.
Member-Get-A-Member Campaign

Listed below are the AWS members who are participating in the 2009–2010 campaign. See page 85 in this Welding Journal or visit www.aws.org/mgm for the campaign rules and prize list.

The following standings are as of Feb. 2010. 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.

- J. Medina, International — 5
- J. Barber, Connecticut — 5
- J. Hope, Puget Sound — 5
- J. Ciaramitaro, N. Central Florida — 5
- J. Hennessy, Fox Valley — 6
- T. Sumal, British Columbia — 11
- J. Compton, San Fernando Valley — 17
- N. Carlson, Idaho-Montana — 3
- J. Boyd, San Diego — 3
- D. Newman, Ozark — 3
- S. McDaniel, Inland Empire — 3
- D. Kowalski, Pittsburgh — 21
- J. Gerber, Allegheny — 22
- T. Gerber, Stark Central — 23
- W. Harris, Pascagoula — 10
- S. Kunz, Pittsburgh — 10
- R. Rummel, Central Texas — 10
- C. Schiner, Wyoming — 10
- P. Swattland, Niagara Frontier — 10
- J. Thompson, New Orleans — 10
- W. Galvery, Long Bch./Or. Cty. — 9
- V. Harthun, Northern Plains — 8
- J. Hill, Puget Sound — 8
- J. Fitzpatrick, Arizona — 7
- A. Mattox, Lexington — 7
- D. Roskiewich, Philadelphia — 7
- J. Grossman, Central Michigan — 6
- M. Hayes, Puget Sound — 6
- R. Jones, Puget Sound — 6
- A. Badeaux, Washington, D.C. — 5
- D. Howard, Johnstown-Altoona — 5
- D. Kearns, Northern Michigan — 5
- S. Ltu, Colorado — 5
- S. Colton, Arizona — 4
- R. Davis, Syracuse — 4
- S. Hansen, SE Nebraska — 4
- S. Henson, Spokane — 4
- E. Hinojosa, L.A./Inland Empire — 4
- A. Kitchens, Olympic Section — 4
- J. Lynn, Idaho-Montana — 4
- S. Mackenzie, Northern Michigan — 4
- R. Madrigal, L.A./Inland Empire — 4
- J. Smith, Greater Huntsville — 4
- M. Stevenson, J.A.K. — 4
- J. Boyd, San Diego — 3
- N. Carlson, Idaho-Montana — 3
- B. Chin, Auburn — 3
- J. Compton, San Fernando Valley — 3
- W. Davis, Syracuse — 3
- C. Gilbertson, Northern Plains — 3
- G. Kimbrell, St. Louis — 3
- S. McDaniel, Inland Empire — 3
- G. Moore, San Diego — 3
- D. Newman, Ozark — 3
- J. Pummer, Long Bch./Or. Cty. — 3
- R. Richwine, Indiana — 3
- S. Robeson, Cumberland Valley — 3
- A. Rodden, W Tennessee — 3
- J. Pummer, Long Bch./Or. Cty. — 3
- W. Davis, Syracuse — 3
- C. Gilbertson, Northern Plains — 3
- G. Kimbrell, St. Louis — 3
- S. McDaniel, Inland Empire — 3
- G. Moore, San Diego — 3
- D. Newman, Ozark — 3
- J. Pummer, Long Bch./Or. Cty. — 3
- R. Richwine, Indiana — 3
- S. Robeson, Cumberland Valley — 3
- A. Rodden, W Tennessee — 3

**3+ Student Member Sponsors**

- C. Rogers, San Antonio — 49
- G. Kirk, Pittsburgh — 47
- H. Hughes, Mahoning Valley — 40
- D. Berger, New Orleans — 38
- C. Hardbarger, Mid-Ohio Valley — 35
- D. Keller, Willamette Valley — 34
- J. Morash, Boston — 34
- C. Lindquist, Central Michigan — 32
- R. Durham, Cincinnati — 31
- M. Anderson, Indiana — 28
- D. Saunders, Lakeshore — 28
- J. Carney, Western Michigan — 27
- D. Kowalski, Pittsburgh — 27
- S. Miner, San Francisco — 26
- S. Sviski, Maine — 24
- A. Baughman, Stark Central — 23
- T. Gerber, Allegheny — 22
- R. Wahrman, Triangle — 22
- D. Aragon, Puget Sound — 21
- T. Geisler, Pittsburgh — 21
- S. Burdge, Stark Central — 20
- A. Duron, New Orleans — 20
- R. Evans, Siouxland — 20
- E. Norman, Ozark — 20
- G. Marx, Tri-River — 20
- K. Rawlins, Columbia — 20
- B. Suckow, Northern Plains — 20
- C. Donnell, NW Ohio — 19
- J. Durbin, Tri-River — 19
- V. Facchiano, Lehigh Valley — 19
- J. Theberge, Boston — 19
- M. Arand, Louisville — 18
- J. Boyer, Lancaster — 18
- J. Fox, NW Ohio — 18
- K. Carter, Tri-River — 17
- G. Smith, Lehigh Valley — 17
- N. Baughman, Stark Central — 16
- A. Reis, Pittsburgh — 16
- J. Roberts, Sacramento — 16
- G. Seese, Johnstown-Altoona — 16
- D. Zabel, SE Nebraska — 15
- J. Kline, Northern New York — 14
- J. Ciaramitaro, N. Central Florida — 14
- B. Chinf Auburn — 14
- G. Woomer, Johnstown/Altoona — 14
- S. Kuntz, Pittsburgh — 10
- R. Munns, Utah — 14
- J. Stallsmith, South Carolina — 11
- T. Stallsmith, South Carolina — 11
- T. Garcia, New Orleans — 10
- W. Harris, Pascagoula — 10
- S. Kuntz, Pittsburgh — 10
- R. Rummel, Central Texas — 10
- C. Schiner, Wyoming — 10
- P. Swattland, Niagara Frontier — 10
- J. Thompson, New Orleans — 10
- W. Galvery, Long Bch./Or. Cty. — 9
- V. Harthun, Northern Plains — 8
- J. Hill, Puget Sound — 8
- J. Fitzpatrick, Arizona — 7
- A. Mattox, Lexington — 7
- D. Roskiewich, Philadelphia — 7
- J. Grossman, Central Michigan — 6
- M. Hayes, Puget Sound — 6
- R. Jones, Puget Sound — 6
- A. Badeaux, Washington, D.C. — 5
- D. Howard, Johnstown-Altoona — 5
- D. Kearns, Northern Michigan — 5
- S. Litu, Colorado — 5
- S. Colton, Arizona — 4
- R. Davis, Syracuse — 4
- S. Hansen, SE Nebraska — 4
- S. Henson, Spokane — 4
- E. Hinojosa, L.A./Inland Empire — 4
- A. Kitchens, Olympic Section — 4
- J. Lynn, Idaho-Montana — 4
- S. Mackenzie, Northern Michigan — 4
- R. Madrigal, L.A./Inland Empire — 4
- J. Smith, Greater Huntsville — 4
- M. Stevenson, J.A.K. — 4
- J. Boyd, San Diego — 3
- N. Carlson, Idaho-Montana — 3
- B. Chin, Auburn — 3
- J. Compton, San Fernando Valley — 3
- W. Davis, Syracuse — 3
- C. Gilbertson, Northern Plains — 3
- G. Kimbrell, St. Louis — 3
- S. McDaniel, Inland Empire — 3
- G. Moore, San Diego — 3
- D. Newman, Ozark — 3
- J. Pummer, Long Bch./Or. Cty. — 3
- R. Richwine, Indiana — 3
- S. Robeson, Cumberland Valley — 3
- A. Rodden, W Tennessee — 3

**President’s Club**
Sponsored 3–8 new members.

- J. Hennessy, Fox Valley — 6
- D. Berger, New Orleans — 5
- J. Ciaramitaro, N. Central Florida — 5
- J. Hope, Puget Sound — 5
- B. Gevery, Fox Valley — 4
- S. Keskar, India Int’l — 4
- E. Ravelo, International — 4
- T. Baber, San Fernando Valley — 3
- G. Burrian, S. Florida — 3
- J. Compton, San Fernando Valley — 3
- E. Ezell, Mobile — 3
- T. Morris, Tulsa — 3
- P. Newhouse, British Columbia — 3

**President’s Honor Roll**
Sponsored 2 new members.

- G. Baldree, Rio Grande Valley — 5
- J. Barber, Connecticut — 5
- T. Blakeney, Green & White Mountains — 5
- G. Callender, San Fernando Valley — 5
- K. Carter, Tri-River — 5
- R. Davis, Utah — 5
- G. Euliano, Northwestern Pa. — 5
- M. Haynes, Niagara Frontier — 5
- K. Hurst, Kansas City — 5
- D. Mandina, New Orleans — 5
- V. Matthews, Cleveland — 5
- J. Medina, International — 5
- T. Moffitt, Tulsa — 5
- E. Nguni, New Jersey — 5

**President’s Roundtable**
Sponsored 9–19 new members.

- R. Ellenbecker, Fox Valley — 17
- A. Sumal, British Columbia — 11
- H. Thompson, New Orleans — 9

**President’s Guild**
Sponsored 20+ new members.

- B. Chin, Auburn — 24

**Membership Counts**
As of March 1, 2010

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<th>Member Grades</th>
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<td>Affiliate</td>
<td>470</td>
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<tr>
<td>Welding distributor</td>
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| Total corporate members | 1,862 |
| Individual members      | 53,496 |
| Student + transitional members | 8,041 |

| Total AWS Membership | 61,537 |
District 1
Thomas Ferri, director
(508) 527-1884
tferri@thermadyne.com

BOSTON
JANUARY 25
Activity: The Section’s executive board met to discuss officer nominations, the upcoming Fay Butler and CWI seminars, additional training, welded products month, and other future events. The meeting was held at Artisan Industries in Waltham, Mass. Attending were Chair Rick Moody, District 1 Director Tom Ferri, Treasurer Gary Hylan, Vice Chair Bob Lavoie, and directors Dave Paquin, Jim Reid, and Laurie Jones.

GREEN & WHITE MOUNTAINS
FEBRUARY 11
Activity: The Section members toured the cylinder filling, testing, and repair facilities of Airgas East in Charlestown, N.H. Lisa Ramsey, facility manager, conducted the program. Following the tour, the board members convened to discuss the upcoming SkillsUSA contest, District 1 conference, and Section events. A highlight was a meeting of the Poor Pooped Past District 1 Directors (PPPD1Ds), at which Geoff Putnam was elected chair and Russ Norris named vice chair, secretary, treasurer, membership chair, webmaster, publicist, and bottle washer. Tom Ferri was advised that he would be eligible for membership in six years or so.

MAINE
JANUARY 28
Activity: The Section held its fifth annual vendors’ night and open house at Southern Maine Community College in South Portland, Maine. Lead welding instructor and CWI Mark Legel demonstrated the features of various welding equipment used at the college. The vendors participating were Chuck Sarcia from ITW, District 1 Director Tom Ferri from Thermadyne, Chris Bremer from Bremer Sales, and Bill Falin representing Pferd Abrasives and Hougen Drills. Eric Miskin demonstrated how he makes ice cream using liquid nitrogen.
New York Section members are shown with Chair Dominick Colasanto (left-center) greeting speaker David Sharp.

Shown at the Florida West Coast Section program are (from left) Chair Robert Brewington, speaker Rick Maslyn, and Steve Mattson, District 5 director.

Shown at the North Florida Section meeting are Steve Mattson (left), District 5 director, and induction heating presenters Andrew Riley (center) and Tim Tidwell.

FEBRUARY 4
Activity: The Maine Section held an executive board meeting at Binga’s Stadium in Portland, Maine. Chairman Scott Lee discussed a number of items then formed a committee to arrange for the lobster bake to be held during the District 1 conference. Tom Ferri, District 1 director, discussed a number of topics on the national and District level.

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District 3
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District 4
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District 5
Steve Mattson, director
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NEW YORK
January 11
Speaker: David Sharp, QA manager
Affiliation: Gilsanz Murray Steficek

PHILADELPHIA
January 13
Speaker: Dennis Sullivan, northeast region sales manager
Affiliation: ESAB Welding and Cutting Products
Topic: Submerged arc welding

FLORIDA WEST COAST
February 10
Speaker: Rick Maslyn, bridge inspector
Affiliation: Ayres Associates
Topic: Bridge inspection codes and requirements for bridge inspectors
Activity: The program was held at Frontier Steakhouse in Tampa, Fla. District 5 Director Steve Mattson attended the event.

NORTH FLORIDA
January 21
Activity: Andrew Riley and Tim Tidwell of Red-D-Arc Welderentals demon-
strated induction heating techniques using a Miller Electric Pro 35 induction heater. Chair Steve Mattson, who is also District 5 director, presided at the program. This North Florida Section meeting was held at JEA in Jacksonville, Fla.

**District 6**

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**District 7**

Don Howard, director  
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DAYTON  
JANUARY 12  
Speaker: Jim Hannahs, CWI, PE, CMfgE  
Affiliation: Professor, welding engineering (ret.)  
Topic: The analysis of weld-related corrosion failure in brewery transfer piping  
Activity: This was a joint meeting with members of the Dayton and Cincinnati Chapters of ASM International. The meeting was held at the historic Engineers Club of Dayton, Ohio. Participating were AWS Dayton Section Chair Steve Whitney, Cincinnati ASM Chair Michael Anderson, Dayton ASM Chair Raghavan Srinivasan, and Dayton ASM Treasurer Emil Lesner.

PITTSBURGH  
JANUARY 12  
Speaker: Victor Matthews, AWS president  
Affiliation: The Lincoln Electric Co. (ret.)  
Topic: Careers in welding  
Activity: The Section hosted its past chairmen’s night at Siba Cucina in Seven Fields, Pa. District 7 Director Don Howard attended the event.

FEBRUARY 16  
Speaker: Jim Sekely, principal consultant  
Affiliation: Welding Services, Inc.  
Topic: Codes used to qualify welding procedures and welder performance  
Activity: This Pittsburgh Section meeting was held at Siba Cucina Restaurant in Seven Fields, Pa.

**District 8**

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**District 9**

George D. Fairbanks Jr., director  
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BIRMINGHAM  
JANUARY 11  
Speaker: George Fairbanks Jr., District 9 director

Affiliation: Fairbanks Inspection & Testing  
Topic: Requirements for becoming a Certified Welding Inspector (CWI)  
Activity: George Fairbanks presented Jim Cooley the District Director’s Award, and the Section Meritorious Award to Ken Jobes. Jim Thompson and Joey Foster of Wallace State C.C. were cited for winning the national SkillsUSA college-level welding gold medal. Jim Casey and Joshua

Shown at the joint meeting of the AWS Dayton Section and ASM International Dayton and Cincinnati Chapters are (from left) Steve Whitney, speaker Jim Hannahs, Emil Lesner, Michael Anderson, and Raghavan Srinivasan.

Shown at the January Pittsburgh Section program are (from left) Carl Ott, District 7 Director Don Howard, Tom White, Jim Sekely, Tom Geisler, and Chuck McGowan.

Victor Matthews (left), AWS president, is shown with Dave Daugherty, Pittsburgh Section chair, at the January event.

Speaker Jim Sekely (left) chats with Dave Daugherty, Pittsburgh Section chair, at the February program.
Mike Barnett (left) receives the Section Meritorious Award from John Bruskotter, AWS president, at the Mobile Section event. Smith of Shelby County School of Technology were cited for winning the national SkillsUSA high school welding gold medal. Brian Copes was recognized for outstanding achievements with his students in the preengineering program at Calera High School. This Birmingham Section meeting was held at Home Plate Diner in Birmingham, Ala.

Jim Cooley (left) receives the District Director’s award from George Fairbanks, District 9 director, at the Birmingham Section event.

Smith of Shelby County School of Technology were cited for winning the national SkillsUSA high school welding gold medal. Brian Copes was recognized for outstanding achievements with his students in the preengineering program at Calera High School. This Birmingham Section meeting was held at Home Plate Diner in Birmingham, Ala.

Tony Hopper (left) receives the District Educator Award from John Bruskotter, AWS president, at the Mobile Section program.

Shown at the Northwestern Pennsylvania Section program are speaker Dennis Klingman (left) and Chair Jessie McIntosh.

CLEVELAND
February 9
Activity: The Section members met at Pipe Line Development Co. (Plidco®) in Cleveland, Ohio, for a tour of the facilities. The company designs and manufactures pipeline repair and maintenance fittings for a variety of on- and offshore installations. Pete Haburt, international marketing manager, conducted the program.

NORTHWESTERN PA.
January 19
Speaker: Dennis Klingman
Affiliation: The Lincoln Electric Co.
Topic: Careers in welding
The program was held at Tri-State Business Institute in Erie, Pa.

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District 11
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DETROIT

February 12
Activity: The Section hosted its annual ladies’ night ball at the Henry Ford Museum in Dearborn, Mich. Vice Chairman John Bohr hosted the program. The event organizing committee members were Tim Cesarz, John Bohr, Don Czerniewski, and Rod Bereznicki.

SAGINAW VALLEY

January 14
Activity: The Section members met at Delfield Co. in Mt. Pleasant, Mich., for a tour of the facility. The company is a manufacturer of refrigeration and food service equipment for restaurants, hotels, and institutions. Mike Curtiss, director of manufacturing custom division, conducted the tour.

District 12

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MILWAUKEE

December 17
Activity: The Section hosted its past chairmen’s and scholarship program at Tanner Paul in Milwaukee, Wis. Attending were past chairs Jerry Blaski, John Albanese, Richard Nowicki, John Hinrichs, Jim Potter, and Roger Edge. Previous winners of Section scholarships spoke on how the Section’s help advanced their careers.

January 19
Activity: The Section sponsored a discussion on leasing vs. buying equipment and the new tax laws affecting capital equipment acquisitions. Also addressed were the benefits of the Workforce Development Training Grants administered by the local colleges. Participating were Chair Karen Gilgenbach and Mary Witte with Airgas; Mark Charlton with Tech Financial Services; Bob Nelson, LA Crystal Services; Bill Mazur and John Murphy with Plant and Facilities Maintenance Assn.; Roe M. Parker, president, Roe M. Parker & Assoc.; Mona Schroeder-Beers and Robert Bruss with Milwaukee Area Technical College; and Robert Kettenhoven with the YWCA. The program was held at Plano’s Char House in Brookfield, Wis.

District 13

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St. Louis Section awardees are (from left) Ed Godden, John Biama, Frank Slinkard, Gay Cornell, Mike Kamp, Curt Eggen, Larry Elms, Scott Zimmer, Dan Wiegand, Steve Wilson, and Charles Wandling.

Members of the St. Louis Section joined ASNT local chapter members for the January program.

Shown at the Arrowhead Section meeting are (from left) District 15 Director Mace Harris, Tom Baldwin, Doug Mroz, and Chairman Loren Kantola.

District 14
Tully C. Parker, director
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ST. LOUIS
DECEMBER 4
Activity: The Section hosted its annual holiday party and awards-presentation program at Royale Orleans banquet hall in St. Louis, Mo. Ed Godden received the Silver Membership Award for 25 years of service to the Society. Other award winners included John Biama, District Educator; Frank Slinkard, District Private Sector Instructor; Gay Cornell, District Meritorious; Mike Kamp, District Dalton E. Hamilton CWI of the Year; Curt Eggen, Section Meritorious; Larry Elms, Section Private Sector Instructor; Scott Zimmer, Section Meritorious; Dan Wiegand and Charles Wandling, Section Dalton E. Hamilton CWI of the Year; and Steve Wilson, Section Educator.

JANUARY 27
Speaker: Mike Krusz, regional services line manager
Topic: Nondestructive testing, heat treating, and field mechanical services
Activity: This St. Louis Section event was a joint meeting with members and guests of the St. Louis chapter of ASNT. The program was held in South Roxana, Ill.

APRIL 2010
**District 15**  
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**ARROWHEAD**  
**FEBRUARY 16**  
Activity: The Section held an executive committee meeting and awards-presentation program, conducted by Mace Harris, District 15 director. Chairman Loren Kantola received the Section Educator Award. Doug Mroz received the District Dalton E. Hamilton Memorial CWI of the Year Award. The District Director Awards were presented to Tom Baldwin, Doug Mroz, and Loren Kantola. The program was held at Mesabi Range Community and Technical College in Eveleth, Minn.

**District 16**  
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**IOWA**  
**FEBRUARY 10**  
Activity: This was a joint meeting with members of the Central Iowa Chapter of ASM International and 14 students at Marshalltown Community College, Marshalltown, Iowa, where the meeting was held. The presenters were Richard M. Hutchison and John Moran from Miller Electric Mfg. Co., and Michael Byerly and Kurt Goltz from Lincoln Electric Co., who demonstrated their company’s pipe welding equipment. Welding instructor Mary Means hosted the program. The college provided the dinner. District 16 Director David Landon attended the program.

**KANSAS**  
**JANUARY 23**  
Activity: The Section hosted its first annual bowling tournament as a fund-raiser for its scholarship fund. Twenty-four two-person teams participated. The tournament was open to the public as well as AWS members. The event was held in Wichita, Kan.

