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Reducing Mn Fumes through Electrode Development
Two electrode manufacturers involved in a Navy project to reduce manganese emissions from high-strength flux cored welding wires provide results of their research
M. F. Mruczek et al.

The Experts Speak out on Issues Facing Our Industry
The collective sage observations of AWS Counselors are offered on the state of the welding industry and its needs
H. Woodward

Nanofibers Offer Filtering Efficiency and Money Savings
The benefits of nanofiber filtration of welding fumes are explained
E. Ravert

How to Properly Care for Flame-Resistant Garments
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H. Hoagland

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L. Larsen

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On the cover: Portability is one of the prime benefits of individual weld fume source capture systems such as the one shown here. (Photo courtesy of Donaldson Torit, Donaldson Co., Inc., Bloomington, Minn.)
FABTECH Mexico to Co-Locate with AWS Weldmex and METALFORM Mexico Shows

A new trade show named FABTECH Mexico will co-locate with the established AWS Weldmex and METALFORM Mexico shows beginning next year. A letter of intent to co-locate the shows was recently signed by the American Welding Society and Weldmex LLC (organizers of AWS Weldmex) and the Fabricators and Manufacturers Association and the Society of Manufacturing Engineers (joint organizers of FABTECH Mexico). The first combined exhibition will be held June 2-4, 2009, at the Cintermex Convention and Exhibition Center in Monterrey, Mexico. The location for the annual AWS Weldmex and FABTECH Mexico show will alternate between Monterrey and Mexico City.

“The organizers of AWS Weldmex are extremely pleased to co-locate with FABTECH Mexico,” said Ray Shook, AWS executive director. “The AWS alliance with FMA and SME in producing the FABTECH International & AWS Welding Show has proven valuable to both show attendees and exhibitors. We expect the same success with our new alliance in the Latin American market.”

Exhibitors at this show will feature a variety of bending and fabrication products, including laser beam and plasma arc cutting, coil processing, roll forming, plate and structural fabricating, saws and cut-off machines, tooling, press brakes, shears, punching, and tube and pipe equipment. AWS Weldmex exhibitors focus primarily on welding and cutting products, including thermal spray, metal finishing, and safety equipment. METALFORM Mexico exhibitors will feature metalforming products, including tool and die, metal stamping, forming, and assembly equipment.

Jacobs Receives Contract for the San Francisco Public Utilities Commission’s Bay Tunnel Project

Jacobs Engineering Group Inc., Pasadena, Calif., has received a contract from the San Francisco Public Utilities Commission to provide construction management (CM) services for the Bay Tunnel Project in California. Approximately five miles of 9-ft-diameter soft ground tunnel below the San Francisco Bay, two vertical shafts in areas adjacent to the Bay, and a watertight final lining of welded steel pipe will be constructed.

“The tunnel is one of the most critical elements of the Water System Improvement Program to ensure the delivery of reliable, high-quality, and affordable water to 2.4 million customers in the four Bay Area counties of Alameda, Santa Clara, San Mateo, and San Francisco,” said Jacobs Group Vice President Bob Clement.

The total installed cost of the construction project is valued at approximately $270 million with a CM contract value of $18 million.

U.S. Steel and Worthington Industries to Expand Joint Venture

United States Steel Corp., Pittsburgh, Pa., and Worthington Industries, Inc., Columbus, Ohio, have signed an agreement to expand and modify their current Worthington Specialty Processing joint venture in Jackson, Mich.

U.S. Steel would contribute ProCoil Co. LLC, its steel processing subsidiary in Canton, Mich., and Worthington Industries would contribute Worthington Steel Taylor, its steel processing subsidiary in Taylor, Mich. Worthington Industries will own 51% and U.S. Steel will own 49% of the joint venture.