**FEBRUARY 11**  
Activity: The Kansas Section members met at Center Industries in Wichita, Kan., to tour its production facilities. The facility is a nonprofit organization that trains and employs about 240, mostly disabled, workers. The processes used include welding, CNC machining, brake presses, and specialized machining. Don Davis conducted the tour.
Shown at the Kansas City Section program are (seated, from left) Rich Rowe, Keith Nelson, Dustin Whitfield, and Frank Kirk; (standing, from left) Sarah Hurt, Dennis Wright, Michael Williams, Richard Blaisdell, Brian McKee, Sam Newhouse, Dave McKenzie, Mike Vincent, Bob Worthington, and Chair Jason Miles.

The Ironworkers Local #21 team is shown at the Nebraska Section bowling tournament. Shown are (from left) Matt Mehser, Todd Lincoln, James Swenson, Mike Lincoln, Jason Willey, Josh Titus, Ryan Mehan, and Jerry Swenson.

Nebraska Section officers having fun at the bowling outing are (from left) Monty Rodgers, Karl Fogelman, Chris Beaty, Eric Nordhues, Chair Rick Hammy, Nick Weidenbach, and Jason Hill.

Sarah Hurt, Kansas City vice chair, presents Rich Rowe a speaker gift.

East Texas Section Chair Bryan Baker presents a speaker gift to Vice Chair Dan Bricker at the February seminar.

KANSAS CITY
January 14
Speaker: Rich Rowe, welding professor
Affiliation: Johnson County C.C.
Topic: The college’s welding program
Activity: Frank Kirk presented students Keith Nelson and Dustin Whitfield with the first annual Johnson County C. C. Kirk Scholarship Awards.

NEBRASKA
January 23
Activity: The Section hosted its third annual bowling event as a fund-raiser for its scholarship program. Lane sponsors were Davis Erection Co., Ironworkers Local #21, Linweld, Metropolitan C.C., Olsson & Associates, and Praxair. More than 50 participated in the event, held in Omaha, Neb.

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EAST TEXAS
January 21
Speaker: Larry Richardson, inspector
Affiliation: Hi-Tech Testing
Topic: Using phased array ultrasonics
Activity: The program was held at Papacitas Restaurant in Longview, Tex. District 17 Director J. Jones attended the program.

February 18
Activity: The East Texas Section hosted a seminar to prepare for the CWI exam. Welding instructor Dan Bricker, a CWI/CWE and Section vice chair, presented the course at Papacita’s Mexican Restaurant in Longview, Tex.
NORTH TEXAS

FEBRUARY 16
Speaker: John Bruskotter, AWS president
Affiliation: Bruskotter Consulting Services
Topic: Oil platforms, the space stations of the deep
Activity: The program was held at Lincoln Technical College in Arlington, Tex. Red Ball Oxygen sponsored this program, which attracted 92 attendees.

TULSA

JANUARY 26
Speaker: Butch Webb, president
Affiliation: BKW, Inc.
Topic: Pipeline laying technology and buoyancy control with different types of anchors
Activity: The meeting was held in Tulsa, Okla.

SAN ANTONIO

FEBRUARY 9
Speaker: Edgar Lozano, supervisor, code compliance
Affiliation: City of San Antonio
Topic: The latest updates to the City’s building codes
Activity: More than 30 students from the Floresville High School and Alamo Student Chapters attended the program.
Students from the Floresville High School and Alamo Student Chapters attended the San Antonio Section program.

Olympic Section members learned about gas tungsten arc welding at the February program.

District 19
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Olympic Section Chair Rob Rothbauer presents a speaker gift to Ernie Leimkuhler at the February program.

Speaker Julia Kossowski is shown with John Little at the January British Columbia Section program.

BRITISH COLUMBIA
DECEMBER 4
Activity: The Section hosted its annual event to show appreciation to its sponsors. Each sponsor company was given two tickets to attend the Fraser Downs Clubhouse buffet and watch the races. Forty-four sponsors and guests participated in the event.

JANUARY 19
Speaker: Julia Kossowski, project manager
Affiliation: Grouse Mountain Resort
Topic: The Grouse Mountain wind turbine project
Activity: This British Columbia Section program was held in Delta, B.C.

OLYMPIC
JANUARY 19
Activity: Thirty Section members met at the Praxair Distribution Plant in Tacoma, Wash., for a tour of the facilities. Mark Lulich, manager, plant operations, conducted the program.

FEBRUARY 16
Speaker: Ernie Leimkuhler
Affiliation: Divers Institute of Technology
Topic: Pulser and sequencers used in gas tungsten arc welding
Activity: Seventy members attended the talk then participated in the hands-on demonstrations of gas tungsten arc welding equipment presented by ESAB, Lincoln, Miller, and Thermal Arc representatives. The event was held at Bates Technical College in Tacoma, Wash.
Shown are the participants in the recent Stanwood High School Student Chapter’s arc welding course. Front row, center, are instructors Kaity Hampton and Chairman Brandon Nickles. Advisor Darryl Main is far-right in overalls. Instructor Scott Weisse is back row, center, wearing a green hat.

Olympic Section members toured the Praxair plant in January.

Stanwood High School Student Chapter
JANUARY 14–FEBRUARY 18
Activity: Chapter member Kaity Hampton, Chapter Chairman Brandon Nickles, and student Scott Weisse presented a 12-hour course in arc welding for student volunteers and community members at Stanwood High School in Stanwood, Wash. The two-hour-long classes were presented weekly for six weeks, coordinated by Advisor Darryl Main. Hampton taught the first three classes in shielded metal arc welding as her senior project. Nickles and Weisse taught the last three classes on gas metal arc welding. About 25 student members assisted with equipment setup, preparing the metal, grinding, and cleaning the work area after the classes. The project also served as a fundraiser for the school’s Agricultural Mechanics Club.

District 20
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IDAHO-MONTANA
JANUARY 20
Speaker: Steve Laflin, president, CEO
Affiliation: International Isotopes, Inc.
Topic: Overview of the company’s nuclear medicine activities
Activity: This was a joint meeting with members of the local chapter of the American Nuclear Society. Bruce Madigan and four of his Montana Tech welding engineering students, Tanner Patterson, Joe Stavinoha, Shane Krause, and Levi George, traveled from Butte, Mont., to attend the program, held in Idaho Falls, Idaho. The next day, they toured the Idaho National Laboratory welding
Shown at the Idaho-Montana Section program are (from left) Tanner Patterson, Joe Stavinoha, Denis Clark, Bruce Madigan, Ofilia Tremblay, Paul Tremblay, Shane Krause, and Levi George.

Speaker Richard Seals (right) chats with Tom Smeltzer, San Francisco Section chair. laboratories and obtained some equipment for use at the college. Denis Clark, membership chair, arranged the tour and the equipment transfer. Bruce Madigan and Paul Tremblay set plans for the weld inspection seminar for presentation in February.

February 5
Activity: The Idaho-Montana Section hosted an inspection seminar based on the AWS D1.1, Structural Welding Code—Steel, AISC Steel Construction Manual, and other references. William Komlos, District 20 director, from Arc Tech, LLC, was the instructor. The training session included 17 attendees. Bruce Madigan of Montana Tech and Bob Shook of the University of Montana at Missoula, College of Technology, were recognized for their contributions to the education of our future welding workforce. The event was held at Montana Tech in Butte, Mont.

Utah
January 21
Speaker: Richard Carver Sr., welding engineer
Affiliation: ATK Aerospace Systems
Topic: Joining thick 4340 forgings using electron beam welding
Activity: This was a joint meeting with members of the local chapter of ASM International. The meeting was held in Salt Lake City, Utah. Participating were ASM chair Brett Fuller, ASM Vice Chair Mike Shemkunas, and District 20 Director William Komlos.

District 21
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District 22
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Participants will also be eligible to win prizes in specialized categories. Prizes will be awarded at the close of the campaign (June 2010).

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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 2009-2010 MGM Campaign runs from June 1, 2009 to May 31, 2010. Prizes are awarded at the close of the campaign.*
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06 Engineer — design
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03 Nonferrous metals except aluminum
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20 Marine
21 Piping and tubing
22 Pressure vessels and tanks
23 Sheet metal
24 Structures
25 Other
26 Automation
27 Robotics
28 Computerization of Welding
**SACRAMENTO VALLEY**

**November 4**
Speaker: Victor Matthews, AWS president
Affiliation: The Lincoln Electric Co. (ret.)
Topic: Your career in welding
Activity: More than 70 attendees attended the event held at American River College in Sacramento, Calif.

**SAN FRANCISCO**

**February 3**
Speaker: Richard Seals
Topic: The big five nondestructive testing methods relevant to welding
Activity: Sixty-eight members and guests attended the program, including many new student members from Las Positas College in Livermore, Calif. The meeting was held at Spenger’s Restaurant in Berkeley, Calif.

**SANTA CLARA VALLEY**

**January 12**
Speaker: Alex Gutierrez
Affiliation: Pacific Gas & Electric
Topic: Methods used to identify unknown metals prior to welding
Activity: The meeting was held at Harry’s Hofbrau in San Jose, Calif.

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For more information contact the Member Services Dept. at (800/305) 443-9353, ext. 259, or e-mail marthac@aws.org.

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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.

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Fargo, ND 58103
Representative: James Waa
www.wanzek.com

Wanzek is a heavy-industrial construction firm specializing in power, oil and gas, renewable energy, and industrial processes. For 40 years, the company has been involved in the construction and expansion of hundreds of industrial facilities throughout the United States, and it continues to build relationships that foster repeat business based on its fine past performance.

EEW Malaysia Sdn. Bhd.
PLO 109 Jalan Tengar
Tanjung Langsat Ind. Complex
Pasir Gudang, Johor 81700, Malaysia
Representative: Ahmad K. B. M. Salleh
www.eew-group.com

EEW Malaysia Sdn. Bhd. is a major producer of submerged arc welding (SAW) large-diameter pipe supplying markets in Malaysia, southeast Asia, and Australia. The goal of its new facility, which started operation last June, is to supply 90% of the typical SAW pipe for the region. Pipe are fabricated with 4 to 16-ft diameters, wall thicknesses to 4.7 in., and lengths to 41 ft.

Huntingdon Fusion Techniques, Ltd.
Stukeley Meadow, Burry Port
Carmarthenshire SA16 OBU, UK
Representative: Jon Lewis
www.huntingdonfusion.com

Huntingdon Fusion designs and manufactures a wide range of weld-purging accessories and tungsten electrode products. Included are the Argweld® weld purge monitors, trailing shields, welding enclosures, inflatable pipe-purging systems, weld backing tape, water-soluble weld dam material, pipe purge plugs, MultiStrike™ tungsten electrodes, and Techweld™ tungsten electrode grinders.

Inspectech Corp.
8550 W. Charleston Blvd. #102-148
Las Vegas, NV 89117
Representative: Nate Lindell
www.inspectechconsulting.com

Inspectech Corp. is a pioneer in the Total Quality Management approach. Its innovative and proven project and weld-tracking technology allows industries to raise their productivity and quality control. Successful industry leaders recognize the need to replace outdated paper-based systems with green mobile-software solutions using hand-held devices that synchronize captured data to their back-end systems.

Piping Systems, Inc.
719 Industrial Park Ave.
Hortonville, WI 54944
Representative: Kevin Werthy
www.pipingsystems.com

Piping Systems provides shop-fabricated piping assemblies for the power, refining, petrochemical, chemical, water treatment, biofuels, industrial gases, air-quality, and food and beverage industries. Its piping includes carbon steel, all stainless steel grades, chrome alloys, nickel-based alloys, Hastelloy™, titanium, 6 moly, and duplex alloys. The company maintains customer satisfaction though consistency of product quality, on-time deliveries, and fabrication accuracy.

Supporting Companies

Bohler Soldaduras S.A. De C.V.
Henry Ford #16
Tlalnepantla 54030, Mexico
Koke, Inc.
582 Queensbury Ave.
Queensbury, NY 12804
Markland Welding, Inc.
168 Lafayette Rd.
Salisbury, MA 01952

Affiliate Companies

American Alloy, LLC
18001 E. Euclid Ave. Ste. A
Spokane Valley, WA 99216
Applied Fabrications, LLC
9889 Wolftrap Ln.
Dayton, VA 22821
Atlantic Steel, Inc.
500 Plumas Ave.
Altamonte Springs, FL 32701
C & R Racing
6950 Guion Rd.
Indianapolis, IN 46268
Errickson Equipment Inc.
19 Milltown Rd.
Stockton, NJ 08559
Fast Trek Steel Inc.
17 Industrial Park
Coxsackie, NY 12051
JB Enterprises
PO Box 987
Alamogordo, NM 88311
Metal Pros, LLC
4323 Bounous St.
Wichita, KS 67209

New Sustaining Companies

New Mexico Steel Fabricators, Inc.
PO Box 654
Dona Ana, NM 88032
Phoenix Steel Erectors, Inc.
14991 Shady Oak Ln.
Haymarket, VA 20169
Sonomatic, Ltd.
Marsham House
The Village
Birchwood Pk., Warrington
Cheshire WA3 6GN, England

TowerWorx, LLC
6789 Hwy. 69 S.
Pryor, OK 74361

Underwater Construction Corp.
110 Plains Rd.
Essex, CT 06426
Universal De Inspecciones SA De CV
Guillermo Rossell No. 111
Col. Cerro De Cubitos Pachuca De Soto
Hidalgo 42090, Mexico

Educational Institutions

Camara Boliviana
de Hidrocarburos
Av. Radial 171/2 con 6to Anillo
Santa Cruz 3920, Bolivia

College of the Siskiyous
800 College Ave.
Weed, CA 96094

Eastern Maine C. C.
354 Hogan Rd.
Bangor, ME 04401

D’Hanis L.S.D.
6751 County Rd. 5216
D’Hanis, TX 78850

Hoonah City Schools
366 Garteeni Hwy.
Hoonah, AK 99829

McAllen Careers Institute
1101 East St. Dallas Ave., Ste. 1
McAllen, TX 78501

National Center for Construction Education and Research
3600 NW 43rd St., Bldg. G
Gainesville, FL 32606

North American Trade School
6901 Security Blvd., Ste. 16
Baltimore, MD 21244

Sabine High School, CTE
5424 FM 1252 W.
Gladewater, TX 75647
Guide to AWS Services

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Bruskotter@wcb.com

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Managing Director, Technical Operations
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Pritti Jain..pjain@aws.org \(258\)

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Personnel and Facilities Qualification, Computerization
of Welding Information

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Metric Practice, Safety & Health, Joining of
Plastics and Composites, Welding Iron Castings

Senior Executive, Technical Publications
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AWS publishes about 200 documents widely used
throughout the welding industry.

Staff Engineers/Standards Program Managers
Annette Alonso..aalonso@aws.org \(299\)

Automotive Welding, Resistance Welding, Oxy-
Fuel Gas Welding and Cutting, Definitions and
Symbols, Sheet Metal Welding

Stephen Borreto..sborreto@aws.org \(334\)

Joining of Metals and Alloys, Brazing and Soldering,
Brazing Filler Metals and Fluxes, Brazing Handbook,
Soldering Handbook

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Filler Metals and Allied Materials, Int’l Filler Metals,
Instrumentation for Welding, UNS Numbers
Assignment

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Welds, Welding in Marine Construction, Piping
and Tubing

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Welding Qualification, Structural Welding

Matthew Rubin..mmrubin@aws.org \(251\)

Welding in Sanitary Applications, High-Energy
Beam Welding, Fricion Welding, Railroad Welding,
Thermal Spray

Note: Official interpretations of AWS standards may be obtained only by sending a request in writing
to the Managing Director, Technical Services, Andrew R. Davis, at adavis@aws.org.

Oral opinions on AWS standards may be rendered.
However, such opinions represent only
the personal opinions of the particular individuals
giving them. These individuals do not speak
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of AWS. In addition, oral opinions are informal
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official interpretation.

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Director
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General Information
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AWS Foundation, Inc., is a not-for-profit cor-
poration established to provide support for edu-
cational and scientific endeavors of the American
Welding Society. Further the foundation’s work
with your financial support. Call for information.
Welding Gas Gauges and Tips Pictured in Catalog

The 80-page CONCOA Industrial Catalog illustrates and details the company’s complete lines of single- and dual-stage heavy-duty welding, heating, and cutting gas regulators; gas flowmeters; pipeline regulators; cutting torches and tips; heating tips; welding outfits; and numerous parts and accessories. A few of the accessories include tip cleaners, flashback arrestors; spark lighters, mixers, guards, flash circle burners, torch check valves; and wrenches, hoses, and fluxes. The PDF catalog may be downloaded from the Web site.

CONCOA Precision Controls
www.concoa.com
(800) 225-0473

Surface Coatings for Al Castings Evaluated

Performance Evaluation of Surface Finishes on Aluminum Die Castings compares the results of subjecting 15 different surface finishes applied to raw die cast aluminum components to a 30-day accelerated corrosion testing program. Only six of the surface finishes continued to provide protection while the others failed. The 48-page report should be helpful in narrowing the possible coating systems based on the priority for corrosion protection, product appearance, or other factors. The report may be ordered or downloaded from the Web site for $20 list. To order, visit the site, then click on the NADCA Store button.

North American Die Casting Assn.
www.diecasting.org
(847) 279-0001

Book Details Systems Failure Analysis

Systems Failure Analysis, authored by Joseph Berk, an expert witness and engineering technology faculty member at California State Polytechnic University, Pomona, is intended to give product teams the tools and concepts to get at the root causes of defects and failures in complex manufacturing and engineered systems. The techniques include brainstorming, Ishikawa diagrams, the five-whys approach, mind mapping, and fault tree analysis. The illustrated, 200-page hardcover book includes chapter titles: Downsizing the Hidden Factory, Systems Failure Analysis Concepts, Identifying Potential Failure Causes, Fault Tree Analysis Quantification, Failure
Mode Assessment, Pedigree Analysis, Change Analysis, Analytical Equipment, Mechanical and Electronic Failures, Leaks, Contaminants, Design Analysis, Statistics and Probability, Design of Experiments, Corrective Action, and Post Failure Analysis Activities. The book lists for $90, $72 for ASM members. Visit the Web site to order and to view the index, table of contents, and a sample chapter.

ASM International
www.asminternational.org
(440) 338-5151

LIA Proceedings Available Online

Laser Institute of America (LIA), Orlando, Fla., recently announced the availability of all submitted conference abstracts and papers are now archived online for reference by end users, scientists, engineers, and technicians. To find abstracts of interest, visit the Web site and select “Conference Proceedings.” Then, filter through more than 1500 proceedings and papers by searching by keywords. Conference proceedings are available for $28 list, $25 for institute members.

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

SAW Wires and Fluxes Detailed in Brochure

A six-page, full-color brochure offers complete information on Tri-Mark® composite wires and Hobart® flux combinations for submerged arc welding (SAW). A graphic displays metal core melt off characteristics vs. solid wire. Information is provided on principles of SAW operation, advantages of SAW for heavy-plate fabrication, benefits of metal core vs. solid wire, electrode-flux cross references, and detailed explanations of the classification for carbon steel electrodes and fluxes per AWS A5.17, and classification for low-alloy steel electrodes and fluxes per AWS A5.23. One page offers a brief history of Hobart Brothers and contact information for its regional offices worldwide and affiliated companies. The brochure may be downloaded online as a PDF. Click “Downloads” and scroll down to Tri-mark® Subarc Brochure.

Hobart Brothers
www.hobartbrothers.com
(937) 332-4000

Gas Metal Arc Products Pictured in Catalog

The recently released Tweco MIG Gun, MIG Consumables and Welding Accessory Catalog, No. 64-2103, features the company’s complete product line. Illustrated and detailed are electrode holders, ground clamps, lugs, carbons, welding guns, and consumables. Included is information to help customers identify and select the most appropriate welding gun for their applications, and part drawings for easy ordering. The catalog may be obtained from a Tweco or Thermadyne® representative or call.

TWECO®
www.thermadyne.com/tweco/
(636) 728-3000

Book Documents the Story of Stainless Steel

Author Harold M. Cobb has documented The History of Stainless Steel as an
intriguing story of the inventiveness and metallurgical progress of its discoverers in three countries, their lives, and some of the many obstacles that they encountered. Included are numerous photographs and a “Stainless Steel Timeline” that lists more than 450 facts and events in stainless steel technology and its applications. The softcover edition list price is $30, $24 for ASM International members. A hardcover edition is available.

ASM International
www.asminternational.org
(440) 338-5151

A 12-page, full-color, well-illustrated brochure presents an overview of the numerous work-holding solutions offered by the company. Shown are modular components, self-aligning fixture elements, grids, force cartridges, tombstones, locating systems, and high-density work-holding systems. The company offers a wide variety of fixtures custom made to customers’ requirements, including dedicated or modular, manual, hydraulic, machining and inspection fixtures, incremental, and turnkey services. Technical consulting services are available for building special machines for a variety of industries, rebuilding, retrofitting, and contract manufacturing services. E-mail your request for a PDF or hard copy of the brochure to info@ame.com.

Advanced Machine & Engineering Co.
www.ame.com
(815) 962-6076

Online Video Displays
Temperature-Sensing Devices

An online video offers demonstrations of a number of temperature-indicating and measuring products for a variety of industrial applications. Shown are the Tempilstik® crayons, Tempilaq G® lacquers for calibrating ovens, Tempilabels® color-changing indicators, and Estik™, a hand-held thermocouple thermometer with digital readout from 32° to 999°F. The five-min-long video is available from the home page of the Web site.

Tempil®
www.tempil.com
(800) 757-8301
Become Certified in Robotic Arc Welding and Join the Ranks of the Elite in the Robotics Industry

AWS understands that the certification of individuals in robotic arc welding is important to the industry, and has developed a program, based on the AWS QC19 standard and AWS D16.4 specification, that defines the requirements for personnel to be considered qualified to test for certification.

Depending on the level of experience, individuals who pass a written exam and performance test can be certified as either Robotic Arc Welding Technicians or Operators.

For more information regarding this program, including how to become an AWS Approved Test Center, visit our website today at www.aws.org/certification/CRAW or call (800) 443-9353 ext. 211 (email flopez@aws.org).

To schedule training and testing to become certified in robotic arc welding, contact one of these AWS Approved Test Centers.

Colorado // Wolf Robotics // 4600 Innovation Drive // Fort Collins, CO 80525 // (970) 225-7736
Michigan // ABB, Inc. // 1250 Brown Road // Auburn Hills, MI 48326 // (248) 391-8421
Ohio // The Lincoln Electric Co. // 22221 St. Clair Ave. // Cleveland, OH 44117 // (216) 389-8542
Wisconsin // Milwaukee Area Technical College // 1200 South 71st Street // West Allis, WI 53214 // (414) 297-6996

SEMINAR / EXAM SCHEDULE

<table>
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<tr>
<th>Week of</th>
<th>AWS Approved Test Center</th>
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<tr>
<td>10/25/2010</td>
<td>The Lincoln Electric Co., Cleveland, Ohio</td>
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<tr>
<td>On request</td>
<td>Milwaukee Area Technical College, Milwaukee, Wis.</td>
</tr>
</tbody>
</table>
Wall Colmonoy Fills Three Key Posts

Joe Hetzer

Wall Colmonoy, Madison Heights, Mich., has promoted Joe Hetzer to director of manufacturing for Aerobraze, Cincinnati. Hetzer, with 23 years of experience in the aerospace industry, previously served as engineering manager. Daria Johnson has joined the company as accounting manager. With 25 years of experience in the field, Johnson most recently was controller for a gauge, cable, and adapter manufacturer for the heavy truck and military industries. Joel Gutierrez has joined the company as business manager for the Alloys Products Group. Gutierrez previously held positions at Goodman Mfg. and Modine Mfg. Co. in the brazing engineering and quality areas.

SME Honors Its Outstanding Members

The Society of Manufacturing Engineers (SME), Dearborn, Mich., recently announced this year’s Awards of Merit and Richard E. Morley Outstanding Young Manufacturing Engineer Award recipients. SME President Barbara M. Fossum said, “For more than 50 years, SME has presented the Award of Merit to honor members who have made valued contributions to the society’s professional activities and growth.” Honored were Raju Dandu, Vincent Wyatt Howell Sr., Mark Michalski, Randall T. Raikes, and Phillip S. Waldrop. Fossum said, the Outstanding Young Manufacturing Engineer Awards “has recognized young people age 35 and under for outstanding technical accomplishments in the manufacturing profession.” The awardees are Srikanth Bontha, Salil S. Desai, Mervyn Futhianathan, A. John Hart, Raja Kountanya, Zhaowei Liu, Ravi Shankar, Mike Vogler, and Chengyu Yuan.

Northwire Names Regional Sales Director

Oscar Audelo

Northwire, Inc., Technical Cable, Osceola, Wis., has named Oscar Audelo to the newly created position of regional sales director for the western United States region, Mexico, Puerto Rico, and South America. Prior to joining the company, Audelo was regional manager for Delphi Connection Systems for its military, aeronautical, medical, and commercial product lines in the western United States and Mexico.

Hobart Institute Hires Two Skill Course Instructors

Charles Carpenter Dustin Sharp

Hobart Institute of Welding Technology (HIWT), Troy, Ohio, has added Charles Carpenter and Dustin Sharp to its staff as skill instructors. Carpenter, with five years’ experience working in his father’s welding business, graduated with honors from HIWT’s Combination Structural and Pipe Welding Program. Sharp, an AWS Certified Welding Inspector, worked 13 years with the Sheetmetal Workers International Assn. and completed a training program at the Institute.

Lincoln Elects Board Member

Lincoln Electric Holdings, Inc., Cleveland, Ohio, has appointed Christopher L. Mapes as the eleventh member of its board of directors. Mapes is executive vice president of A. O. Smith Corp. and president of its electrical products unit.

Product Manager Named at Advanced Machine

Christian Schedler

Advanced Machine & Engineering (AME), Rockford, Ill., has appointed Christian Schedler product manager for its Speedcut Saw Technology division. Prior to this promotion, Schedler worked as a global service representative for a German machine tool company and as a designer of carbide saws at AME.

Cooper Industries Appoints Division President

Cooper Industries, Ltd., Houston, Tex., has appointed Laura K. Ulz president, Cooper Tools Division. Ulz, who served as vice president, operations, since 2007, previously worked for Honeywell International and Texas Instruments. She succeeds Gary A. Masse who has left the company.

Beckwood Press Fills Two Key Posts

Dan Michki Dan Steinkamp

Beckwood Press Co., St. Louis, Mo., a supplier of hydraulic presses and automated systems, has hired electrical engineer Dan Michki to coordinate its technical support processes for all company products, and Dan Steinkamp as Hastings product manager. Previously, Michki served as a project engineer for Flo-Matix Co. Steinkamp joined the company after Beckwood teamed with Hastings Manufacturing Co. to manufacture and support its heat transfer and hot stamping equipment lines.

Wagner Companies Fills New Director Spot

Wagner Companies, Milwaukee, Wis., a supplier of metal products, has appointed
Andrew Chatfield
director of architectural glass systems, a newly created position. Prior to joining the company, Chatfield was affiliated with Corma-Glas Geeze GmbH and WSS GmbH as director of their architectural glass systems.

Obituaries

Carmen A. Paponetti Sr.

Carmen A. Paponetti Sr., 58, a resident of Massillon, Ohio, died Feb. 5. An AWS member since 1991, he was a member of the Johnnay Appleseed Section, and a member of the AWS C3 Committee on Brazing and Soldering. He also served as chairman of the C3A Subcommittee on the Brazing Handbook for many years, and worked on the C3D Subcommittee on Brazing Specifications and C3E Subcommittee on Brazing Conferences. He authored a chapter in Vacuum Technology, published by ASM International, chaired the ASM Heat Treating Society (HTS) 2009-2010, and was a member of the HTS Conference and Expo Organizing Committee and the Awards and Nominations Committee for several years. Paponetti started his career in 1969 at Hi Tec Metal Group as a heat treat furnace operator. He was serving as president when he left the company in 2005 to start his own business, Expert Brazing & Heat Treating, Inc., in Massillon. He received a degree in business management in 1998 from David N. Myers College and a degree in metallurgy from Applied Technical Institute. He is survived by wife, Suzanne, four children, two step-children, three brothers, one sister, and nine grandchildren.

Alfred P. Chippero

Alfred P. “Chip” Chippero, 85, an AWS Life Member, died Feb. 19. He was affiliated with the AWS Rochester Section where he served as chairman 1966-1967. Born in Philadelphia, Pa., he served with the U.S. Navy Seabees in France during WW II and also served in the Korean War. He worked for Eastman Kodak Co. for 25 years until his retirement in 1986. During his retirement years, he was a substitute teacher at Edison Tech and a consultant. He served the Rochester City School District for more than 15 years where he taught welding technology evening classes for the Adult Continuing Education Program. He received the Adult Education Teacher of the Year Award for 1986-1987, and served on the District’s Occupational Education Advisory Council. Chippero is survived by his wife, Fayette, four daughters, three sons, nine grandchildren, and three great grandchildren.

NEW PRODUCTS

— continued from page 32

(1024 x 1024). This camera also offers frame rates at up to 500,000 frames/s at reduced resolution. It is available with an RS422 remote control keypad with built-in, 5-in. LCD viewfinder for remote operation. In addition, this camera features a variable region of interest with 12-bit uncompressed data, a one-microsecond global shutter, and 20-micron pixels for low-light, high-sensitivity applications. Memory options include 8, 16, or 32 GB. The company’s Fastcam Viewer freeware is included along with the software developer’s kit. The imager is offered with an optional sealed housing (Fastcam SA4 RV). Applications include materials test and research, automotive safety testing, microscopy, combustion, and aerospace.

Photron USA, Inc.
www.photron.com
(800) 585-2129

Dry Erase Marker Removes Easily, Leaving No Residue

DURA-INK Dry Erase, an industrial strength felt-tip ink marker designed for temporary applications, offers a fast drying mark that can be removed quickly and easily without leaving behind residue. When applications require the cap to be left off the marker for extended periods, the safe and nontoxic ink is formulated to provide a long lasting life. They are able to withstand repeated, heavy use, and write on various surfaces such as metal, glass, stone, plastic, and those that require a low-chloride/low halogen specification. The markers ½-in. bullet tip will not scratch the surface of unfinished parts and is soft enough for use on most painted surfaces. Marks wipe away simply with a dry rag, towel, or eraser. The markers come in red, black, blue, and green.

LA-CO Industries, Inc./Markal
www.laco.com
(800) 621-4025

Want to be a Welding Journal Advertiser?

For information, contact Rob Saltzstein at (800) 443-9353, ext. 243, or via e-mail at salty@aws.org.
train components for fuel-efficient passenger cars as well as commercial and military trucks.

The project will focus on developing fuel efficiency and cost effectiveness to offer the potential for 60% weight reduction without compromising performance, cost, safety, or recyclability. The material technology is self-propagating high-temperature synthesis. Magnesium-based composites are the primary focus.

The NADCA will work on this project in conjunction with the Colorado School of Mines, The Ohio State University, Case Western Reserve University, Worcester Polytechnic Institute, Purdue University, and Oak Ridge National Lab. To learn more, visit www.diecasting.org/research/roadmap.htm.

Steel Dynamics to Begin Shipping Standard Rail to Railroads

Steel Dynamics, Inc., Fort Wayne, Ind., has begun commercial production of standard strength rails that meet all current American Railway Engineering and Maintenance-of-Way Association (AREMA) specifications. The company's Structural & Rail Division at Columbia City, Ind., produces this rail in lengths up to 240 ft and is capable of producing 300,000 tons of rail per year.

Additionally, its standard strength rail has been tested and qualified by the first of the seven North American Class I railroads. Evaluations by other Class I railroads are underway and expected to result in additional approvals soon.

To secure this certification, samples of the rail produced at the company’s rail mill have undergone evaluations by independent testing laboratories to certify adherence to the AREMA specifications.

Using the Columbia City mill’s ability to produce 240-ft-long rail, Steel Dynamics employs its on-site rail welding plant to weld rails together into continuously welded rail strings 1600 ft in length. This winter, it completed modifications to the rail-welding plant that allow year-around operation on an uninterrupted basis.

Boomerang Tube Finalizes Funding for Oil Goods and Line Pipe Facility

Boomerang Tube, LLC, Chesterfield, Mo., has finalized funding to build a new manufacturing facility in Liberty, Tex., to produce welded oil country tubular goods and line pipe for oil and gas customers in the United States and Canada. Construction will be financed by Access Industries, a New York-based industrial group that has committed $200 million for the project. This facility will commence operations in August and employ up to 350 people once fully operational. Also, the new 487,000-sq-ft facility will utilize modern equipment, and modifications to the existing building are underway.

Welding Facility at Cochise College Utilizes Solar Power Capabilities

The welding technology facility at Cochise College, Sierra Vista, Ariz., recently implemented a solar energy system. This comes in the form of two units provided by Solon Corp., Tucson, Ariz., each producing 30 kVA (480 V) three-phase power.

The open circuit voltage for this facility is 477 VDC with a maximum current of 63.6 A. The cell units are approximately 43 ft² and connected to the grid through a production meter provided by Sulphur Springs Valley Electric Cooperative. During daytime, all of the power produced is used in the welding laboratory, the facility goes on the grid at night.

“Arizona is trying to develop the state as an example of solar power technology,” said Ralph E. Long, an AWS Counselor and a part-time teacher at the college. “This is an example of how solar technology is being applied in sunny Arizona and in the welding education arena.”

Miller/United Association Web Site Offers Welding Solutions for Union Tradesmen


Union leaders may choose from the products best suited to UA work instead of evaluating the features and benefits of hundreds of welding, plasma cutting, and power generation products. To eliminate the potential for incomplete grant applications, it offers complete package recommendations. Training resources specific to UA school needs are compiled here as well.

Industry Notes

- STS Welding Consultation, Inc., Mandeville, La., recently merged with Construction Technical Services, Inc. (CTSI), Houston, Tex., whose services include mechanical, piping, electrical, and instrumentation inspection as well as vessel/tank, subsea, and topsides equipment inspection and fabrication consultancy. Steve Snyder joins CTSI as upstream projects technical manager.
- Northern Iowa Die Casting has been guaranteed a loan of almost $1.5 million, saving an estimated 82 jobs. The funds are being provided through the U.S. Department of Agriculture Rural Development's Business and Industry Guaranteed Loan Program and were funded in the American Recovery and Reinvestment Act of 2009. Iowa Senator Tom Harkin worked to secure these.
- Fronius USA, Welding Division, opened its second U.S. sales/service office in Chattanooga, Tenn. All aspects of customer support in the Southeast region will be handled at this new 5000-sq-ft location that includes a fully functional application lab.
- The Canadian Welding Bureau Group has been ranked #34 among the Top 50 Best Small and Medium Employers in Canada. Also, the organization recently acquired NDT Training & Education Group INTEG.
At last there’s a D1 for strengthening and repairing existing structures

Since the first D1 standard in 1928, the AWS D1 structural welding series has provided a consensus of the finest minds in the industry on the most reliable approaches to welding new structures.

Now there is a D1 that provides the same guidance for repair, corrective issues, and strengthening of existing steel structures. AWS D1.7/D1.7M, Guide for Strengthening and Repairing Existing Structures, is invaluable to the engineer who is obligated under D1.1 Clause 8 to plan for projects that involve strengthening and repairing.

Preview and order your AWS D1.7 by visiting www.awspubs.com, or call 888-WELDING for information on all of AWS’s structural welding codes.

American Welding Society
Founded in 1919 to advance the science, technology and application of welding and allied joining and cutting processes, including brazing, soldering and thermal spraying.
PROFESSIONAL PROGRAM ABSTRACT SUBMITTAL
Annual FABTECH International & AWS Welding Show
Atlanta, GA - November 2 – 4, 2010

Submission Deadline: March 31, 2010
(Complete a separate submittal for each paper to be presented.)

Primary Author (Full Name):
Affiliation:
Mailing Address:

City: State/Province Zip-Mail Code Country:
Email:

Co-Author(s):
Name (Full Name): Affiliation:
Address: City:
State/Province Zip-Mail Code Country:
E-Mail:

Name (Full Name): Affiliation:
Address: City:
State/Province Zip-Mail Code Country:
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Name (Full Name): Affiliation:
Address: City:
State/Province Zip-Mail Code Country:
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Answer the following about this paper
Original submittal? Yes □ No □ Progress report? Yes □ No □ Review paper? Yes □ No □ Tutorial? Yes □ No □
What are the welding/Joining processes used?
What are the materials used?
What is the main emphasis of this paper? Process Oriented □ Materials Oriented □ Modeling □
To what industry segments is this paper most applicable?
Has material in this paper ever been published or presented previously? Yes □ No □
If “Yes”, when and where?
Is this a graduate study related research? Yes □ No □
If accepted, will the author(s) present this paper in person? Yes □ Maybe □ No □

Keywords: Please indicate the top four keywords associated with your research below

Guidelines for abstract submittal and selection criteria:
- Only those abstracts submitted on this form will be considered. Follow the guidelines and word limits indicated.
- Complete this form using MSWord. Submit electronically via email to techpapers@aws.org
- Technical/Research Oriented
  - New science or research.
  - Selection based on technical merit.
  - Emphasis is on previously unpublished work in science or engineering relevant to welding, joining and allied processes.
  - Preference will be given to submittals with clearly communicated benefit to the welding industry.
- Applied Technology
  - New or unique applications.
  - Selection based on technical merit.
  - Emphasis is on previously unpublished work that applies known principles of joining science or engineering in unique ways.
  - Preference will be given to submittals with clearly communicated benefit to the welding industry.
- Education
  - Innovation in welding education at all levels.
  - Emphasis is on education/training methods and their successes. Papers should address overall relevance to the welding industry.

Check the category that best applies:
□ Technical/Research Oriented □ Applied Technology □ Education
Abstract:

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

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

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

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

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

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

Return this form, completed on both sides, to

AWS Education Services
Professional Program 2010
550 NW LeJeune Road
Miami FL 33126
FAX 305-648-1655

MUST BE RECEIVED NO LATER THAN MARCH 31, 2010
School Profiles

Employers
Are you in need of good welders?

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

Welders
Is it time to expand your talents and knowledge?

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

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

University of Alaska Anchorage Welding and NDT Technology
Founded 1970

The welding/NDT program at UAA offers a choice of certificates and an Associate of Applied Science degree that centers on welding skills, welding inspection and nondestructive testing. Program courses include skill development in major welding processes, pipe fitting and basic metallurgy, as well as hands-on NDT training in the RT, UT, MT and PT processes. Our program serves about 175 students each year.

American River College
Founded 1955

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

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

Akron Testing Lab. & Welding School Ltd.
Founded 1953

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

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

Asheville-Buncombe Technical Community College
Founded in 1959, A-B Tech offers a welding associate’s degree and diploma, as well as certificates in basic welding and ornamental ironwork. The campus is located in the mountains of Western North Carolina and serves 27,000 students, annually. The curriculum provides students with an understanding of the science, technology, and applications essential for successful employment in the welding and metal industry. Instruction includes SMAW, GMAW and GTAW.
Atlantic Technical Center
Founded 1973
Atlantic Technical Center provides a review for persons currently employed in welding occupations who wish to take an AWS test to become a Certified Welder, or first time students who are interested in learning advanced and basic welding skills techniques. Shop activities are an integral part of this course and provide instruction to develop skills in Industrial, Structural, Aircraft, Marine, Petroleum and Nuclear Welding. At the successful completion of laboratory activities, an AWS Welding Certification test is available. Accredited by the Commission of the Council on Occupational Education.

Bellingham Technical College
Welding Technology Program
Founded in 1956
Bellingham Technical College’s Welding Technology Program offers AAS and AAS-T degrees in certified welding and fabrication for a vibrant community of pipelines and Northwest Washington refineries, ship building and repair, transportation, and shops and fabricators. Our award-winning program is in an 80,000 sq. ft. state-of-the-art facility that houses our 200 plus enrollment in pipe welding, aluminum welding and fabrication, steel fabrication, and creative welding. Our Annual Welding Rodeo Sculpture Contest is a one-of-a-kind experience for Amateurs and professional artists throughout the Pacific Northwest.

Brazosport College
Brazosport College offers welding training on its campus on the beautiful Texas Gulf Coast. With over 40 years experience and customized classes, BC offers a top-rated program with employer-driven curriculum and lots of individual attention. NCCER recognized classes are offered at a variety of convenient times. Earn a certificate or associate of applied science degree in welding and quality assurance (CWI).

Brevard Community College
Founded 1960
Brevard Community College, located in the heart of the nation’s space coast, offers a one and one-half year Welding Technology certificate program. The program provides the theoretical and practical experience necessary to develop a basic foundation in the skills of welding, and is designed to train students to become certified welders in structural steel and piping codes approved by the AWS, ASME, API and ANSI. Graduates of the program will be prepared for entry-level positions as welders and are eligible to take the AWS certification exam. OSHA industry standards will be enforced.

Bellingham Technical College
Welding Rodeo
BTC’s 9th annual team welded sculpture competition and auction will be held Friday and Saturday, May 21st and 22nd, 2010. The theme for 2010 is "Human Form." Friday we will showcase 10 amateur high school and college level teams, and on Saturday we will showcase 10 professional level teams competing for prizes and cash. The public is invited both days. Contact us for more information or visit our website.

Butte-Glenn Community College
Founded 1967
The Welding Technology Program is a vocational core of courses designed to produce qualified personnel for certified welding jobs. Program performance standards for certification are in accordance with those established by the American Welding Society and/or American Society of Mechanical Engineers. Courses are held in a completely modern and well-equipped welding lab. This program is designed to produce entry-level welding technicians in the 6-G pipe position (qualifies for all positions in plate and pipe). Heavy plate 3G and 4G are also obtainable. The student will be able to weld with SMAW, FCAW, GMAW, GTAW, OAW, OFC, PAC and AAC in all positions with a variety of metals and alloys. Students will be able to certify under at least one of the following codes: API, AWS, and ASME, according to individual skills.
Cal-Trade Welding School of Modesto
Founded 1975

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

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

The Calhoon MEBA Engineering School

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

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

Central Region Career and Technical School

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

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

Center For Employment Training

Founded 1967

Center for Employment Training is accredited by the Western Association of Schools and Colleges (WASC). We are employer-driven teaching a curriculum that meets the workforce demands. Graduates will receive a welding fabrication certificate, along with the opportunity to receive six AWS D1.1 approved Certifications (SMAW E7018 3G & 4G, FCAW NR211, NR232 3G & 4G GMAW ER70S-1 & 4G, GTAW ER70S-1 & ER4043). Customized training is available to employers. We are certified to train veterans and offer financial aid to those who qualify.