This move is expected to better serve the changing needs of automotive and flat-rolled steel customers by allowing each of the three entities to maximize their individual processing specialties.
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Welding: Providing Energy for the Future

No matter where we turn today it seems all we hear is bad news. Whether we’re reading the daily newspaper, watching television, checking the Internet, or simply talking with friends, the tone is generally the same. Every day we see and hear about how bad the housing market is, and how the mortgage credit debacle continues to expand. We hear how industry is leaving this country because America can no longer compete. We’re told the dollar isn’t what it used to be, and global warming is heating up and we’re to blame.

Wow, is anything going right in the United States? You betcha there is… actually there is a lot going right in America. Despite the fact we truly appear to be in a downturn and despite the fact we have significant challenges to our country and our economy, we have been in similar situations throughout our history and somehow we have always managed to come back as a stronger and better nation.

So, what is going right for America and how is welding playing a part in it? For starters, let’s just look at what has happened in the oil industry over the past year and what new opportunities are being created right here in the U.S.A. as a result. Oil prices along with other natural resource commodities went through tremendous pricing spikes. Just one year ago, who would have thought that the cost of oil in 2008 would reach $150 dollars a barrel? And while that price shock at the pump has hit all of us in the pocketbook, let’s look at what it is spawning for our future and what impact it will have on welding.

We have finally woken up to the fact that sending $700 billion dollars a year to other countries for oil is not a sustainable economic policy. So, in response, we are finally moving to expand oil production here in this country. That in turn will eventually create the need for significant development of new infrastructure, much of which must be welded together. In addition to drilling infrastructure, we will need transportation, refining, and processing infrastructures.

But that’s not all. Because of the new focus on energy, people are also more aware that oil is, in fact, a finite resource. So, finally, we are aggressively tackling great new alternative energy research and development programs, all of which will require welded infrastructures.

Eventually, we will need new energy-efficient automobiles, which will require a resurgence of resistance welding in an expanding automotive industry. We’ll need new nuclear power plants, wind farms, and new infrastructures to support other new-to-market alternative energy forms.

WEMCO, the Welding Equipment Manufacturers Committee of AWS, is made up of companies that build and supply the equipment that will be needed to support these expanding opportunities in the welding industry. As an association, WEMCO members see a future we can build on if we have an adequate supply of qualified welders to meet the demand. That is why WEMCO in conjunction with AWS supports the Image in Welding campaign as a way to give back to our industry. It is hoped through Image of Welding we can help inspire young, aggressive individuals who have a desire to succeed through the work of their hands, the intellect of their minds, and the spirit of their souls.

WEMCO members also actively and financially support the AWS Foundation and its educational programs, scholarships, loan programs, and fellowships.

If you are a welder, you know the value of the American Welding Society and I hope you are taking advantage of the many programs AWS has to offer. If you are a welding equipment manufacturer, I encourage you to support WEMCO and take advantage of the many programs and benefits it can provide to your company and to the industry we all serve. Working together we can help to sustain the strong, vibrant welding industry necessary to meet America’s energy needs of today while building the new infrastructure needed to keep the country growing in the future.

Dennis Brown
Chair, WEMCO
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United Association Provides Welding Careers for Native Americans

The United Association (UA), working with the Department of the Interior/Indian Affairs, is striving to find a welding shortage answer by reaching out to the Native American workforce. As a result of these efforts, 19 Native Americans — 18 men and 1 woman — have enrolled as apprentices in the Hybrid Welding Program of the UA. They were selected from eight states nationwide and come from several tribes.

“We are pleased to be working with the Department of the Interior on this exciting project,” said UA President William Hite.

Training will be received at UA Local 597 Pipe Fitters’ Training Center in Mokena, Ill. Additionally, this program is provided at no cost to these apprentices. During the 16-week fast-track program, students attend class for 8 hours per day, 40 hours per week. Once training is complete, they will be re-located to communities in need of their welding skills.

The project began when Department of the Interior/Indian Affairs officials approached the UA with the idea of training Native Americans for new careers. Hite approved the concept on the spot. “When I heard about this program with the Department of the Interior, I said, ‘Bring them here. I want them in our program,’” stated James Buchanan, business manager of Local 597. “We need skilled workers. Welding is our lifeblood. It’s the most skilled craft to have today. Everything flows through pipe.”