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

Central Wyoming College

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

The College of Southern Nevada, located in the “Jewel of the Desert”, fabulous Las Vegas, offers both a one year certificate of achievement and a two-year associate of applied science degree in welding technology. As both a Sustaining Company and S.E.N.S.E. affiliate member, students have the opportunity to certify as entry or advanced level welders. In addition, the college also offers various specialty courses covering NDT and CWI preparation.

700 College Dr.
Henderson, NV 89002-8419
John W. Cavenaugh, Program Director
(702) 651-3065
john.cavenaugh@csn.edu

Cosumnes River College

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

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

Cuesta College Welding Technology

Located on the central coast of California, the Cuesta College Welding Technology program has a strong history of preparing students for work in industry. Students certify to AWS D1.1 and ASME Section IX and have the opportunity to obtain associate science degrees in welding technology. Our curriculum is well rounded with courses ranging from basic welding through certification, as well as courses in metallurgy, blueprint reading and welding power. The shop facility includes twenty multiprocess welding stations newly appointed with current power supply technology. There are a total of eight part-time instructors and one full time instructor representing a collective total of 185 years industry experience and 100 years teaching experience in welding technology. Four of our instructors are CWI’S. Article sponsored by CBI of San Luis Obispo, California.

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

CTC Lackawanna Co,
(Formerly Lackawanna Co AVTS)
Founded in 1973

CTC serves the secondary students and adult community of the greater Scranton (PA) region. Emphasis is placed on safety as well as blueprint reading, properties of metal, metal identification, types and use of electrodes, welding rods, electrical principles, and NDT. Secondary and adult students have the opportunity to take AWS and ASME certification tests. Accredited by Pennsylvania State Board of Education.

3201 Rockwell Ave
Scranton PA 18508
(570) 346-8471
Email: admctc@ctclc.edu
www.ctclc.edu.

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

3201 Rockwell Ave
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www.cda.edu
DALUS was founded in 2000 for the purpose of training and testing people in certifiable skills and knowledge that will help to integrate them into a world class workforce. DALUS is an AWS Accredited Test Facility (ATF) and a member of the S.E.N.S.E. (Schools Excelling through National Skills Education) program and administers SCWI, CWI and CWE prep course and exams three times a year. DALUS also offers courses designed to meet employer’s specific needs.

Davis Applied Technology College

Davis Applied Technology College (DATC) offers welding training on its Kaysville, Utah campus. Students can earn a basic and/or advanced certificate in as little as 8-12 months. Learn from welding experts who provide real-world training through a new partnership with Lincoln Electric. Oxyfuel, SMAW, GTAW, GMAW, FCAW, SAW, plasma cutting, pipe welding, and more will be offered through this exclusive training collaboration. Scheduling is flexible, tuition is affordable, and financial aid and scholarships are available to those who qualify.

Del Mar College

Del Mar College is a comprehensive community college in Corpus Christi, Texas. The welding program offers training in SMAW, GMAW, GTAW, FCAW, and various other processes. Welding is done on plate and pipe. Training is based on AWS and industry standards. Certificate and associate degree programs are offered. Visit us on the web or call 1-800-652-3357 for information.

Lynnes Welding Training, Inc.

Fast track your career in just a few weeks. Extensive hands on training w/blueprint reading. Small classes for more personal attention. Customized courses available for employers. Earn a certificate – GMAW, GTAW, SMAW, and Pipe (Tig or Stick). We provide customized training for companies, as well as give assistance with job placement. Providing training since 2004 with over 550 students. We now have two locations. We also except the G.I. Bill.

The Divers Academy International

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

Delaware Area Career Center

Welding students at the Delaware Area Career Center design, engineer, build, and troubleshoot complex manufacturing solutions for actual clients. They learn to interpret blueprints and specifications using math and computer technology. They also develop the strength, work ethic, and stamina necessary for a career in fabrication. Upon completion, the students are prepared for NC3CR (National Center for Construction Education and Research) Welding Certificate, AWS (American Welding Society) Certifications, immediate employment as an apprentice, and further education.
Earlbeck Gases & Technologies

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

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

Eastern Maine Community College

Founded 1966

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

354 Hogan Road,
Bangor, ME 04494
(207) 974-4643
cmaseychik@emcc.edu
www.emcc.edu

El Camino College

Founded 1947

The El Camino College Welding Department strives to meet diverse student needs by providing quality instruction in morning, afternoon, and evening classes. Introductory through advanced courses are available in oxy-acetylene welding and cutting, GMAW, GTAW, FCAW, and SMAW. Successful students may then progress through intermediate and advanced classes in SMAW, GMAW and GTAW. Intermediate classes offer certification testing in plate. Advanced classes offer certification testing in pipe. Customized and mobile training is also available for employers.

Welding Department
16007 Crenshaw Boulevard
Torrance, CA 90406
(310) 660-3600
www.elcamino.edu

Ferris State University

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

Welding Engineering Technology
915 Campus Drive, Swan 107
Big Rapids, MI 49307
(231) 591-2952

Frank Phillips College Welding Technology department is dedicated to providing students with superior performance-based training from basic oxy fuel skills through advanced alloy pipe welding, blueprint reading and pipe fitting techniques. With our new environmentally controlled facility and state-of-the-art equipment, our team has an excellent reputation for high job placement and producing quality craft personnel. Located in the heart of the Texas Panhandle, you can — “Start Here, Go Anywhere.”

Gadsden Technical Institute

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

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

Hill College

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

Hobart Institute of Welding Technology

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

Hutchinson Community College

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

Illinois Valley Community College

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

Monroe County Community College

Monroe County Community College, Welding Center of Expertise under the Industrial Technology Division offers an accelerated beginning and advanced welding program funded by a grant awarded under the Community-Based Job Training Grant program as implemented by the U.S. Department of Labor’s Employment and Training Administration. The Industrial Technology Division is offering 10-week courses to prepare students for American Welding Society QC10 and QC11 certifications. The examinations for these certifications are offered at MCCC. Enrollment is limited.

MCCC / Welding Center of Expertise

1555 S. Raisinville Road
East Technology Building
Monroe, MI 48161
(734) 384-4145

Larry Byrnes,
Welding Grant Coordinator
lbyrnes@monroeccc.edu
www.mcccweldcoe.org
SCHOOL PROFILES  APRIL 2010

Las Positas College

Located in the heart of the San Francisco Bay Area, Las Positas College offers students a well rounded welding education from industry seasoned instructors. Building on a foundation of basic skills, the student progresses through courses in SMAW, GTAW, FCAW, and GMAW as well as skills in arc cutting and gouging. Day, evening and weekend course work includes steel, aluminum, stainless steel, sheet, plate and pipe in all positions to AWS, ASME, and API codes.

Lincoln Electric Welding School

Learn to weld at the Lincoln Electric Welding School. We have trained over 100,000 welders in many different trades (ironworkers, boilermakers, pipefitters, and sheet metal). Learn to weld with the latest technology in equipment and consumables, on different base metals (carbon steel, stainless, aluminum and cr/mo) and all arc welding processes (SMAW, GMAW, GTAW, FCAW, SAW). Our instructors have real world experience in factory and motorsports, including trackside welding at NASCAR®, IRL® and NHRA® events. We also can complete jobsite training at your location.

Lassen Community College

Lassen Community College offers a comprehensive welding technology program. The program has an extensive array of classes that is sure to meet everyone’s needs, including AWS qualification testing SMAW, GTAW, FCAW-S and FCAW-G. In addition, we offer an A.S. degree and a one or two year certificate of achievement in welding technology. We also have a new facility that provides students with production experience using state-of-the-art welding equipment.

Lorain County Community College

Lorain County Community College welding technology program is a stand alone, two year, full-time Associate degree program designed to provide students with the knowledge, skills, and professional behaviors necessary for the competent performance as a welding technician. The program’s design is based on the occupational needs of maintenance and fabrication technicians in the manufacturing and construction industries. Employment opportunities exist in a variety of industries such as steel, construction, fabrication, pipelines, and others. Students who successfully complete the program may be qualified to take certain welding certification tests. LCCC also offers a short term technical certificate and a one year technical certificate that both leads to the AAS degree. Weld-Ed is a national center for welding education and training located at LCCC, its lead partner.

Jamestown Community College

Be in demand! Jamestown Community College offers a one-year certificate program and a full associate degree program in welding technology in a state-of-the-art facility in cooperation with the Manufacturers Association of the Southern Tier. On-campus suite-style residence halls are available along with a dynamic campus life program including intercollegiate and intramural athletics. Small classes offer personal attention. Full employment services available.

Kenai Peninsula College

Kenai Peninsula College is a branch of the University of Alaska located 150 miles south of Anchorage on the Kenai Peninsula. KPC offers certification on AWS D1.1, D.375 steel plate 3G and 4G SMAW, ASME Section IX pipe certification on steel 6-inch schedule 80 6G SMAW. Our welding certificate program includes math, blueprint reading, and English (students must certify on pipe to complete certificate). KPC students are provided with 3M® powered air purifying respirator welding hoods. Nonresident tuition is waived for students taking classes at KPC for the Spring and Summer 2010 semesters. This waiver does not apply to students taking distance-delivered courses while residing outside the state of Alaska.

Lorain County Community College

Weld-Ed

National Center for Welding Education and Training

Tom Annable
1005, N Abbe Road
Elyria, OH 44035
(440) 366-7015
tannable@lorainccc.edu
Los Angeles Trade-Technical College

Los Angeles Trade-Technical College welding program offers an Associate in Science Degree in Welding and a Certificate of Completion. The welding curriculum adopted the AWS SENSE guidelines and offers courses in SMAW, GTAW, FCAW, OAW, and welding inspection. NCCER certifications and pipe welding courses scheduled for fall 2010 semester. LATTC welding facility is an AWS Accredited Testing Facility and conducts welder’s performance qualifications for the City of Los Angeles Dept. of Building and Safety.

Mesabi Range Community & Technical College

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

Mid-Plains Community College

Mid-Plains Community College’s welding and machine shop technology is an open-entry, open-exit program that leads to a diploma or associate of applied science degree for employment in the welding/machine shop field. Students may enter at different stages of readiness and progress according to his/her abilities and efforts. Upon completion of a set of prescribed technical competencies, students will be able to perform skills necessary to be successfully employed at the entry level or above with a selected occupation.

Missouri Welding Institute

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

Monroe County Community College

Founded 1964

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

Moraine Park Technical College

Moraine Park Technical College offers a one-year welding diploma program focusing on GMAW, FCAW, SMAW and GTAW in all positions. Instruction includes AWS and ASME welding codes, print reading and fabrication courses. New this year is a one-year Metal Fabrication program, emphasizing the manufacturing process of taking a product from conception to final product using lasers, plasma and flame tables, rollers, press brakes, and welding equipment.
New Castle School of Trades
Founded 1945

The New Castle School of Trades offers welding training at its western Pennsylvania campus. Earn a diploma in combination welding. Hands on training in SMAW, GTAW, GMAW, FCAW, PAC, CAC and pipe welding. Support courses such as welding blueprint reading, pipe blueprint reading and welding fabrication. AWS certifications offered for all processes. Enjoy small classes, free tutoring, and personalized attention. Customized courses available for employers. Teaching America's trades since 1945. Real people—Real training—Real jobs.

Northeast Community College / South Sioux City Education Center

Earn a welding diploma in one year at the South Sioux City, Neb. location. Curriculums include SMAW, GMAW, GTAW, FCAW, OA and plasma torch. Support courses include metallurgy, related drafting, shop tools operations, blueprint reading, basic machine tool and OSHA 30 hour safety. Advanced Training available for iron pipe welding and fitting (6G Qualification skills). Full time instructor has 35 years field experience, 20 years ASME qualified. Affordable tuition, quality education, and small class sizes.

South Sioux City Education Center
3309 Daniels Lane, PO Box 989
South Sioux City, NE 68776
(402) 241-6400 or (888) 698-6322
Email: russell@northeast.edu

Northeast Wisconsin Technical College

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

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

North Georgia Technical College

North Georgia Technical College, an educational facility since 1907, offers students the opportunity to live and learn in the mountains of northeast Georgia. Students enrolled in our welding technology program can choose the path that is right for them. Whether you're looking to earn a degree, diploma, or technical certificate you can find it at NGTC. Programs range from two to six quarters and specific areas of training include GMAW/MIG, GMAW/TIG, oxyfuel cutting, shielded metal arc welding, pipe welding, and advanced nuclear pipe welding. On campus housing, hands-on training and knowledgeable, caring instructors give students a well-rounded educational experience. Program graduates are prepared to take qualification tests and can enter the workforce armed with the skills necessary for successful employment.

P.O. Box 65
1500 Highway 197 N
Clarkeville, GA 30523
(706) 754 7700
Ronnie Ayers, Instructor
ayers@northgatech.edu
(706) 754 7764
www.northgatech.edu

National Polytechnic College of Science

Nat Poly's underwater nondestructive testing (SpecTech) concentration is a 20-week program that provides training in the use of sophisticated techniques that include underwater photography, video documentation, ultrasonic, magnetic particle, dye penetrant, and visual inspection. A student is eligible to receive qualification certificates of training for Levels I and/or II in ultrasonic (UT), magnetic particle (MT), and dye penetrant (PT) and visual testing (VT) in accordance with the American Society for Nondestructive Testing.

National Polytechnic College of Science
3580 Aero Court
San Diego, CA 92123-1711
(858) 309-3500
Dan Roberts, Director, Student Services and Admissions
droberts@natpoly.edu

Orange Coast College

The Orange Coast College welding curriculum has been a part of this college curriculum since the college was first conceived. Our program offerings include both a welding certificate of achievement and an associate in science degree. We are proud to offer a comprehensive welding program which includes oxyacetylene welding and cutting, SMAW, GMAW, FCAW, GTAW, orbital welding and plasma arc cutting. On our academic side we teach metallurgy for welders, codes and specifications for welders, math and fabrication for welders and testing and inspection for welders. Our instructors have AWS QC-I CWI and CWE credentials as well as California Community College teaching credentials. We qualify welders to ANSI standards and we are licensed Los Angeles City testing laboratory. Our testing laboratory does both destructive and non-destructive examinations.
Odessa College

The welding technology department at Odessa College in Odessa, Texas, offers a full range of certificate and associate degree options. The lab areas are equipped with 45 modern welding stations for training in SMAW, GMAW, FCAW and GTA processes as well as 15 OFW stations. Currently, classes are offered in the morning and evening to accommodate an average of 100 students each semester. Odessa College received a U.S. Department of Labor grant for $1.75 million in January 2007 for the Welding Training Center. This new 30-station training facility opened in January 2008 and offers 8-week “Introduction to Welding Fundamentals” courses through the continuing education division. The Welding Training Center received the AWS “Image of Welding Award” in October 2008.

Ozarks Technical Community College

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

Owens Community College

Owens Community College welding technologies provides students with knowledge and skills for job placement in the welding industry. Students are educated in all aspects of welding including SMAW, GMAW and GTA welding, torch and plasma cutting as well as brazing. Students who excel in their welding skills are encouraged to complete their plate and pipe welding certification. Students may also chose from coursework in welding fabrication, welding codes and procedures and certified welding inspector.

Pennsylvania College of Technology

Pennsylvania College of Technology, a Penn State affiliate since 1989, offers “degrees that work” in more than 100 careers including welding. In addition to an associate’s degree and certificate, Penn College offers a unique bachelor’s degree in Welding and Fabrication Engineering Technology that prepares graduates for technical careers and positions in mid-management, super-vision, sales, service, and research. The College also is a regional partner for the National Center of Excellence in Welding Education and Training.

Portland Arts and Technology High School

Portland Arts and Technology High School in Portland, Maine offers excellent welder training. AWS certifications in SMAW, Structural D 1.1., GTA, FCAW, and GMAW on carbon, aluminum and stainless plate and pipe are also taught. The 2-or 3-year course (800-1000 hrs) is designed to give students plenty of practical application and theory in oxyfuel, plasma cutting and SMAW. Blueprint reading and blacksmithing are also practiced. Adult Education welding is offered four times a year.
Pulaski Technical College

The welding program at Pulaski Technical College in North Little Rock, Arkansas focuses on structural welding and offers AWS Level I and II certification. The two-semester technical certificate program includes instruction in welding processes, joint design and metallurgy. The certificate of proficiency will allow an individual to complete certification requirements in 3G (vertical) positioning.

Santa Fe College

Serving Alachua and Bradford Counties
Founded 1966

The applied welding technologies Program is a one and one-half year certificate program that consists of SMAW, GMAW, GTAW, FCAW, oxy fuel welding/cutting, blueprint reading and power tool and equipment operation performed on carbon steel, stainless steel, and aluminum. The training helps prepare students to pass nationally recognized plate and pipe welding certification tests. The welding lab at SFC is an AWS Accredited Testing Facility.

Southern Maine Community College

Southern Maine Community College offers courses in introduction to welding, structural welding I, A, W, American Welding Society D1.1 and the advanced process, GTAW, FCAW, GMAW, and metal art. Earn a certificate in welding or an associate degree in integrated manufacturing that combines welding with machining. In addition to small classes and personal attention, SMCC students enjoy picturesque 80-acre campus surrounded on three sides by water with a sandy beach, a pier, and a working lighthouse. SMCC is a NCCER Certified Training Center.

Rock Valley College

RVC’s welding program currently includes 60 students trained in the facility which includes a lab with 28 welding booths. Welding processes being taught include GMAW, FCAW, GTAW, SMAW, and oxyacetylene. RVC is an AWS Certified Accredited Testing Facility. The welding lab has been at current location for eight years staffed by one full time and five part-time faculty. RVC is a certified ICAR welding testing center. For information, contact Mike Merriman.

South Plains College

Founded: 1957

The SPC welding technology program offers basic and advanced certificates along with an associate of applied science degree. Entry level and advanced training certificates through AWS are also awarded to those who qualify. Specific areas of training include: OFC, PAC, SMAW plate and pipe, GMAW plate and pipe, FCAW plate and pipe, GTAW sheet and pipe, welding symbols, blueprint reading, welding metallurgy and structural and pipe layout and fabrication.

SouthWest Collegiate Institute for the Deaf of Howard College

Founded in 1980

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

Southern Union State Community College located near Auburn, Alabama, offers an associate degree of applied science in welding technology and a short certificate in structural welding. We offer plate and pipe welding in 50 weld booths with the capabilities to weld GMAW, FCAW, SMAW, and GTAW on carbon, aluminum, and stainless steel. Southern Union is a certified NCCER training facility and is the only school in the state that is an AWS Accredited Testing Facility.

SUNY College of Technology at Alfred

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

SUNY College of Technology at Alfred

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

Tom P. Haney Technical Center

The welding program at Tom P. Haney Technical Center offers training in SMAW, GMAW, GTAW, and Oxyfuel skills. The course follows the NCCER curriculum. The 1080-hour course prepares students to enter the welding market with skills needed for today's high demand welding field with special emphasis on pipe and tube welding. The school is partnered with several companies for employment opportunities upon completion. The course instructor is an AWS Certified Welding Inspector/Educator.

SOCC located in Coos Bay on the beautiful Southern Oregon coast offers the chance to earn 6 month or 1 year certificates, or an associate in applied science degree {A.A.S.}. A broad curriculum trains students in: SMAW, GTAW, GMAW, FCAW, Oxyfuel, plasma cutting, and CNC operations. Industry relevant, state of the art equipment funded 100% through a $1,998,815 US Dept of Labor grant is “Putting Education to Work” making SOCC a leader in welding education.

Tulsa Welding School

Tulsa welding school is the largest accredited* welding institution in America with training centers in Tulsa, Okla. and Jacksonville, Fla. Founded nearly 60 years ago, diplomas and associate degrees are awarded. Welding competencies include structural, pipe, pipeline, and thin alloy welding. Associate degree also includes numerous NDT techniques plus QA/QC methods. Graduates are available every three weeks along with thousands of alumni who contact TWS. *ACCSC

Tulsa, OK

Laryssa Keeney
Graduate Employment
(918) 587-6789, ext. 260
Email: lkeeney@twsweld.com
or
Jacksonville, FL

Drew Duffy
Graduate Employment
(904) 646-9353, ext. 260
Email: dduffy@twsweld.com
Tyler Junior College

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

University of Alaska Southeast Ketchikan Campus

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

Washtenaw Community College

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

Welder Training and Testing Institute

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

Welding 101

A 12,000 Ft² facility with 30 state-of-the-art welding booths and plenty of fabricating. Offering an intense 9 month, AWS entry level Welder, program designed to prepare individuals for employment. All instructors are AWS CWI/CWE with over 93 years combined experience. Welding personnel prescreening services, customized industrial training, and company certifications programs are also available. Contact us today for your training and testing needs.

Welding School Administrators

We would like to thank all the welding schools that participated in Welding School Profile section of the Welding Journal.

If for some reason you could not participate this year and would like for us to send you information on how your school can be included in the 2011 edition, just e-mail a note to Rob Saltzstein at salty@aws.org or to Ms Lea Garrigan at garrigan@aws.org.

You can send us a fax at 1-305-443-7559. Please include the name of your welding school, the mailing address, the contact person, phone, fax and e-mail information.
### POSTER ABSTRACT SUBMITTAL

**Annual FABTECH International & AWS Welding Show**

Atlanta, GA – November 2-4, 2010

(Complete a separate submittal for each poster.)