Apprentice Cora Quaderer, age 20, a member of the Leech Lake Tribe in Minnesota, said, “There are few jobs in my area, and I was unemployed. I want to learn everything they do so I can get a good job. I know this will change my life a lot. And I’m proud to be the only woman entering this program.”

Also, according to Mike Arndt, UA training director, Local 597 is not the only UA local working with the Department of the Interior. “Local Union 469 in Phoenix, Ariz., will also be starting the program in the near future,” he said.

Hobart Brothers Expands Manufacturing, Hobart Institute Opens New Training Area

Hobart Brothers Co. is expanding its manufacturing operations into a new 65,000-sq-ft facility in Troy, Ohio. The facility will be used to increase production capacity for the company’s welding consumables. Also, it anticipates an additional 40 people will be added to the workforce once this plant is at capacity. The building will contribute thousands of dollars to the local property tax base and will be built by Ferguson Construction, a local contractor. Construction will be completed by spring 2009.

In other news, the first day of classes in the expanded, lower level training area at Hobart Institute of Welding Technology, Troy, Ohio, got off to a smooth start as students in the Oxyacetylene Welding and Cutting Course familiarized themselves with their surroundings. Instructors Mike Moore and Luke Bailey are conducting the two-week class for 23 students who actually began their training at Hobart Institute in the Welding Technology and Blueprint Reading Course that is part of the five- or nine-month
program at the school. This training area contains 27 oxyacetylene stations, 1 demonstration station, 10 blueprint layout tables, and 2 classrooms. An additional 26 new welding booths are being added to the main level of the facility.

Welding Technology Put on Hold at College of San Mateo

The Welding Technology Program at the College of San Mateo, San Mateo, Calif., is officially on hiatus because there presently is not any space on campus for it, said Department Chair Durella Combs. And while there are more students than can be accommodated, keeping up with materials (like electricity) is also a concern, she added.

The College of San Mateo’s Welding Technology Class of 2009 (from left) are Marc Weber, Justin Bell, Phillip Lennox, Paul Wagner, Nick Krejci, Daryl Legaspi, Ben Burns, Shawn Piercy, and assistant instructor Boyd Brooks.

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ity, gas, and metal) in the current economy is difficult.

“We are limited by our facilities and plan to grow if we can find new digs. In my opinion, it wasn’t a mistake that welding was left out of the building plan of our new campus. Welding is a costly program to run. We have dedicated experienced faculty, modern equipment, and a tried and true program of instruction; what we need is a building. We are looking for an off-campus site, but we don’t have any funds for rent, so presently we are begging for space,” Combs said.

Topics taught include shielded metal arc, gas metal arc, gas tungsten arc, low hydrogen arc, and oxyacetylene welding, cutting, and brazing. A full program is being run for welding majors in the class of 2009, who started in the fall of 2007. A major class was not accepted for the fall of 2008, but it is yet to be seen if the 2009 class is the college’s last. “Never say never — we also have a dedicated program committee,” Combs added.

E.H. Wachs Celebrates 125th Anniversary

The company started 125 years ago with the ideas and entrepreneurial spirit of a young German engineer, Edward H. Wachs. From its founding in 1883, E.H. Wachs Co. graduated quickly from steamfitting to manufacture of the Wachs Vertical Steam Engine. The third generation Edward H. Wachs III pioneered what the company says is the first cold cutting pipe cutting machine; today, this is referred to as the Model E Trav-L-Cutter™.

Additional product highlights include pipe saws such as Goliath™ Guillotine, which feature fast setup and operation with the ability to cut most materials in virtually any position. Split Frame designs can be mounted directly to the O.D. of the casing and offer a lathe quality finish with dimensional tolerances; this lineup is divided into four subcategories. A major contributor to the quality of its products is tooling, which is CAD/CAM designed and engineered/fabricated with high-strength materials, and is designed for higher speed, heavier feed rate, and exotic materials.

Another part of its business is a full line of portable and vehicular-mounted valve operators and exercisers. All products are available with the company’s VITALS™ software.

Facilities are set up in the United States, Canada, United Kingdom, Germany, Africa, and United Arab Emirates, as well as other locations around the globe. It has also been an AWS Sustaining Company Member since 2001.

In June, a party in honor of this anniversary took place at the company’s Lincolnshire, Ill., headquarters. About 125 employees were in attendance, along with Mrs. Edward Wachs Sr., to enjoy a barbecue. Ed Wachs III spoke at the event.
Ribbon Cutting Event Held for Kansas Institute of Welding

A partnership to train welders with modern technology recently got a ceremonial start when Hays Area Chamber of Commerce Ambassadors cut a ribbon opening the Kansas Institute of Welding, a partnership between North Central Kansas Technical College (NCKTC) and Fort Hays State University (FHSU).

The seven students in this first class, which began August 25, are part of a partnership known as the Gateway Program announced in March 2007 by Dr. Edward H. Hammond, FHSU president, and Dr. Clark Coco, president of NCKTC, Beloit.

The institute resulted when the two institutions matched resources. NCKTC has a welding program in Beloit but not at its Hays campus, while FHSU has a limited welding program designed to familiarize future teachers with the basics but that does not produce certified welders needed by Kansas industry.

The welding students study in a classroom and a lab in FHSU’s Davis Hall. NCKTC has equipped it with eight new Lincoln advanced process welding machines. With this equipment, they can become skilled at gas metal, gas tungsten, and shielded metal arc welding and flux core are welding, and carbon arc and plasma cutting. Oxyacetylene welding will also be taught. They will work with welding high-strength and special-purpose steels, stainless steel, aluminum, titanium, and others metals.

Industry Notes

• Northwest Pipe Co., Vancouver, Wash., was named as the pipe supplier for two water pipeline projects having a total contract value of $26 million. These are with S.J. Louis Construction, Mansfield, Tex., and Garney Construction, Kansas City, Mo.

• The Air Industries Machining subsidiary of Air Industries Group, Inc., Bay Shore, N.Y., has won new contracts valued at more than $2,250,000 from a single customer.

• Tata Steel and Nippon Steel Hardfacing Co. signed an agreement on the transfer of overlay welding technology for surface conditioning of steel rolls used at steelmaking processes.

For info go to www.aws.org/ad-index
GSI Spearheads Laser Research Project in United Kingdom

GSI Group Laser Div. is partnering with the LPA Group at Heriot-Watt University, PowerPhotonic Ltd., and Cranfield University for a $2.13 million collaborative research and development project. Funding is provided through the UK Technology Strategy Board.

As lead partner in the High-Efficiency Laser Process Systems Project, the company plans to develop fiber-coupled diode laser sources with beam qualities high enough for a broad range of mainstream applications. This will include a significant increase in the efficiency of current laser-based welding processes.

“Diode system beam quality has so far limited the accessible market to niche applications such as soldering, plastic welding, hardening, and cladding,” said Dr. Mark Greenwood, GSI technical director. “The significant beam quality improvements proposed by this project would enable diode laser systems to enter many of the markets dominated by incumbent technologies such as high-power CO2 and lamp-pumped Nd:YAG lasers.”

The Technology Strategy Board’s technologist for electronics, photonics, and electrical systems, Mike Biddle, said, “The Technology Strategy Board aims to stimulate the development and deployment of technologies which offer major business opportunities for the UK. The advanced laser processing system that will be developed through this project has the potential to be exploited globally. We are very pleased to have had the opportunity to invest in this world-class research and development.”

Titanium Tubing to Be Installed in India’s Tata Mundra Project

Titanium tubing from RathGibson will be installed in India’s $4.2 billion Tata Mundra Project.

RathGibson Inc. will supply welded titanium tubing for the condensers for the Tata Mundra power plant in India. RathGibson manufactures welded, welded and drawn, and seamless stainless steel, nickel, and titanium tubing.