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**Poster Requirements and Selection Criteria:**

- Only those abstracts submitted on this form will be considered. Follow the guidelines and word limits indicated.
- Complete this form using MSWord. Submit electronically via email to techpapers@aws.org or print and mail.
- Any technical topic relevant to the welding industry is acceptable (e.g. welding processes & controls, welding procedures, welding design, structural integrity related to welding, weld inspection, welding metallurgy, etc.).
- Submittals that are incomplete and that do not satisfy these basic guidelines will not be considered for competition.
- Posters accepted for competition will be judged based on technical content, clarity of communication, novelty/relevance of the subject & ideas conveyed and overall aesthetic impression.

Criteria by category as follows:

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

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

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

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

#### (E) High School
- Junior or Senior high school students enrolled in a welding concentration at the time of submittal.
- Presentation should represent technical concepts and application to the welding industry.
- Practical application and creativity are important and should be demonstrated.
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**B) Student**
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- Poster should represent the student's own experimental work. Emphasis is placed on demonstrating a clear understanding of technical concepts and subject matter.
- Practical application and/or potential relevance to the welding industry is important and should be demonstrated.

**C) Student**
- For students enrolled in graduate degree programs in engineering or engineering technology at time of submittal.
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Microstructural Changes in Grade 22 Ferritic Steel Clad Successively with Ni-Based and 9Cr Filler Metals

A study was conducted of the interface microstructure in a Grade 22 ferritic steel base metal weld clad with ENiCrFe-3 and P91 filler metals

BY R. ANAND, C. SUDHA, V. THOMAS PAUL, S. SAROJA, AND M. VIJAYALAKSHMI

ABSTRACT

This investigation demonstrates the effectiveness of using a nickel-based interlayer in preventing the formation of hard and soft zones during postweld heat treatment of Grade 22 ferritic steel weld clad with Grade 91 ferritic steel. Since carbon diffusion due to the activity gradient is responsible for the formation of the zones, a nickel-based interlayer (ENiCrFe-3) was introduced by welding to prevent carbon diffusion, thereby controlling the formation of hard and soft zones. Postweld heat treatment of weldments with 0.1-mm-thick interlayers was carried out at 1023 K for 1 and 15 h. Interfacial microstructure and microchemistry between Grade 22/ENiCrFe-3 and Grade 91/ENiCrFe-3 were investigated in detail using electron microprobe and transmission electron microscopy. Formation of a hard zone was not observed at the interface of the P91 steel and ENiCrFe-3 interlayer. However, presence of a zone of retained austenite (~6 μm in width) at the interface between Grade 22 and ENiCrFe-3 was confirmed. This zone did not show any systematic variation in width with postweld heat treatment schedule. Formation of retained austenite was understood based on nickel dilution across the interface during welding.

KEYWORDS

Cr-Mo Steels  
Diffusion Barrier  
Hard Zone Formation  
Elemental Redistribution  
Dissimilar Metal Welding

Introduction

Ferritic steels are the preferred structural materials for steam generator circuits of thermal and nuclear power plants due to their good high-temperature oxidation and corrosion resistance as well as moderate creep rupture strength (Ref. 1). In-service exposure or postweld heat treatment (PWHT) of ferritic steel dissimilar weldments often results in the formation of a carbon depleted “soft zone” in the low-Cr side and a precipitate-rich “hard zone” in the high-Cr side near the weld interface (Refs. 2, 3). Diffusion of carbon due to the activity gradient from low-Cr to high-Cr side was identified as the principal cause for the formation of the zones (Ref. 4). It has been recognized that formation of such deleterious zones at the weld interface leads to premature failure of the welds, well before their design life period.

A number of methods have been identified (Refs. 5–7) to prevent the formation of hard and soft zones in dissimilar joints: 1) introducing a diffusion barrier to carbon, 2) reducing the activity gradient by welding steels with graded Cr composition, and 3) reducing the carbon activity on the low-Cr side by alloying with elements like Nb, V, or Ti, which have a higher affinity for carbon. Of these methods, introduction of a nickel-based diffusion barrier was found to be most effective. In dissimilar weldments of Fe-0.47C and Fe-19Cr-8Ni-0.09C steels, presence of a 50-μm-thick interlayer of spectrally pure nickel was found to have a retarding influence on carbon redistribution (Ref. 8). The retarding effect was found to be directly proportional to the thickness of the interlayer. Further, a nickel-based diffusion barrier between a corrosion-resistant steel (Fe-3%Si) and carbon steel was found to reduce the thickness of the carburized zone by a factor of almost three (Ref. 9). Several such studies are available suggesting the beneficial effect of nickel-based antidualiffusion barriers (Refs. 10–13). Nickel was also the preferred filler metal in ferritic-ferritic transition joints since its thermal expansion coefficient (14.9 × 10^-6 for ENiCrFe-3) lies closer to that of a ferritic steel (14 × 10^-6 for Grade 22) (Ref. 14).

The microstructure that develops at the interface between a low-Cr ferritic steel and nickel-based filler metal in austenitic-ferritic and ferritic-ferritic transition joints has been extensively studied and debated. J. Barford et al. (Ref. 15) have reported dark etching “finger like” duplex structure (a+y) extending from the 2¼Cr side to the Inconel® weld metal side in high-temperature exposed joints. Uniaxial tensile tests and creep tests performed on such joints showed that these duplex structures do not pose serious problems during fracture. There is agreement among several authors (Refs. 16–20) that instead of a duplex structure, M23C6 and M6C carbides precipitate at the weld interface. These carbides are together designated as Type I or II depending on the microstructural feature associated with them and distance from the interface. Type I carbides appear as a narrow, sharp, well-delineated feature close to the weld interface and Type II carbides appear as a relatively wider band (~50–100 μm from the interface) of fine precipitates. Type I carbides are found to be responsible for premature failure of the joint in service. This is attributed to the cavitation around
Fig. 1 — Schematic representation of the weld cladding under study (region of interest is marked by dotted lines).

Fig. 2 — Optical microstructure and superimposed hardness profile across as-received weld cladding of Grade P91 on Grade 22 ferritic steel with 0.1-mm-thick ENiCrFe-3 interlayer.

Fig. 3 — A — TEM micrograph showing the presence of globular $M_2$C- and acicular $M_7$C-type of precipitates in Grade 22 base material of as-received weld cladding; B — microdiffraction pattern along $<001>$ zone axis for $M_7$C-type of precipitate; C — corresponding key for the microdiffraction pattern; D — microdiffraction pattern along $<0110>$ zone axis for $M_2$C-type of precipitates; E — corresponding key for the microdiffraction pattern; F — EDS spectra showing Fe enrichment in $M_7$C-type of precipitate; G — Mo enrichment in $M_2$C-type of precipitate.

Table 1 — Chemical Composition of the Base Metal and Electrodes

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<tr>
<th>Description</th>
<th>C</th>
<th>Cr</th>
<th>Mo</th>
<th>Mn</th>
<th>S</th>
<th>P</th>
<th>Si</th>
<th>Ni</th>
<th>Nb</th>
<th>Ti</th>
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<tr>
<td>Grade 22 (ASTM A387)</td>
<td>0.12</td>
<td>2.18</td>
<td>1.0</td>
<td>0.46</td>
<td>0.001</td>
<td>0.01</td>
<td>0.25</td>
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<tr>
<td>Grade 91 (Electrode)</td>
<td>0.08</td>
<td>10.25</td>
<td>0.98</td>
<td>0.91</td>
<td>0.02</td>
<td>0.02</td>
<td>0.40</td>
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<tr>
<td>ENiCrFe-3 (Electrode)</td>
<td>0.05</td>
<td>13.8</td>
<td>—</td>
<td>7.84</td>
<td>0.004</td>
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<td>1.84</td>
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Table 2 — Welding Parameters Used for the Preparation of Weld Cladding

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<th>Base Metal</th>
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<th>Electrode Diameter (mm)</th>
<th>Current (A)</th>
<th>Voltage (V)</th>
<th>Speed (mm/min)</th>
<th>Preheat (°C)</th>
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<td>Grade 22</td>
<td>ENiCrFe-3</td>
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<td>150</td>
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<td>ENiCrFe-3</td>
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Despite all these observations concerning the carbide particles leading to interfacial crack propagation (Refs. 21, 22). Investigation on the crack propagation in power plant boilers after service at 838 K from 40,000 to 200,000 h revealed that these carbide precipitates redissolve when heated above 977 K (Ref. 23).
Concerning the interfacial microstructure between Grade 22 ferritic steel and nickel-based filler material, there is a universal agreement that the nickel-based interlayer reduces the peak hoop stress of the weld joint by about 38% (Refs. 24, 25). No failures were reported in Grade 22Ni-17Cr-6Fe-0.1C joints even after being in service for 15 years (Ref. 26). Nickel-based interlayers are still considered to be the best choice to reduce carbon diffusion in dissimilar weldments of ferritic and austenitic steels (Refs. 27-29).

The authors have carried out extensive investigations on the formation of hard and soft zones in direct dissimilar weldments of 9Cr-1Mo/2½Cr-1Mo ferritic steels (Refs. 5, 30). Numerical simulations based on the finite difference method predicted that an ~80-µm-thick nickel-based diffusion barrier is sufficient to prevent the formation of the zones (Refs. 31, 32). In the present study, the above prediction has been experimentally verified by introducing an ~100-µm-thick nickel-based interlayer in dissimilar joints of ferritic steels. The effectiveness of using ENiCrFe-3 filler metal in preventing the formation of hard and soft zones in ASTM A387 Grade 22 weld cladding on ASTM A387 Grade 22 ferritic steel has been investigated. Detailed microstructural and microchemical characterization has been carried out using electron microprobe and analytical transmission electron microscopy analysis.

**Experimental Details**

Weld cladding was performed by shielded metal arc welding (SMAW) on Grade 22 base metal using ENiCrFe-3 and Grade 91 electrodes successively. Grade 22 base metal prior to welding was in the normalized and tempered condition. Composition of Grade 22, Grade 91, and ENiCrFe-3 are given in Table 1 and the welding parameters are listed in Table 2. Thickness of the ENiCrFe-3 interlayer between the ferritic steels was restricted to 0.1 mm. Figure 1 shows the schematic representation of the weld cladding used for the present investigation, where the region of interest is marked by dotted lines.

The welded specimens were given PWHT at 1023 K for 1 and 15 h. The weldments were polished using conventional metallographic procedure and etched using Villela’s reagent for microstructural examination. Easier observation of ENiCrFe-3/ferritic steel interface was facilitated by using an etchant only for the ferritic steels. A specific etchant for retained austenite, 30%glycerol-10%HNO₃, 20%HCl was used to reveal the structure at Grade 22/ENiCrFe interface. Microstructural examination was carried out using an optical microscope (model No: MEF4A of M/s Leica) and scanning electron microscope (XL 30 ESEM of M/s FEI), which was attached with an energy-dispersive spectrometer (EDS). A Leitz microhardness tester with an applied load of 100 g was used for microhardness measurements. An X-ray diffractometer (XRG3000 model of M/s INEL) equipped with a curved position-sensitive detector was used to identify different phases present in Grade 91 filler metal and at the interface of Grade 22/ENiCrFe-3. Cu Kα was used as the incident radiation at 40 kV and 30 mA. Angular 2θ range from 10 to 90 deg was covered with a step size of 0.012 deg.

Elemental distribution across the weld interface between Grade 22/ENiCrFe-3 and Grade 91/ENiCrFe-3 was identified using a Cameca SX50 electron probe micro analyzer (EPMA). Accelerating voltage of 20 kV and beam current of 20
Fig. 5 — A — TEM micrograph obtained from Grade 91 ferritic steel showing the presence of both ferrite (α) and austenite (γ) phases; B — SAD pattern obtained from a phase along the <011> zone axis; C — key for the SAD pattern; D — SAD pattern obtained from γ phase along <111> zone axis; E — key for the SAD pattern; F — EDS spectrum obtained from the γ phase showing the presence of Ni.

Fig. 6 — X-ray diffraction pattern showing the presence of both α (ferrite) and γ (austenite) phases in Grade 91 steel of as-received weld cladding.

nA were used for the analysis of iron, chromium, and nickel, whereas 10 kV and 20 nA were used for the analysis of carbon. Crystals used were LiF for Fe Kα, Cr Kα, and Ni Kα, and PC2 for C Kα. Quantitative analysis was performed by comparing the intensities of Kα or Lα radiation of the elements obtained from the sample with that of the standards. A specialized computer package was used for quantitative analysis, which takes care of the corrections to be made while calculating the concentrations of various elements.

Base metal, weld metal, as well as the weld interface were analyzed using a Philips CM 200 analytical transmission electron microscope (TEM) with an energy-dispersive spectrometer (EDS) with a superultra-thin window. Thin foils as well as carbon extraction replicas were used in the investigation. To prepare the carbon extraction replicas, initially the samples were polished to a mirror finish and etched using Villela’s reagent. The entire specimen except the specific region to be studied was then masked with thin Al foil. After carbon coating, the Al foil was removed and again the sample was etched using Villela’s reagent. On etching, the carbon film with extracted carbides could be removed from the region of interest and collected in Cu mesh for TEM analysis.

To prepare thin foils of Inconel interlayer and 9Cr-1Mo weld bead, these portions were cut from the weld cladding. The samples were initially mechanically polished using silicon carbide papers up to a thickness of ~100 μm. Then 3-mm discs were punched out of these polished specimens. To get electron transparent material the 3-mm discs were further polished by jet thinning technique using 20% perchloric acid+10% methanol as electrolyte at a temperature of 258 K. Selected area diffraction (SAD) or micro diffraction patterns were used to get crystallographic information and EDAX spectra were used to get information about microchemistry, as given in the Appendix.

Results

Characteristics of As-Received Weld Cladding

Figure 2 shows the optical microstructure and superimposed hardness profile of the as-received weld cladding. Grade 22 ferritic steel showed a bainitic structure, while the Grade 91 ferritic steel exhibited a solidification structure. ENiCrFe-3 was not etched by the Villela’s reagent. Average hardness of 229 VHN was obtained on Grade 22 base plate and ENiCrFe-3 weld bead. Heat-affected zone (HAZ) on the base metal side showed a high hardness of ~399 VHN. Hardness values of around
Fig. 7 — EPMA concentration profiles for Cr, Ni, and Fe as a function of distance x from the interface for as-received weld cladding.

Fig. 8 — Optical microstructure and superimposed hardness profile across a weld cladding of Grade 91 on Grade 22 ferritic steel with 0.1-mm-thick ENiCrFe-3 interlayer subjected to PWHT at 1023 K for 1 h showing no change from as-received condition.

Fig. 9 — TEM micrographs, electron diffraction patterns, and EDS spectra obtained from Grade 22 base metal after PWHT at 1023 K for 15 h showing the following: A — Needle-shaped $M_6C_3$-type precipitate; B — micro diffraction pattern from $M_6C_3$ precipitate along $<301>$ zone axis; C — key for the micro diffraction pattern; D — EDS spectrum showing Mo enrichment in $M_6C_3$ precipitate; E — TEM micrograph showing bulky $M_23C_6$-type precipitate; F — SAD pattern from $M_23C_6$ precipitate along $<111>$ zone axis; G — key for the SAD pattern; H and I — EDS spectra showing Fe and Cr enrichment in $M_23C_6$ precipitate, respectively.
Fig. 10 — Optical microstructure of weld cladding after PWHT at 1023 K for 15 h showing microstructural modification (marked as X and Y) in Grade 22/ENiCrFe-3 interface.

Fig. 11 — X-ray intensity profile across the weld cladding after PWHT at 1023 K for 15 h showing carbon enrichment in the dark etching region X near the Grade 22/ENiCrFe-3 interface.

Fig. 12 — EPMA concentration profiles for Fe, Ni, and Cr as a function of distance x from the interface after PWHT at 1023 K for 15 h.

237 VHN only were obtained on Grade 91 ferritic steel, which were consistent with the observed microstructure.

Figure 3 shows the TEM micrographs and electron micro diffraction patterns, as well as EDS spectra obtained from Grade 22 base metal. Figure 3A shows the presence of both globular M₃C and acicular M₇C type of precipitates in the base metal. Analysis of the micro diffraction patterns given as Fig. 3B and D showed that the globular M₃C-type of precipitate is along <001> zone axis and acicular M₇C precipitate is along the <011₀> zone axis, respectively. M₃C precipitates are Fe rich and M₇C precipitates are all Mo rich as shown in the EDS spectra given as Fig. 3F and G, respectively.

Figure 4A shows the TEM micrograph obtained from the ENiCrFe-3 interlayer, which shows the presence of an intermetallic phase in the matrix. From the analysis of the micro diffraction pattern (Fig. 4B), the matrix was found to have austenite structure with the orientation along the <111> zone axis. The EDS spectrum (Fig. 4D) obtained from the matrix showed higher Fe content than what is expected from the composition of the interlayer. From the analysis of the SAD pattern given in Fig. 4E, the secondary phase existing in the matrix was identified as Ni₃Ti (γ') intermetallic phase. The intermetallic phase exhibited a spherical morphology and the orientation was found to be along <111> zone axis. EDS spectrum could not be obtained from the intermetallic phase due to matrix interference. Figure 5A shows the TEM micrograph obtained from Grade 91 ferritic steel showing a contrast difference, suggesting a two-phase structure. Analysis of the SAD patterns (Fig. 5B and D) obtained from the two regions showed the presence of both ferrite (α) and austenite (γ) phases along <011> and <111> zone axes, respectively. The EDS spectrum (Fig. 5F) obtained from the γ phase showed the presence of ~29% Ni. To further confirm the presence of γ phase on the Grade 91 side X-ray diffraction pattern (Fig. 6) was obtained. The XRD spectrum showed the presence of (111), (200), and (220) peaks corresponding to γ phase as well as (110), (200), and (211) peaks corresponding to α phase. Lattice parameter for the γ phase was obtained as 3.5891 ±0.003 Å and for α phase as 2.8715±0.004 Å.

To determine elemental distribution across the weld interface, quantitative X-ray intensity measurements were obtained...
using an electron microprobe — Fig. 7. Within ~6 µm distance on the Grade 22 side of the Grade 22/ENiCrFe-3 interface, Ni content decreased from 20 wt-% near the interface to 0% corresponding to the base metal. Cr concentration changed from about 10 wt-% near the weld interface to 2.25% corresponding to the base metal. However, across the Grade 91/ENiCrFe interface, significant distribution of the alloying elements was observed. On the ENiCrFe-3 side, nickel content decreased from 66 to 40% and iron content increased from 8 to 15%. Similar observation was also made on the Grade 91 side where the Fe content was found to have decreased from 90 to 66%, whereas the nickel content increased from 0 to 30%.

Effect of PWHT on Weld Cladding

Figure 8 shows the optical microstructure of the weld cladding after PWHT at 1023 K for 1 h. Grade 22 showed tempered bainitic structure and Grade 91 retained the solidification structure. Superimposed hardness profile shows a hardness value of 366 VHN in the HAZ and 212 VHN in Grade 22 base metal. Average hardness value of 225 VHN was obtained on ENiCrFe-3 and Grade 91. No observable microstructural change could be seen either in Grade 22/ENiCrFe or in Grade 91/ENiCrFe interface.

After 15 h of heat treatment, Grade 22 showed predominantly a ferrite structure with limited retention of bainite in the base metal away from the interface. Figure 9 shows the TEM micrographs, electron diffraction patterns as well as EDS spectra obtained from Grade 22 base metal. Both M_6C- and M_23C_6-types of precipitates were detected. The M_6C-type precipitate had needle-shaped morphology (Fig. 9A) with orientation along <301> zone axis (Fig. 9B). It was also found to be Mo rich as shown by the EDS spectrum in Fig. 9D. The M_23C_6 precipitates were globular (Fig. 9E) along <111> zone axis (Fig. 9F). Both Fe- and Cr-rich M_23C_6 precipitates were detected, as shown by the EDS spectra in Fig. 9H and I, respectively. Even after 15 h of heat treatment, 9Cr-1Mo retained the solidification structure. An overall reduction in the hardness of the weldment was observed.

Microstructural modification was not observed in the Grade 91/ENiCrFe interface after 15 h of heat treatment — Fig. 10. Electron microscopy studies carried out on carbon replicas extracted from the interface of Grade 91/ENiCrFe showed no evidence of the presence of carbide precipitates. This is in sharp contrast to the behavior that had a hard zone formed. In Grade 22 and ENiCrFe-3 interface, a dark etched zone of ~6 µm width (marked as X in Fig. 10) and a light etched region of ~20 µm width (marked as Y in Fig. 10) were observed. Average hardness of 289 VHN on X and ~152 VHN on Y was obtained. The X-ray elemental line scan for carbon (Fig. 11) obtained using an electron microprobe showed increase in carbon intensity corresponding to X. Quantitative elemental analysis across the weld interface using electron microprobe (Fig. 12) showed that variation of Ni, Cr, and Fe concentration across Grade 91/ENiCrFe-3 interface as well as Grade 22/ENiCrFe-3 interface was similar to that in as-received joints. No redistribution for chromium was observed between X and Y.

Figure 13A shows possibly a dual-phase structure of X and ferrite grains in Y. To further investigate the dark etching band X, a cross section of the weld was cut parallel to the Grade 22/ENiCrFe-3 interface (marked by dotted lines in Fig. 13A). The cut surface (Fig. 13B) was repeatedly polished and etched till the area fraction of X was ~> 0.5. EDS spectrum given as Fig. 13C shows the presence of Ni in the dark etching band X. Figure 13D shows the retained austenite structure of the dark etching band X, which was revealed only after using a special etchant for retained austenite. Further confirmation for the presence of retained
austenite in X was obtained using X-ray diffraction pattern (Fig. 14), which showed the presence of (111), (200), and (220) peaks corresponding to the γ phase and (110), (200), and (211) peaks corresponding to the α phase.

Discussion

In the as-received weld cladding, Grade 22 base material, which was in the normalized and tempered condition, exhibited a bainitic structure with a hardness value of around 229 VHN. In the HAZ, a high hardness value of around 399 VHN was obtained (Fig. 2). During welding, the base material, which is directly in contact with the weld metal, can experience temperatures above A3 (temperature at which transformation from ferrite to austenite is complete). Depending upon the cooling rate, the austenite can transform to martensite or bainite. A high hardness value of around 399 VHN is indicative of a martensitic transformation in the HAZ during cooling subsequent to welding. Electron microscopy investigations carried out on the carbon extraction replicas obtained from the base metal showed the presence of Fe₃C and Mo₂C type of precipitates — Fig. 3. This is in accordance with the reported microstructure of normalized and tempered Grade 22 steel (Ref. 33).

After PWHT for 1 h, a slight reduction in the overall hardness of the weld cladding was noticed as a result of tempering of the microstructure. Otherwise no significant change in the microstructure was observed after 1 h of heat treatment — Fig. 8. When the PWHT duration was increased to 15 h, the microstructure of Grade 22 base metal showed predominantly a ferrite structure with limited retention of bainite — Fig. 10. The presence of bulky globular Fe or Cr-rich M₂₃C₆ and needle-shaped Mo-rich M₆C were confirmed through electron microscopy investigations — Fig. 9. The microstructure obtained was similar to that of high-temperature (1023 K) exposed Grade 22 steel containing 0.11% C (Ref. 34).

Microstructure of ENiCrFe-3 interlayer in as-received weld cladding (Fig. 4) showed the presence of Ni₃Ti (γ′) intermetallic phase in γ matrix. This observation is in accordance with the microstructure observed for nickel-based superalloys (Ref. 35). On the Grade 91 side, a solidification structure was obtained both in as-received and PWHT weld cladding — Figs. 2, 8, and 10. Electron microscopy investigations did not reveal the presence of carbides on the Grade 91 side after heat treatment. From electron microprobe investigation (Fig. 7), it is found that considerable redistribution of the alloying elements had taken place between Grade 91 ferritic steel and ENiCrFe-3 interlayer due to mixing during welding. On the Grade 91 side, the Ni content was found to be quite high (30 wt-%). It is expected that the high Ni content near the weld interface on Grade 91 side would favor the formation and retention of γ phase during cooling subsequent to welding. Confirmation for the existence of γ phase on Grade 91 was obtained both from electron microscopy and X-ray diffraction analysis — Figs. 5 and 6. Since these investigations were performed on the cross section of the weld overlay, the α phase also was detected along with γ. Volume fraction of γ phase in Grade 91 can be calculated using the following formula (Ref. 36)

\[
I_γ = \frac{R_V}{I_α + R_V}
\]

and

\[
V_γ + V_α = 1
\]

where \(V_γ \) and \(V_α \) are volume fraction of the austenite and ferrite phase, respectively, \(I_γ \) and \(I_α \) are measured integrated intensity of (111) and (200) peaks for γ and (110) and (200) peaks for α phase, respectively. \(R_γ \) and \(R_α \) are constants calculated from crystal structure and lattice parameters for both phases as follows

\[
R = \frac{1}{v^2} \left[ \sin^2 θ \left( \frac{1}{p} \right) \left( \frac{1 + \cos^2 2θ}{\sin^2 θ} \right) \right]^{-2M}
\]

where \(v \) is the volume of the unit cell (m³), \(F \) is the structure factor, \(p \) is the multiplicity factor, θ is the Bragg angle, and \(e^{-2M} \) is the temperature factor. Using the above formulas, volume fraction of the γ phase in Grade 91 steel is found to be 0.38 and that of the α phase is 0.62. High Ni content in Grade 91 will expand the γ phase field and also reduce the martensitic start (Ms) temperature. The effect of Ni on Ms temperature was evaluated based on Andrews (linear) equation (Ref. 37) given below where the concentration of the alloying elements are expressed in wt-%.

\[
Ms(°C) = 539 + 423C - 30.4Mn - 12.1Cr - 17.7Ni - 7.5Mo
\]

On substituting the concentration of alloying elements in Grade 91 filler metal, the Ms temperature is obtained as 137 K, which is much below the room temperature. In a recent work in literature (Ref. 38), the following empirical equation based on neural network analysis has been suggested for accurate determination of the Ms temperature of steels.

\[
Ms(K) = 765.2 - 302.6C - 30.6Mn - 16.6Ni - 8.9Cr + 2.4Mo - 11.3Cu + 8.58Co + 7.4W - 14.55\alpha
\]

Input variables for the neural network were obtained from a range of elemental concentration (e.g., C 0.001 to 1.62%, Mn 0 to 3.76%, Cr 0 to 17.9%, Ni 0 to 27.2%, Mo 0 to 5.10%). Ms temperature for Grade 91 filler metal calculated using the above equation agreed well with the value obtained using Andrews equation. The martensitic start temperature reported in the literature (Ref. 39) for 9Cr-1Mo steel having 8.25%Cr is below 673 K. Hence, the presence of Ni in Grade 91 would have drastically reduced the Ms temperature as a consequence of which the martensitic transformation is completely suppressed on cooling subsequent to welding. This explains the solidification structure with very low hardness than what is expected on Grade 91 side in as-received weld cladding.

Such a change in the structure of Grade 91 steel is brought about due to mixing during welding. Since the melting point of ENiCrFe-3 (1369–1673 K) is close to that of Grade 91 ferritic steel (1281–1473 K), it is possible that during deposition of Grade 91 bead, the underlying ENiCrFe bead would also have melted or heated to high temperature leading to mixing of the molten material. No zone or formation of intermetallics was observed at the interface of Grade 91 and ENiCrFe-3. Even otherwise, the interface between a high-Cr ferritic steel/Ni-based interlayer is considered to be less problematic when compared to low-Cr ferritic steel/Ni-based interlayer since the low-carbon activity gradient at the interface inhibits carbon diffusion. It has been reported (Ref. 20) that in single V-groove butt joint welds of Alloy 800 (Fe-31Ni-20Cr-0.03C) and Grade 91 steel, because of the low-carbon activity in the Grade 91 ferritic steel, only limited precipitation is observed at the interface after prolonged aging. An increase in the Ni content in the filler metal may further limit this precipitation.

In the interface of Grade 22 and ENiCrFe-3, the dark-etched region of ~6-μm thickness observed after PWHT at 1023 K for 15 h (marked as X in Figs. 10 and 13A) was identified as retained austenite. The adjacent light-etched region of ~20 μm thickness (marked as Y in Figs. 10 and 13A) was identified as ferrite. Reason for the formation of dark etching zone X can be understood as follows:

Electron microprobe based investigations showed high concentration for Ni and Cr, from the interlayer to ~6 μm distance into the Grade 22 side of the interface, which may be a result of dilution of the base metal during welding. Concen-
The formation of an additional zone Y adjacent to X after heat treatment for 15 h can be explained as follows:

Formation of retained austenite (in X) during welding introduces an α/γ interface (between base material and X) within Grade 22 ferritic steel, thereby introducing a carbon activity gradient. PWHT would have led to the diffusion of carbon from the Grade 22 side to the zone X. Using an electron microprobe carbon enrichment has been observed in the region corresponding to X — Fig. 11. Since the solubility of carbon in γ phase is much higher than that in ferritic steel, no precipitation is observed. Also, since carbon is an austenite stabilizer it would have further stabilized the retained austenite structure at the interface. Due to the diffusion of carbon, the precipitates on Grade 22 side will dissolve leading to the formation of a zone of ferrite (marked as Y in Fig. 10) adjacent to X. The width of Y was much smaller (~20 μm) when compared to the width of soft zone (~300 μm), which forms in direct dissimilar welds between Grade 91 and Grade 22 ferritic steels for the same heat treatment condition (Ref. 5).

Conclusions

- A nickel-based interlayer of about 0.1 mm thickness was used to effectively control the formation of soft and hard zones in dissimilar weld cladding of ferritic steels.
- The hard zone was found to be absent in the Grade 91/ENiCrFe-3 interface. However, a zone of retained austenite of about 9-μm thickness formed in the interface of the Grade 22 and ENiCrFe-3 interlayer due to diffusion welding.
- Subsequent PWHT resulted in the formation of a soft zone adjacent to the retained austenite layer in the Grade 22/ENiCrFe-3 interface due to the diffusion of carbon.
- Width of the soft zone that forms adjacent to the zone of retained austenite was found to be much smaller than that observed in direct dissimilar welds without an interlayer for the same PWHT conditions.

Acknowledgments

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Development of a Time-Resolved Energy Absorption Measurement Technique for Laser Beam Spot Welds

By relating the instantaneous delivered power and pulse energy to the scattered power during welding, a time-resolved description of the power and energy absorption can be obtained

BY J. T. NORRIS, C. V. ROBINO, M. J. PERRICONE, AND D. A. HIRSCHFELD

ABSTRACT

A method has been developed to temporally characterize the power and energy absorbed in laser beam spot welding (LBSW). As a spot weld is created, the absorption of laser power changes as the surface of the weld pool changes from initial melting through the development of the keyhole. By relating the instantaneous delivered power and pulse energy to the scattered power during welding, a time-resolved description of the power and energy absorption can be obtained. The method uses two gold-plated integrating spheres containing Nd:YAG notch-filtered photodiodes to capture and detect the scattered laser light. Under various welding parameters (pulse energy, duration, and shape), the level of scattered light changes with the condition of the weld pool. For high depth-to-width aspect ratio keyhole mode welds, power transfer efficiency (or instantaneous energy transfer) ranges from ~40 to 80% depending on the state of the weld pool. In contrast, low aspect ratio conduction mode welds maintain less than 50% transfer efficiency throughout the welding process. Overall energy transfer efficiencies measured by this method show good agreement with calorimetric (Refs. 1, 2) and thermal expansion measurements (Ref. 4). Time-resolved energy absorption was also evaluated for square and constant ramp down (CRD) pulse shapes. Through characterization of keyhole formation and transfer efficiency in relation to welding parameters, the laser welding process can be optimized, and insight into keyhole phenomena necessary for developing and improving modeling capabilities can be obtained.

Introduction

Power transfer, energy transfer, and melting efficiency are fundamental to the welding process. Mapping these efficiencies to process parameters allows process optimization (Refs. 1–3, 6). With the finer resolution provided by temporal measurements, a better understanding of such phenomena as keyhole formation and laser beam interactions may be obtained. The measurement technique presented here determines the power and energy transfer to the part by evaluating the difference between two independent temporal measurements: one of the delivered laser power and one of the power reflected during welding. Fueschbach et al. (Ref. 1) characterized pulsed laser weld energy absorption through calorimetry by using hundreds of spot-on-plate welds made in rapid succession on 304 stainless steel. As the welds cooled to room temperature, the energy released was measured by a calorimeter. These results were then divided by the number of welds to yield the average energy absorbed per weld. The energy absorbed was found to range from 38 to 67% of the delivered pulse energy. Temporal resolution is not obtained by this method, and for low-pulse-energy welds, absorption measurements can be difficult. Micro-calorimetry was performed by Perret et al. (Ref. 2). Perret measured energy transfer efficiency to range from 32 to 80% for welds made on titanium Alloy Ti-6Al-4V. In lieu of calorimetry, Cremers et al. determined energy absorption by measuring the thermal expansion of the welded metal sample. The transient displacement of the welded sample was evaluated using interferometry complemented by a second method that monitored coaxial displacement using a linear variable differential transformer (LVDT). Transfer efficiency for this measurement technique ranged from 30 to 62% on 316 SS and 21–50% on Al 1100.

As both calorimetric and thermal expansion measurement techniques correlate well with the average energy transfer determined by the reflections measurement method described here, confidence in this method is established. Development of the reflection measurement method is discussed with emphasis on system calibration and preliminary results that highlight the relevance of temporal mapping to laser process optimization. Total pulse energy transfer and melting efficiency are mapped to reveal the importance of intelligent selection of pulsed laser welding parameters and the effectiveness of pulse shape design.

Experimental Procedures and Calibrations

Integrating Sphere Configuration

An integrating sphere is an optical device that is hollow and spherical in shape. The interior is coated for a specific light source wavelength to maximize transmittance and promote lambertian reflectance. The result, ideally, is isotropic illumination of the sphere’s interior walls (Refs. 4–6). An aperture on the side of the sphere allows a flux of constant irradiance light to be measured with a photodiode that is optically filtered to isolate the desired wavelength(s). The current method for time-resolved energy absorption uses two gold-plated integrating spheres. A schematic of this setup is presented in Fig. 1. In this approach, the
Total scattered energy collected by the two spheres is subtracted from the known delivered laser pulse energy to determine the absorbed energy. The two gold-plated integrating spheres contain a narrow band-pass filtered photodiode to measure light flux as a function of time. A beam splitter is used to redirect possible exiting reflections from the weld sphere into the secondary sphere. The first (or primary) sphere is positioned directly beneath the fiber delivery laser head assembly (source light). The weld sample (here, a 304L stainless steel 12.5-mm-diameter disk, 3 mm thick with a surface finish of ~0.8 \( \mu m \) RMS) is contained within the sphere and is positioned at sharp focus by an adjustable gold-plated post. Depending upon the state of the weld pool (initial melting → conduction → keyhole), the reflected light from the weld’s surface is either captured by the weld sphere or exits through the sphere’s 25-mm entrance opening and is captured by the secondary sphere. Preliminary tests revealed a secondary sphere to be necessary due to the entrance angle of the primary sphere and the beam focus angle forcing focused welds to be conducted above the centerline of the primary sphere rather than at the more optimal base of the sphere. Thus, a significant amount of the reflected light was found to escape from the entrance hole of the primary sphere, and in order to account for this loss, the secondary sphere was added to collect this light. This will be discussed later in further detail.

The captured light is integrated within each respective sphere, filtered by a 1064 ± 3-nm wavelength narrow band-pass filter, and then measured with an InGaAs photodiode with a variable resistance terminan (VRT) and a LeCroy Waverunner oscilloscope. The VRT allows for quick adjustment of the voltage output for optimal signal resolution from the photodiode. The result is a temporally defined voltage that varies in amplitude with light intensity.

A sample of exiting laser reflections are redirected with a 70:30 ratio beam splitter. The beam splitter is optically coated for a 45-deg maximum transmittance angle and mounted accordingly in the vertical path of the exiting light. Only a 30% sample of the reflected light is directed to the secondary sphere; the remaining 70% continues toward the laser head. As the beam splitter is positioned to redirect a sample of all exiting reflections, it also redirects a fraction of the incoming focusing laser light (\( E_{WT} \)) — Fig. 1. This fraction is discarded, but by measuring the delivered pulse energy at a position coinciding with the workpiece location (after the beam splitter), it has no effect on the system’s calibration. To accurately quantify the scattered laser light during welding, system calibration is paramount. Calibration, design of the sample positioning post, and the effect of the quartz tube weld shield (Fig. 1) are discussed in detail later.

### Primary Sphere Calibration

Temporal pulse characterization provides an accurate description of the pulse generated by the laser for a specific laser setting. The amplitude of the waveform in volts is scalable to the laser’s output power. Stability of the laser, which is characterized by consistent energy distribution over time, is determined by comparison of multiple measurements of a set parameter. The pulse-forming capability of the laser may also be verified through this method. In Fig. 2, a typical temporal profile for a square (or top-hat) pulse of 6 ms (blue curve) is presented. The initial fluctuation in output about the nominal at the start of the pulse is common for modern processing lasers of this type, as are the several microsecond ramp-up and -down times. After approximately 1 ms, a nominal output is reached with only moderate jitter in the light intensity detected. Since the output of the photodiode prior to the laser pulse does not show similar fluctuations, this scatter is not considered noise but is either a lack of total light integration within the sphere or real variation in energy output from the laser. Either assumption is adequate for this study. The red curve is an integration of the pulse

![Fig. 1 — Schematic of energy absorption setup including energy balance. Energy absorbed by the weld and beam splitter are denoted with subscripts W and BS, respectively. Subscripts P and T indicate energy that passed through and was turned by the beam splitter.](image-url)

![Fig. 2 — Typical waveform captured with an integrating sphere and photodiode.](image-url)

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waveform (volts*seconds) and can be correlated to the energy pulse ($E_0(p)$). By independently measuring the pulse energy at the workpiece (an Ophir L40 energy meter was used here), the amplitudes of both waveforms (volts and volt*seconds) are calibrated to the nominal power and delivered energy ($E_0(p)$), respectively, of the laser pulse. Nominal power is calculated as follows:

$$\text{Power} = \frac{\text{Pulse Energy (Joules)}}{\text{Pulse Time (seconds)}} = \frac{E_{0(p)}}{t_p}$$

Mapping a series of processing parameters of various power and energy, respectively, yields the necessary calibration equations for power to voltage ($\text{Power} = 9.93\text{mW}$) and energy to volt*seconds ($\text{Energy} = 0.0105\text{mJ}$). Calibration of the primary sphere is presented in Fig. 3.

Effect of Weld Sample Position

A pulse profile, or waveform, is captured by targeting a defocused beam onto a reflective cone inside the integrating sphere. By placing the cone at the base of the sphere, direct reflections off the cone, which can possibly damage or saturate the photodetector, are avoided. The result is a measure of only integrated reflected laser light. Ideally, weld trials would also be conducted at the base location. However, due to the sphere’s 25-mm opening, the raw beam size, and the divergence of the 150-mm focal length lens, focused welds at this location could not be made without clipping the beam. As a result, a gold-plated positioning post and a reflective cone were designed to place the sample at a height sufficient for focused welding. Welding and calibration were conducted at the same height to ensure consistency between welding and calibration. A weld sample height of 15 mm above the sphere’s center was chosen, preferentially directing reflections to the upper half of the sphere and preventing direct exposure of the photodiode detector.

During calibration of the primary sphere and diode system, it was found that the photodetector’s output varied with the size of the laser beam illuminating the cone. As the cone’s tip is not infinitely sharp, a small spot size nearing focus will effectively encounter a flat reflective plate as opposed to a sharp pointed cone. The result is more light reflected into the secondary sphere and less light retained in the primary — Fig. 4. The sum of the reflected light measured by each sphere is constant (black curve) regardless of spot size. For calibration of the primary sphere, it is desired to minimize exiting reflection as the measured pulse energy taken at the workpiece is scaled to the volt*seconds output of the primary sphere. A large defocused beam is therefore preferred during calibration. The maximum output produced by the diode for a fixed weld schedule was observed when the beam nearly filled the diameter of the cone. This occurred when the laser was focused 45 mm above the cone’s tip.

Secondary Sphere Calibration

As the calibration of the primary sphere was carried out by relating the diode’s output to the measured pulse energy ($E_0(p)$), a similar approach was taken to calibrate the secondary sphere. By substituting the gold cone that was previously used to calibrate the primary sphere with a gold reflective plate (positioned orthogonal to the beam), laser light is split, redirecting most of the light, but not all, to the secondary sphere. By applying the primary sphere’s energy calibration, any retained light within the primary sphere is quantified; thus, the energy exiting the sphere can be calculated, $E_{0(p)} - E_{S,I} = E_{S,II}$ (Table 1). This quantity of energy is used to scale the volts*seconds output of the secondary sphere. Repetition of this process at various pulse energies yields a calibration of the secondary sphere. By this approach, characterization of energy loss through the 70/30 beam splitter and the distribution of turned and passed energy to the total redirected energy is rendered unnecessary. Instead, with this approach a direct calibration is obtained. Energy and power calibration for the secondary sphere are presented in Fig. 5.

Effects of Quartz Weld Shield

To avoid damage or contamination while
welding inside the gold-plated sphere, a quartz weld shield (a cylinder of fused silica) was positioned from the top of the sphere down to the weld sample —Fig. 1. Without shielding, continued buildup of metal vapor on the sphere's interior would absorb reflections from the weld yielding an artificially high measure of weld energy absorption. To quantify the effect of the weld shield on the 1064-nm Nd:YAG wavelength, temporal profiles were made by characterizing pulse energy vs. volt*seconds with and without the shield in place. A range of processing parameters of varying pulse energy were examined. Figure 6 shows two overlaying curves demonstrating the weld shield to be transparent under these conditions to the Nd:YAG wavelength.