The $4.2 billion power plant is being built near the city of Mundra, in the state of Gujarat. The project will provide power to more than 16 million customers in the states of Gujarat, Rajasthan, Maharashtra, Punjab, and Haryana. It is India’s first private power plant to use supercritical technology. The term “supercritical” refers to the state of water when it cannot be clearly defined as either a liquid or a gas. By achieving this supercritical state, energy generation efficiency is increased while emissions are decreased.

Linde Supplies Flameless Oxyfuel System in Finland

The Linde Group has supplied a flameless oxyfuel preheating system for stainless steel producer Outokumpu’s ferrochrome converter in Tornio, Finland. The self-cooled flameless oxyfuel system will replace the existing conventional water-cooled oxyfuel system. Outokumpu’s Tornio Works produces 1.3 billion tons of stainless steel per year.

The system will be Finland’s first flameless oxyfuel system. The 2.5-MW system will be used for drying and preheating of the ferrochrome converter. Benefits of the system at the Tornio Works will be reduced heating cycles, greater energy efficiency, and up to 50% lower fuel consumption and CO2 emissions.

Messer Supporting Welding Training in Serbia

The Messer Group GmbH is supporting welding training in Serbia in a variety of ways through a collaboration with the Technical University in Belgrade and the country’s Ministry of Education. Messer is an industrial gas company that is active in more than 30 countries in Europe and Asia, as well as Peru.

The Welding and Welded Structures Department was established at the university in 2007. Messer has supported training of welding engineers by offering its expertise and by providing scholarships for students. In addition, Messer and Castolin have built a joint laboratory for welding and metal coating. Practical demonstrations are part of the training program, and the facility is also used as a venue for international seminars.

Messer is also promoting an expanded education program for holders of a vocational baccalaureate diploma in mechanical engineering, and has introduced welding to five mechanical engineering schools throughout Serbia. The five schools have been supplied with welding and cutting equipment, as well as a jointly used flame spray gun from Castolin; Messer has supplied gases to the schools as well.
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Q: When we qualify stainless steel welds, we have to run transverse bend tests and sometimes longitudinal face bend and/or root bend tests. Some filler metals, like 308L and 316L, routinely produce very clean bent test surfaces, but other filler metals, like 310 and 330, usually show small openings that look like little cracks on the bent surface. Normally the bend test criteria allow openings smaller than \( \frac{1}{8} \) in. (3.2 mm), and the openings are about half that length or less, so the tests are considered successful. Nevertheless, these openings concern us. What can you tell us about them?

A: What you are experiencing with the observation of small openings on the bent surface is another way of finding microfissures. In the discussion of “linear porosity” of 310 stainless welds in my March 2003 column, I noted that the aligned dye penetrant indications found on ground 310 stainless welds are evidence of microfissures. The ferrite found in nominally austenitic weld metals like 308L and 316L generally eliminates microfissures. But fully austenitic stainless steel weld metals such as 310, 330, and a number of others, as well as nickel-based alloy weld metals which cannot contain ferrite, are prone to microfissures. Microfissures are small openings in the weld metal that can be found on the bent surface of a bend test specimen. They are not cracks, but rather small cracks or fissures that are typically less than \( \frac{1}{8} \) in. (3.2 mm) long, and are usually less than half that length. These microfissures can be detected using dye penetrant or magnetic particle inspection methods. They are often found in welds containing ferrite, such as 310 and 330, but are less likely to be found in fully austenitic welds like 308L and 316L, where ferrite is typically eliminated by heat treatment. The presence of microfissures can indicate potential weaknesses in the weld, and may require additional testing or rework to ensure the weld meets the required quality standards.
sures are a fact of life in these weld metals. You can limit their size by using low heat input welding. You can reduce their number by selecting higher-purity filler metal (low phosphorus and low sulfur). But, without ferrite, it is virtually impossible to eliminate them altogether.