The effect of metal vapor deposition on the shield was also evaluated. Multiple welds were made without any removal of the accumulated metal vapor (on the shield's interior) noting the effect on the resulting measured pulse energy. This test was run at 6 ms, 9.5 J. As metal vapor accumulated with each weld, lower pulse energies were measured — Fig. 7. The condensed metal layer absorbs an increasing fraction of the reflected light, reducing the amount detected by the photodiode. For a 20-mm-diameter shield and 1575-W peak power, about a 0.04-W energy loss occurred for each additional weld. As power and energy are changed, the rate of metal vaporization and the rate of metal deposition are also changed. While this test only characterizes the specified weld schedule, it is nevertheless indicative of the effect of an increasingly contaminated shield. To avoid metal vapor buildup, the quartz shield was replaced or cleaned (typically with an isopropyl alcohol cloth) between each weld test.

Welding Parameters

This study utilized a Lasag SLS C16 fiber-delivered, 40-W average power pulsed Nd:YAG laser beam welding machine. Focused spot-on-plate welds were produced with a 150-mm focal length lens. Beam characterization below the beam splitter was carried out via Kapton film (Ref. 8) to identify the beam's waist location. This enabled weld trials to be conducted at sharp focus to optimize keyhole mode welding. Preliminary trials included pulse lengths from 2 to 8 ms with pulse energies from 1.5 to 13 J; pulse energy was measured using an Ophir L40(150)A energy meter. Delivered power varied from 500 to 1600 W. Welds were shielded by using UHP argon. Both square and constant ramp down (CRD) pulse shapes were evaluated; a CRD pulse starts at a high output power and decreases linearly to zero to complete the pulse.

Results and Discussion

Presented in Fig. 8 is the measured reflected light for a 6-ms, 1575-W peak power
pulse (~9.5 J/pulse). The green and red curves represent the reflected Nd:YAG light detected by the primary and secondary spheres, respectively. The appropriate voltage-to-power calibrations were applied to yield a plot of power vs. time, and the area under the curve corresponds to the reflected energy. The sum of the two profiles is depicted by the blue curve, and represents the overall power reflected off the weld at each point in time. By comparing the amplitude of the primary and secondary sphere and the sum of the total reflections detected, a generalized weld pool shape can be inferred as a function of time. At the start of the laser pulse, the majority of reflections exit the primary sphere and are captured by the secondary sphere. These high initial reflections not only show low absorption of laser power (825 W of the 1575 W is reflected) but, since they are mostly measured by the secondary sphere, the reflections are essentially parallel to the incoming beam. This implies a flat, largely perpendicular surface such as that expected at the onset of weld pool formation (Refs. 9–11). Once sufficient melting is reached, surface tension forms a semi-hemispherical weld pool reflecting light in all directions above the surface of the sample. This is evident by the rapid decrease in reflected light detected by the secondary sphere (red curve) and increasing reflection captured in the primary sphere (green curve). Over the next few milliseconds, laser power absorbed by the weld increases as the total measured reflections decrease (blue curve). The decrease in reflections is believed to be indicative of the formation of a weld pool keyhole and the rate of decrease is a measure of the rate at which the keyhole develops. Upon keyhole maturation at approximately 3–4 ms, reflections reach a minimum and are roughly constant for the duration of the pulse. Laser power reflected at this point is ~25% of the power delivered. The metallographic section for this weld displays an aspect ratio common for keyhole mode welds of this depth — Fig. 8B. A weld pore is also present, identified by the dark elliptical region to the right of the weld’s centerline.

The difference between the delivered power and the measured reflected power is the power absorbed to form the weld. This difference, or the absorbed power, is presented in Fig. 9A (blue curve) for a square pulse and Fig. 9B for a constant ramp down pulse, at 1575 W peak and 6 and 8 ms, respectively. The black curve is the laser pulse profile that was acquired prior to welding. Ideally, the pulse profile and weld measurement would be made simultaneously; however, given the low pulse-to-pulse variation of this laser system (less than 3% determined by the Ophir meter), error incurred by independent measurements was determined to be acceptable. At any point along the plot of power absorbed vs. time, power transfer efficiency (or instantaneous energy transfer) is calculated as the quotient of laser power absorbed over (blue curve) the laser power delivered (black curve). This numeric value, as already demonstrated, describes the state of the weld pool. At the onset of welding for both the square and CRD pulse, power transfer efficiency was <50%. As a keyhole developed with the high constant output power of the square pulse, efficiency rose to 75%. As output power was steadily decreased in the CRD pulse, a mature keyhole never formed and, in turn, transfer efficiency remains low at ~50%. The total transfer of laser energy quantified by the energy transfer efficiency is calculated as the quotient of energy absorbed (area under the weld curve) to the energy delivered (area under the pulse profile curve). Energy transfer efficiency for the square pulse weld was 66% (6.3/9.5 J) and only 51% (3.25/6.35 J) for the CRD pulse. For the two pulse shapes defined, a range of parameters from 2 to 8 ms and 1.5–13 J was evaluated. Due to the large spot size of the 150-mm lens, keyhole mode welds with a CRD pulse shape were not formed.

To evaluate variations within this measurement technique, replicate welds were performed. Presented in Fig. 10 are three welds of 1575 W. Again, a keyhole mode weld is apparent due to the rapid rise in the transfer of laser power starting below 50% and increasing to a peak of 74%. As the three curves overlap, it may be inferred that interactions between the laser beam and the weld material are generally similar for the three welds, and despite the chaotic nature of weld pool dynamics commonly associated with keyhole mode welds (Refs. 7, 10–12), the overall rate of formation and general shape of the keyhole are very similar for each weld resulting in essentially equal energy transfer. The measured energy transfer efficiencies for the three welds in Fig. 9 were 60, 61, and 60%. The repeatability and consistent amplitude of the absorption measurements imply that small changes or instabilities within the keyhole have no appreciable effect on the total energy absorbed; and thus reducing complexities often incorporated in many thermal fluid weld models. Conduction and keyhole mode welds at 500 and 1000 W were also evaluated and showed similar repeatability. Constant ramp down pulse welds of 3 J at 4 and 6 ms were comparable repeatably. Through Fresnel reflections (Refs. 13, 14), as the keyhole wall becomes more inclined (steeper), the decreased angle of incidence increases the number of reflec-

Fig. 12 — A — Evaluation of increasing pulse time for 1575-W welds; and B — corresponding metallographic cross sections.
tions (inside the keyhole) yielding a higher net transfer of laser energy. With each reflection, energy is both absorbed and reflected and with the decreased incident beam angle, more energy is deposited at the root of the keyhole. This drives high-aspect-ratio, high-efficiency welds. In Fig. 11A, three temporal absorption profiles of 500, 1033, and 1575 W are evaluated with pulse time constant at 6 ms. At 500 W (green curve), a relatively constant absorption profile is seen from weld start to finish yielding power transfer and energy efficiencies of ~47%. As expected, the metallographic cross section (Fig. 11B) reveals a low-aspect-ratio, conduction-mode weld. With increasing delivered power to 1033 W (red curve), a keyhole is formed as implied by the increased power absorption. Power transfer efficiency starts below 50% and increases to 65% yielding a total energy transfer efficiency of 54%. As previously discussed in Fig. 9, raising output power to 1575 W (blue curve, Fig. 11) yields, upon keyhole maturation, an even higher power transfer efficiency of 77% for an overall energy efficiency of 66%. Comparison of the 1033- and 1575-W welds shows the rate of keyhole maturation (time to maximum power transfer) to be nearly equivalent after ~4 ms. The constant power transfer from 4 to 6 ms implies a fully developed and quasi-stable keyhole. Although both welds are identified as keyhole mode welds, the peak power transfer efficiency at 1585 W is greater than that at 1033 W. The low peak power transfer of the 1033-W weld would imply a shallower keyhole with fewer internal reflections and thus a lower transfer efficiency. In support of this interpretation, the corresponding metallographic sections (Fig. 11B) show a lower weld aspect ratio for the 1033-W weld. Logically, the high-aspect-ratio 1575-W weld implies that upon keyhole maturation, a deeper, more steeply inclined keyhole was formed resulting in the higher maximum power transfer value.

Also evident by comparison of the temporal absorption profiles presented in Fig. 11 is the dependence of overall energy transfer efficiency on the amplitude and rate of change of the power transfer. The fractional time at low and high power transfer rates, as well as the transitional time between, governs the overall energy transfer. This is more evident in Fig. 12 where four welds all having a delivered power of ~1575 W are evaluated at 2, 4, 6-, and 8-ms pulse times. The absorption profile (Fig. 12A) for each weld overlaps as pulse time increases. At 2 ms, there is insufficient time for keyhole development resulting in a low-transfer-efficiency weld with power and energy transfer less than 50%. As pulse time increases (from 4 to 8 ms), the relative amount of time spent in keyhole mode increases, thereby yielding a greater overall energy transfer. A peak power transfer of ~77% is reached and is again relatively constant after ~4 ms. At 4, 6, and 8 ms, energy transfer efficiency increases from 61% to 66% to 70%, respectively. Evaluation of the metallographic cross sections (Fig. 12B) reveals the progression of the weld as pulse time, energy, and efficiency increase. Each weld is similar in overall shape, with weld size increasing with pulse energy. After 4 ms, a single pore of common size is seen (root-type pores such as these are common in keyhole mode laser welds and are generally formed by the collapse of the weld pool keyhole (Ref. 10)).

As the amplitude and fraction of time in keyhole mode dictates the transfer of energy, greater energy efficiency is reached by increasing either pulse time or delivered power. In Fig. 13, energy transfer efficiency is shown as a function of delivered power (or average power in the case of a CRD pulse) and pulse time. Here, both square and constant ramp down pulse shapes are included displaying a clear trend in energy transfer efficiency. At a low output power (i.e., 500 W), transfer efficiency increases from 41 to 45% by increasing time from 4 to 8 ms. At high output powers (i.e., 1575 W) over the same times, efficiency increases from 60 to 70%. It is clear that increasing power yields greater efficiency. In contrast, however, if pulse time is too short, inhibiting keyhole formation (i.e., 2 ms, black curve Fig. 13), only moderate increases in efficiency can be expected regardless of increasing output power. These measurements in energy transfer efficiency for milli-scale stainless steel welds are comparable to those presented by Fuerschbach and Cremers (Refs. 1, 4).

Also crucial for process optimization of laser beam spot welds is the characterization of melting efficiency (Ref. 15). As energy is transferred from the laser beam to the weld sample, heating and melting occur. For a given volume of material, the rate of heat input must be sufficient to induce melting. Melting efficiency is calculated as the weld volume (V) times the heat of fusion (\(H_f\)) divided by the heat input (\(Q_{in}\)) (energy absorbed) (Ref. 15).

\[
\eta_m = \frac{H_f V}{Q_{in}}
\]

For a given quantity of heat, more melting is generated by increasing the rate of heat input since losses due to thermal diffusion through the base metal are minimized. This behavior is seen in Fig. 14 where melting efficiency is plotted as a...
function of pulse energy. Regardless of pulse energy, melting efficiency was found to be a function of the delivered power, or the rate of heat input. In this plot, a latent heat of fusion for 304L steel of 8.7 J/mm$^2$ (Ref. 16) was used in the calculation. Data for power levels of 750 and 1575 W are shown, with pulse time varying from 2 to 8 ms. At 750 W, approximately 20% of the transferred energy results in melting. By increasing the rate of heat input to 1575 W, melting efficiency increases further to approximately 27%. Under 3D heat flow conditions, theoretical melting efficiency is maximum at 31% (Refs. 1, 17). Melting efficiency is further evaluated in Fig. 15 for delivered powers having both square and constant ramp down pulse shapes. Test parameters revealed melting efficiency to linearly increase with average power and to be independent of temporal pulse shape. By optimizing melting efficiency, both heat input and the weld’s heat-affected zone are minimized.

Conclusions

The presented method for quantifying energy absorption, which measures reflected laser light off the weld’s surface, provides a temporal measure of the change in absorption as the state of the weld pool changes. The energy absorption measured by this method showed good agreement with calorimetric (Refs. 1, 2) and thermal expansion methods (Ref. 4). Analysis of this method is continuing, but the current results support the use of this method for energy absorption measurements in LBSWs. Specific conclusions are as follows:

1. Power transfer of < 50% is measured at the start of a laser pulse, but can increase to 80% given sufficient energy density and time to fully develop a keyhole.

2. The overall energy transfer depends upon the fractional time spent at high and low levels of power transfer efficiency.

3. Energy absorption was found to be invariant for replicate welds despite the dynamic nature of keyhole mode welding, thus reducing the complexities incorporated in many thermal fluid weld models, and providing empirically measured boundary conditions as a function of time for critical processing parameters.

4. Melting efficiency of a spot weld was found to be a function of pulse power for both square and constant ramp down pulse shapes.

Future research incorporating this measurement technique will evaluate changes in transfer and melting efficiencies resulting from dissimilar and high reflectivity materials (4047 Al to 6061 Al), and the effects of variable part fitup such as root opening and out-of-plane surfaces. Pulse shaping and the effect of gas shield-ing are also of interest, as both have shown to be beneficial for optimal weld penetration efficiency and avoiding weld porosity (Ref. 18).

Acknowledgments

The authors would like to thank A. Kilgo for her careful preparation of the metallographic samples, and Don Susan and Danny MacCallum for their thorough review of this manuscript. This work was performed at Sandia National Laboratories, which is a multiprogram laboratory operated by Sandia Corp., a Lockheed Martin Co., for the United States Department of Energy under contract DE-AC04-94AL85000.

References


Characterization of Welding Fume from SMAW Electrodes — Part II

The composition and morphology of SMAW fume particles are determined using advanced characterization techniques

BY J. W. SOWARDS, A. J. RAMIREZ, D. W. DICKINSON, AND J. C. LIPPOLD

ABSTRACT

In Part I of this study, an electrical low pressure impactor (ELPI) was used to collect welding fume from E6010, E7018, and E308-16 electrodes and determine number and mass distributions based on fume particle diameter. Fume generation rates were obtained using an improved fume hood design, and bulk fume phases were identified using X-ray diffraction (XRD). Part II of this study makes use of extensive characterization work by evaluating fume particles collected in different size ranges with the ELPI using scanning electron microscopy (SEM) and X-ray photoelectron spectroscopy (XPS). Transmission electron microscopy (TEM) was used to characterize fume particles in the ultrafine (< 0.3 μm) range. Using these techniques, fume particles were classified into three distinct morphologies: spherical, irregular, and agglomerate. Agglomerates were the most common particle type observed followed by spherical and irregular. Many of the spherical and agglomerated particles exhibited a core-shell structure where a core, rich in metal oxides, was coated with a shell consisting of more volatile elements (Si, Na, Mg). This core-shell morphology was evident in fumes generated by all three of the shielded metal arc welding (SMAW) electrodes. Extensive chemical analysis was conducted on a large number of particles and agglomerates over the entire size range (0.03–10 μm) collected in the ELPI. Fume composition was found to vary as a function of aerodynamic diameter, which was attributed to the different fume formation mechanisms.

Introduction

Welding fume produced by the shielded metal arc welding (SMAW) process contains a variety of metallic and nonmetallic elements and compounds that result from the melting and vaporization of the metal core wire and flux coating of the electrode. Part 1 (Ref. 1) of this investigation determined the fume generation rate (FGR), particle number, and mass distributions as a function of particle size, and bulk fume chemistry generated by the three SMAW electrodes (E6010, E308-16, E7018) included in this study. Particle number and mass distributions (as a function of fume particle aerodynamic diameter) were determined using an electrical low pressure impactor (ELPI) as described in Part I. The ELPI system was designed to collect and measure particle size distributions with aerodynamic diameters in the range of 30 nm to 10 μm, with a response time of less than 5 s (Ref. 2). The system charges particles with a corona charger before they are collected in a low-pressure impactor. The impactor separates the particles by aerodynamic diameter, and as the particles impact each separation stage, the charge is recorded with highly sensitive electrometers. This allows real-time determination of particle size distributions. Gravimetric analysis can also be performed on the individual stages to determine particle mass distribution. Particle number distributions measured in Part 1 (Ref. 1) showed that fume particles generated by the three electrodes were contained largely in the ultrafine particle size range (geometric mean diameters between 0.1 to 0.25 μm) while particle mass distributions were shifted to larger particle sizes (mass median diameters between 0.55 to 0.75 μm).

After particle collection with the ELPI, extensive characterization was performed to determine the morphology, composition, and structure of the fume particles in each size range. These characterization techniques included scanning electron microscopy (SEM), transmission electron microscopy (TEM), X-ray energy-dispersive spectroscopy (XEDS), and X-ray photoelectron spectroscopy (XPS). Electron microscopy techniques such as SEM and TEM, often combined with XEDS analytical methods, have been widely used to examine individual fume particle morphology and for performing chemical analysis of both individual and bulk compositions (Refs. 3–5). Scanning electron microscopy is best used to characterize particle morphologies and measure compositions of particles greater than 0.3 μm in size as well as measure compositions of the bulk fume collected in fume filters. Transmission electron microscopy is well suited for imaging particles in the ultrafine particle regime and analyzing particles with microprobe XEDS analyses to find chemical compositions. The electron interaction volume within the particles is a large factor in determining which analysis technique, whether it be SEM or TEM, is better suited to a given particle size because the interaction volume of the beam can vary greatly between the two microscopy techniques. Selected area diffraction (SAD) in the TEM is a useful technique for determining the crystalline structure of the particles.

The XPS is a surface-sensitive analysis technique that analyzes the composition of the sample surface to a depth of approximately 1 to 3 nm (Ref. 6). The basic principle of XPS uses the photoelectric effect where photoelectrons are emitted from a surface illuminated by a source of (X-ray) photons. This XPS is capable of determining valence states of surface atoms on the sample by measuring binding energies of emitted photoelectrons. This
technique also has the ability to remove surface layers by using Ar⁺ ion bombardment (or etching), thus providing depth profiling capabilities. Between each successive Ar⁺ etch, composition can be measured and compared with etching time to provide a composition profile of the sample as a function of analysis depth. Applying this XPS depth profiling technique to welding fume has shown varying composition through the volume of fume particles where the surfaces generally consist of more volatile elements and particle centers are generally metals and their oxides (Refs. 3, 7, 8).

Welding fume particles exist across a large size range from several nm up to several μm in diameter as a result of different particle formation mechanisms (Refs. 9–11). The smallest fume particles (< 100 nm) are formed by homogeneous nucleation from metal and flux vapors. The nucleated particles may experience growth by condensation of additional vapors on particle surfaces. Particle growth by condensation occurs until particles reach an upper limit of approximately 300 nm in diameter (Ref. 9). Accumulation, or growth by collision of particles, results in formation of agglomerates and spherical particles larger than 300 nm. Particles formed by any of these modes may have different composition because the formation mechanism is different. However, the agglomerated particles formed by collision of smaller particles have a composition corresponding to the average of the particles that collided.

Fume contains multiple chemical species, all of which have different volatilities. Less volatile species condense on nucleated particles first (Ref. 9). As temperature decreases, this is followed by condensation of species with increasing volatilities, resulting in the formation of shelled particles. These core-shell particles have been observed in a variety of welding fumes that condense from multi-volatilities, resulting in the formation of fume particles possessing the core-shell ple chemical species (Refs. 7, 8, 11–14). These core-shell particles have been observed in a variety of welding fumes that condense from multi-volatilities, resulting in the formation of fume particles possessing the core-shell ple chemical species (Refs. 7, 8, 11–14).

Semiquantitative composition analysis of ultrathin particles was performed with the added capability of XEDS to the TEM.

Table 1 — Aerodynamic Cutoff Diameter (Dp) of ELPI Stages

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Table 2 — Weld Deposit and Base Metal Compositions*

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<th>AISI 304L</th>
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<th>E7018</th>
<th>E308-16**</th>
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*Carbon and sulfur analyzed by LECO technique, all others by ICP or ICP/MS technique. **Represent compositions from the low-heat input conditions.

The ELPI was used to collect samples for SEM, TEM, and XPS analysis. This system separates particles by cascade impaction and deposits them on Al-foil substrates placed on each ELPI collection stage. Al collection substrate is used because it is highly conductive, making it suitable for use with electron microscopy and XPS. Also, Al was not a major component of any of the fume that was studied. Table 1 shows the average aerodynamic particle diameters collected by each of the 13 collection stages of the ELPI. Transmission electron microscopy samples were collected by briefly passing carbon-coated copper TEM grids through the fume plume at distances of approximately 75 and 150 mm (3 and 6 in.) above the arc during welding. It was determined that the entire particle size distribution range was collected onto the grids using this method. A detailed procedure for collection and analysis developed previously (Ref. 5) was followed for collection and characterization procedures for each of the electrodes. Compositions of the base materials and actual weld deposits for each electrode are presented in Table 2.

The scanning electron microscopy analyses were performed using conventional and high-resolution scanning electron microscopes JEOL LV-SEM JSM 5900LV and JEOL FEG-SEM JSM 6330F, respectively. X-ray energy-dispersive spectroscopy analyses were performed using a microanalysis system NORAN Voyager attached to the conventional SEM.

The aluminum foils used to collect the fumes in the ELPI were secured to the SEM sample holder using electrically conductive tape. In addition, examination of TEM grids in the SEM was possible with the use of a specially designed graphite sample holder.

The SEM analyses were performed using 10 to 30 kV and a pole piece to sample distance of 5 to 10 mm. The XEDS analyses were performed at 15 keV using a live spectrum collection time of 100 s, providing excellent peak to background ratios. Certified standards were used to calibrate the XEDS system and as a reference for the quantitative analyses.

The quantitative analysis used a digital top hat filter for background subtraction and ZAF matrix correction method, both integrated to the Voyager system. Fume deposited on stage collection substrates in piles directly below impactor jet orifices. Bulk stage composition measurements were obtained on each stage by defocusing the electron beam to cover a large area of the piles. Therefore, a large number of particles were simultaneously generating X-ray signals during XEDS measurements.

The scanning electron microscopy analyses were performed using conventional and high-resolution scanning electron microscopes JEOL LV-SEM JSM 5900LV and JEOL FEG-SEM JSM 6330F, respectively. X-ray energy-dispersive spectroscopy analyses were performed using a microanalysis system NORAN Voyager attached to the conventional SEM.
The TEM allowed the morphological and chemical characterization of particles of much smaller physical diameters due to the technique’s finer spatial resolution. The narrow volume of material exited by the electron beam allowed localized chemical analysis of the ultrafine particles.

Chemical elements with atomic numbers lower than Na and C become difficult to quantify with the XEDS technique for a diffusion vacuum pumped SEM and TEM, respectively. Because of this, oxygen was often eliminated from the quantification routines even though most particles were heavily oxidized. Among the difficulties for oxygen XEDS quantification, the low-energy O-K X-ray photons are highly absorbed by very thin C contamination films. These films are very common in SEMs and TEMs, which severely compromises such element quantification. Al was also left out of the analysis because the Al substrates on which the particles are collected resulted in a large stray signal during XEDS analysis. In addition, fluorine was not quantified in most of these samples due to the F-K X-ray peak overlap with the highly excited Fe-L X-ray peak, making such element quantifi-

The XPS analysis was performed on particles collected on stage 3 of the ELPI system. The XPS system was a Kratos Ultra Axis XPS and UPS system with depth profiling capabilities using Ar ion etching. Initial survey scans were completed for each sample to determine the elements contained within particle surfaces. Detailed region scans were then performed for each element observed to obtain higher signal-to-background ratios. Samples were then etched with Ar+ ions for a period of 10 min. Region scans were performed again to observe changes in peak intensity after the etching sequence.

**Results and Discussion**

The initial particle characterization was performed with SEM and XEDS analysis because particle morphology and bulk composition of each ELPI stage are most easily obtained with these two techniques, respectively. Magnifications in excess of 100,000x were readily obtainable with field emission SEM, allowing for imaging of particles at the larger end of the ultrafine region (diameters < 100 nm). Therefore, this technique was used to image particles from all of the ELPI stages, but worked best on stages 3–13. Three distinct particle morphologies were observed, namely spherical, irregular, and agglomerated. Spherical particles were the most abundant type of individual particle. Irregular particles were generally rod shaped and not as common as the spherical ones. Agglomerates were found to consist of anywhere from several to hundreds of spherical and irregular particles bound together. A schematic representation of the types of particles observed is shown along with a schematic of the core-shell structure, which was observed at high magnifications during TEM analysis — Fig. 1.

**SEM – Particle Morphology**

Spherical and agglomerated particles were observed on each stage of the E6010 collections, but individual spherical particles were present in low percentages on the lower stages (1–6). Many of the agglomerates consisted of loosely packed spherical particles with diameters on the

<table>
<thead>
<tr>
<th>ELPI Stage</th>
<th>E6010</th>
<th>E308-16</th>
<th>E6010</th>
<th>E308-16</th>
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<tr>
<td>1</td>
<td>—</td>
<td>—</td>
<td>~ 70</td>
<td>—</td>
<td>~ 30</td>
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</tr>
<tr>
<td>2</td>
<td>—</td>
<td>—</td>
<td>~ 80</td>
<td>—</td>
<td>~ 20</td>
<td>—</td>
</tr>
<tr>
<td>3</td>
<td>—</td>
<td>—</td>
<td>~ 2</td>
<td>~ 10</td>
<td>&gt; 98</td>
<td>~ 90</td>
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<tr>
<td>4</td>
<td>—</td>
<td>—</td>
<td>~ 10-15</td>
<td>~ 10-15</td>
<td>&gt; 98</td>
<td>~ 85-90</td>
</tr>
<tr>
<td>5</td>
<td>—</td>
<td>—</td>
<td>~ 10-20</td>
<td>~ 10-20</td>
<td>&gt; 98</td>
<td>~ 80-90</td>
</tr>
<tr>
<td>6</td>
<td>&lt; 2</td>
<td>—</td>
<td>&lt; 2</td>
<td>—</td>
<td>&gt; 96</td>
<td>100</td>
</tr>
<tr>
<td>7</td>
<td>&lt; 2</td>
<td>—</td>
<td>~ 2</td>
<td>~ 10</td>
<td>&gt; 96</td>
<td>100</td>
</tr>
<tr>
<td>8</td>
<td>&lt; 6</td>
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<td>&lt; 2</td>
<td>—</td>
<td>&gt; 92</td>
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<td>9</td>
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<td>&gt; 80</td>
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<td>&lt; 10</td>
<td>—</td>
<td>—</td>
<td>~ 30-40</td>
<td>&gt; 90</td>
</tr>
<tr>
<td>13</td>
<td>—</td>
<td>—</td>
<td>~ 30</td>
<td>—</td>
<td>~ 70</td>
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order of tens of nanometers. Irregular particles were observed on all stages as well, but were most prevalent on stages 1 and 2. A qualitative bulk estimate of E6010 and E308-16 particle types was performed with SEM on each of the ELPI stages. This estimate, provided in Table 3, should only be regarded as indicative of the distribution of particle morphologies in each stage.

E308-16 fume morphology distribution was similar to E6010 where the highest percentage of individual spherical particles was observed on the upper stages. A large number of agglomerates were found on all the stages for the E308-16 samples, though they were quite different from the agglomerates found in E6010 fume. These agglomerates were generally well packed together, and in some cases formed large consolidated round agglomerates consisting of multiple fume particles of different sizes. These round agglomerates were most prevalent on stages 3–6. On stages 7–11, there were more loosely packed agglomerates similar to the open-structured type observed in E6010 fume. However, during E308-16 fume morphology analysis, most of the agglomerates were generally observed to be spherical in shape and apparently consolidated. Representative secondary electron micrographs are shown for E6010 and E308-16 fume collections — Fig. 2. E7018 fume particle morphology as a function of size was generally consistent with the observations of E6010 fume as well, except irregular particles were observed with lower frequency.

To verify the extent of particle agglomeration occurring before collection in the ELPI, carbon-coated TEM grids were passed through the fume plume at different distances during welding. These grids were examined with SEM using a specially designed stage capable of accepting TEM grids. Examination of particles deposited on the grids showed that agglomerates collected from the plume were representative in size of those observed on ELPI stages. Further agglomeration or deagglomeration was determined to be minimal during ELPI collection.

SEM – Chemical Analysis

The SEM-XEDS measurements were performed on stages 1–13 of the ELPI column for E6010, stages 3–13 for E308-16, and stages 2, 4, 8, 10 for E7018 fume collections. These measurements were performed to determine fume composition as a function of aerodynamic diameter, and to analyze individual particles and agglomerates greater than 0.3 μm in size. Little fume was present on stages 1 and 2 of the E308-16 collection because size dis-
Fig. 6 — Electron micrographs taken with SEM (A) and TEM (B, C, and D). The XEDS measurement locations are indicated on each micrograph except for XEDS 3, which was measured over the entire agglomerate in (C) by spreading the electron beam.

Contributions were skewed toward larger diameters. As fume particles were not observed in large piles on those stages, a statistically meaningful measurement of bulk composition of fume deposited on those stages was not possible.

Measured bulk compositions (in at.-%) of E6010 fume collected on ELPI stages are plotted as a function of aerodynamic diameter (Dp) — Fig. 3. Na decreases in concentration from 10 at.-% to zero as particle size increases toward the larger diameters. Si is present in rather low concentrations on lower stages but increases to its maximum level just above 0.1 \( \mu m \). Fe is fairly uniform in composition except in the presence of high amounts of potassium (K) (50.6 at.-%) on stage 13; however, K was not present in detectable levels on the other stages. Ti was also present in low concentrations and observed initially on stage 5 (0.4 at.-%) and peaked in concentration on stage 13 (3.4 at.-%). Both Ti and K are contained in the flux coating of the E6010 electrode. Due to the lack of fluoride present in the E6010 fume, potassium would likely be present as an oxide that would have lower volatility than a potassium-fluoride (KF) compound. This could shift the distribution of K-bearing particles to larger sizes as compounds with lower volatilities preclude vaporization, whereas vapor-condensed particles (such as those containing the more volatile KF compound) would dominate the fume distributions in the smaller particle diameters (Refs. 11, 15). This reasoning may also explain why Ti increases in concentration with increasing particle diameter. Mn was found in highest concentration (21.8 at.-%) in stage 1 (0.03 \( \mu m \) Dp) of the ELPI. It decreased to approximately 8 at.-% in the larger sizes and remained fairly constant as a function of Dp. The enrichment of Mn in the nucleation range of fumes produced during gas metal arc welding (GMAW) with ER70S-3, more specifically in primary spherical particles with diameters < 0.06 \( \mu m \), has been explained by the degree of supercooling a particle experiences from vapor (Ref. 16). Smaller particles experience larger degrees of supercooling from the initial fume vapor, resulting in higher Mn contents. It is expected that primary particle formation in fumes generated during SMAW would occur in a similar manner. Considering that chemical species from the welding flux condense after the metallic particles nucleate, because they are generally more volatile, the same type of Mn enrichment is anticipated in the smallest SMAW fume particles. This is shown in Fig. 3 where Mn increases in concentration on stage 1.

Approximately 15 individual particles were analyzed with XEDS on each stage. The composition of these particles was generally more complicated than those of the bulk analyses because of the presence of minor additional elements not detected in bulk measurements. Individual analyses were also made difficult because large Al-K and O-K X-ray signals were generated by the background substrate holding the particles. These peaks were subtracted from the X-ray spectra generated.

Table 4 — Composition Ranges (at.-%) for Individual Particles and Agglomerates as Measured with SEM-XEDS

<table>
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<tr>
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<td>1.8</td>
<td>4.4</td>
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<td>7.7</td>
<td>27.1</td>
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<td>5.3</td>
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<tr>
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<td>Mg</td>
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<tr>
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<tr>
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<td>16.8</td>
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<td>Cr</td>
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<td>0.0</td>
<td>0.0</td>
<td>3.0</td>
<td>23.4</td>
</tr>
<tr>
<td>F</td>
<td>0.0</td>
<td>0.0</td>
<td>7.5</td>
<td>22.1</td>
<td>0.0</td>
<td>0.0</td>
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<tr>
<td>Zn</td>
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<td>0.5</td>
<td>6.4</td>
<td>0.0</td>
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</tr>
</tbody>
</table>
during the analyses, introducing some error into the measurement. Composition ranges for individual fume particles and agglomerates are provided in Table 4, which shows that some of the particles contained low levels of Cr, K, Ti, Mg, and S in addition to those shown in Fig. 4 (bulk compositions). However, elemental compositions of individual particles were generally in agreement with bulk analyses performed on the same stage.

**E308-16**

Bulk compositions of the E308-16 fume on the ELPI stages showed more scatter than the E6010 fume with respect to the levels of Mn, Fe, and Cr — Fig. 4. These three metals all varied in level and remained below 20 at.-% across the particle size range. Fe, Cr, and Ti had minima in concentration on stage 5 (Dp = 0.265 μm) of the ELPI and increased in concentration from stage 5 in both the finer and larger particle diameters. Na decreased in concentration with an increase in particle size, whereas Si increased from approximately 10 to 20 at.-%. Analyses of individual particles and agglomerates shown in Table 4 were in agreement with the bulk analyses, although XEDS spectra of individual particles occasionally revealed lower levels of K and higher levels of Fe. It is also worth noting that K and Cr were simultaneously present in many individual particles, and were measured across the entire collected size range. This observation, along with the X-ray diffraction (XRD) data showing K₂CrO₄ in bulk E308-16 fume in Part 1, suggest that the Cr(VI) valence is possible in all particle sizes. However, further examination would be necessary to determine the extent of its presence as a function of particle size.

**E7018**

The ELPI stages 2, 4, 8, and 10 were analyzed for the E7018 fume. Bulk compositions are shown as a function of aerodynamic particle diameter — Fig. 5. Mn and Fe are present in lower concentrations than those found on the E6010 stages. This is largely due to the presence of high concentration of the compounds NaF and CaF₂ in the E7018 fume. Ca appeared to increase in concentration as a function of particle diameter, though the extent of that increase was not large. The F-K X-ray peak overlap with Fe-K prevented accurate measurements of fluorine concentration, and there are obvious problems with oxygen quantification. Therefore, little could be said about the competition of Na and K forming oxide or fluoride compounds, and how this would ultimately affect the distribution of particle size due to different volatilities of those compounds. The E7018 fume generally had high fluoride (based on qualitative comparison of F-K and Fe-K X-ray peak heights) and sodium content in the finer spherical particles, which is expected of elements with higher volatilities. Also, fluorides were present in high concentration in bulk fume according to XRD (Ref. 1). This supports previous explanations (Refs. 9, 11) that fluorides increase the number concentration of finer particle sizes and was shown in particle number distributions of E7018 measured with the ELPI (Ref. 1). Zn measured in the E7018 fume was part of electrode coating formulation, but virtually none was detected in the weld deposit. The Zn ended up primarily in larger particles and agglomerates (> 1 μm) with the levels shown in Table 4. Irregular particles had slightly different compositions, usually consisting of a large percentage of metallic elements, instead of types typically found in the fluxes such as Ca or Na.

Figure 6A represents a typical secondary electron micrograph of a group of agglomerated particles. The corresponding composition data are shown in Table 5 for the spot analysis location indicated as XEDS 1. This agglomerate was imaged on stage 8 of an ELPI collection of E7018 welding fume. Fluorine and oxygen concentrations are included in the quantification to illustrate their presence. The agglomerate is composed mainly of Fe, O, and F along with the presence of two cations typically found in fluoride compounds (Na, Ca). Individual particle analyses showed that E6010 and E7018 fume particles were fairly uniform in composition for both spherical particles and agglomerations, irrespective of size.

**TEM — Particle Analysis**

Fume particles formed by nucleation (primary particles) and growth by vapor condensation vary in composition with size, but as accumulation of these particles occurs from many primary particles, agglomerates become similar to the bulk fume composition (Ref. 16). This is why many of the particles and agglomerates analyzed with SEM do not exhibit much variation in composition with particle diameter. The particle and agglomerate compositions measured with SEM-XEDS...
performed on particles less than 300 nm to be expected to be found. The TEM work was done by spreading the electron beam to investigate the spherical particles within the agglomerate. All of these particles are likely primary particles that are imbedded in a Si-rich matrix. These particles likely occur from collisions of primary particles of different compositions followed by chemical segregation of the different phases driven by minimization of Gibbs energy.

The corresponding SAD patterns of the particles in Fig. 6B and D are shown along with the transmission electron micrographs. The E6010 pattern in Fig. 6B was formed by beam diffraction through all of the crystalline particles in the micrograph. Note this pattern exhibits some indication of diffraction rings, indicating many orientations of magnetite occur within the agglomerate. The convergent beam electron diffraction (CBED) pattern in Fig. 6D identifies an (M,Fe)2O4 type structure along the [111] zone axis. In the magnetite matrix, M may be substituted with Cr and/or Mn. Two high-resolution TEM micrographs of different E7018 particles are shown — Fig. 7. The interplanar spacing of the image on the right side, measured to be 3.1 Å, matches the (111) CaF2 plane. This agrees with results obtained from the bulk X-ray diffraction (Ref. 1), but more detailed analysis is necessary to fully and unequivocally identify this phase. Many of these particles with high fluoride content were observed with TEM. This further supports the observed shift of the E7018 number distribution to smaller diameters relative to E6010 and E308-16 number distributions.

The SAD patterns showed the Fe3O4 type crystal structure was most prevalent in particles found in all three types of fume. As a comparison with the electron diffraction data, XRD results (Ref. 1) revealed that the primary phase present in the three fumes analyzed was Fe3O4. Slight diffraction peak shifts suggest that Mn (or Cr when present) is probably acting as a substitution for Fe in the magnetite matrix. The XRD showed additional peaks for the E308-16 electrodes as K2Mo4 and NaF, while the E7018 had additional peaks for NaF and CaF2 (Ref. 1). However, these phases were not observed with the same frequency as magnetite during SAD analysis of particles.

**XPS — Particle Analysis**

The XPS was used to obtain information about valence states and for partial depth profiling of fume particles. Because XPS has the ability to bombard the sample with Ar+ ions to remove surface layers of the fume particles, the system was used to analyze the composition of the particle shell structures and then remove them via etching to analyze core compositions. Stage 3 of ELPI collections was used for fume analysis (aerodynamic diameter of approximately 0.1 μm) though XPS results

> **Fig. 7** — High-resolution (HR) TEM micrographs of E7018 ultrafine particles of Fe3O4 and CaF2.

> **Fig. 8** — The XPS peak intensities as a function of etching for three welding fumes analyzed.
must be interpreted carefully due to the technique’s limited spatial resolution (Ref. 3). These XPS results showing the element intensities in the initial and etched conditions are summarized — Fig. 8. Area counts per second (CPS) was used as an estimate of composition. This corresponds to the area under the intensity vs. binding energy curve for each element peak (Mn 2p, Fe 2p, etc.). The values shown are area CPS of each element divided by total area CPS. The XPS suggested the existence of a core-shell structure in the fume of all three electrodes.

The E6010 fume responded to etching with an increase in Fe, Mn, and Si, and a corresponding decrease in Na, O, C, and F. The E7018 fume was rich in Ca, K, Na, and F prior to etching and showed only trace levels of Mn in the outer layers of the fume. Mn, Fe, and Si in the E7018 fume increased in concentration with etching. Fe peak positions of both fumes (E6010 and E7018) correlated with the FeO2 form of iron oxide, thus complementing SAD and XRD data. Iron also appeared to be present in the metallic state after the etching was completed. Manganese was detected in complex oxides in the fume from both electrodes, but the absolute valence states could not be determined due to the inability to isolate Mn compounds within the spectrum generated by the system. The XPS data suggest that Mn is present in the form of a metal oxide of the MnO2 and MnO2 type, giving valence states of Mn2+ or Mn3+ in both E6010 and E7018 electrodes. Based on XRD and TEM analysis, it is most likely that Mn is present as a substitutional element in the FeO2 compound.

The XPS etching response of E308-16 revealed an increase in Mn, Fe, Cr, and O suggesting that inner portions of particles are rich in metallic oxides. A large decrease in F intensity after etching suggests a fluoride-rich layer may coat many of the particles. Peak locations of Cr were not clearly discernible; however, they were located within the regime of Cr2O3 (Cr3+) and Cr2O3 (Cr4+), and Cr3+ (Cr5+), which suggests a presence of Cr5+ in the fume, though this observation is unsubstantiated. To reveal this indisputably, other methods would be required such as wet chemical testing (Ref. 17). However, the compound K2CrO4 (Cr4+) was observed in XRD results (Ref. 1), which agrees with the current XPS observations.

**Conclusions**

1. An electrical low pressure impactor (ELPI) was used to collect SMAW fume and separate the particles by aerodynamic diameter, allowing for the different size ranges to be imaged and analyzed with the appropriate analytical methods according to particle size.

2. Fume particles generated by the SMAW process vary across a large size range (several nm to several μm), which requires the use of multiple imaging and chemical analysis techniques to fully characterize the fume.

3. The SEM, TEM, and HR-TEM were used to characterize both individual particles as well as the bulk fume on each ELPI stage for three SMAW electrode fumes. This revealed three unique particle structures: spherical, irregular, and agglomerate.

4. The SEM was used to image fume particles and examine the morphology of particles greater than 0.3 μm. The largest percent of particles on all stages of the ELPI were agglomerates of spherical particles. Individual spherical particles were common to all fumes, but were found in lesser frequency than the agglomerates. Agglomeration was common because metal aerosols are typically highly charged or may sinter at high temperature, providing different mechanisms for particles to adhere together. Irregular-shaped particles were also found in fumes from each electrode, but were not as common as agglomerations or individual spherical particles.

5. The TEM and HR-TEM were used to image nano-scale particles. Most of the ultrafine particles had a crystalline structure, and some particles exhibited a core-shell structure.

6. Chemical analysis techniques used during this investigation included SEM-XEDS, TEM-XEDS, and XPS. The XEDS as a fume analysis technique is limited by the size of the electron beam and interaction volume with the particle, and its inability to accurately analyze light elements. Therefore, SEM-XEDS was limited to analysis of particles above 0.3 μm, and TEM-XEDS was used for particles below this size range.

7. Compositional variations were observed with SEM-XEDS across the collected particle size range, and individual particle analyses generally were within bulk compositions on each stage. TEM-XEDS and SAD showed that ultrafine particles were typically metal oxides of the form (M,Fe)O2, where M may be substituted for Mn and Cr, though different compounds were found when particles exhibited a core-shell microstructure.

8. The XPS confirmed the core-shell morphology by partial depth profiling and revealed that the most likely valence states for Fe and Mn are +2 and +3, because they are found largely in the (M,Fe)O2 compound. Examination of E308-16 fume revealed valence states corresponding to Cr4+ bearing compounds, which agrees with XRD results in Part 1.

**Acknowledgments**

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**References**


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