More than 30 years ago, Lundin et al. (Ref. 1) developed a variation of a longitudinal face bend test that they termed a “fissure bend test,” as the best way of finding and counting microfissures, and found minimum ferrite levels needed to eliminate microfissures from various nominally austenitic stainless steel weld metals. In this test, a longitudinal tensile strain was demonstrated to open microfissures and render them easily visible. The curved surface of a bend test specimen doesn’t photograph very well, but the same effect can be achieved by limited straining of a longitudinal flat tensile specimen. The surface of a longitudinal flat tensile specimen of 310 stainless steel shielded metal arc (SMA) weld metal is shown in Fig. 1, where the tensile test was interrupted after only 10% strain. Several microfissures are revealed, and the centimeter rule beside the tensile specimen shows that the largest microfissures are a bit less than 2 mm (0.080 in.) long. Note that the microfissures are mostly, but not entirely, perpendicular to the length of the specimen (welding direction). The tensile strain opens the microfissures, but does not make them propagate because these weld metals are very tough and blunting of the microfissures occurs readily.

Microscopic examination usually shows that most microfissures form at the interface between two or more weld beads, where the reheating of the later bead induces microfissures in the previous bead. An example of this is shown in Fig. 2.

In the study cited in Fig. 2, Lundin and Cui examined corrosion, fatigue, and creep properties of ferrite-free weld metal containing microfissures as compared to similar weld metal containing ferrite and therefore microfissure-free. They found minimal effects of microfissures except for evidence that microfissures open to the exposed surface tended to initiate pitting corrosion or reduce the critical pitting temperature.

The findings of the WRC study are reassuring because of the many weld metal compositions known to contain microfissures. All sorts of fully austenitic stainless steel and nickel-based alloy weld metals containing microfissures are in use in industry, especially at high temperatures. And they perform well. I think it highly likely that, if the procedure qualification tests of such weld metals failed to find microfissures, it is mainly because most procedure qualification tests look at transverse weldment tests. But, as noted by Lundin and Cui, cited above, longitudinal strain is the best way to reveal microfissures. A longitudinal tensile test, a longitudinal face or root bend test, or a fissure bend test has a much higher probability of revealing microfissures than does a transverse tensile or bend test.

References


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

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

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- Structural Solder Applications
- Test Methods and Evaluation
- Furnace/Vacuum Brazing
- Joint Design and Reliability
- Lead-free Solders
- Light Metals
- Materials and Process Design/Control
- Medical/Dental
- Mining & Heavy Equipment
- Modeling and Process Control
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- Job-Shop & Process Customization
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Reducing Mn Fumes through Electrode Development

Efforts were made to develop a modified MIL-101TM flux cored arc welding electrode to reduce manganese fumes when joining high-strength steels

BY MARK F. MRUCZEK, PAUL J. KONKOL, STAN FERREE, AND MIKE SIERDZINSKI

The Navy Metalworking Center (NMC) was tasked to work with electrode manufacturers to develop a modified MIL-101TM flux cored arc welding (FCAW) electrode that reduces the total amount of manganese (Mn) emitted during joining of HSLA-100 steel used in shipbuilding. The objective was to develop a low-fuming, flux cored welding electrode composition and weld procedures that reduced potential worker exposure to Mn emissions while maintaining required weld properties. (NMC is operated by Concurrent Technologies Corporation (CTC) for the U.S. Navy Manufacturing Technology Program (ManTech).) NMC was asked to examine methods to reduce Mn fume emissions by 50% from the baseline composition (as measured for each manufacturer). While reducing the amount of Mn emissions, the modified electrode was still expected to meet the military specification requirements for MIL-101TM per NAVSEA Technical Publication T9074-BC-GIB-010/0200 (Ref. 1) with 88 ksi (606 MPa) minimum weld metal yield strength and operability characteristics.

Two electrode manufacturers, ESAB Welding & Cutting Products and Hobart Brothers, participated in this project by performing baseline fume emissions testing and then by modifying and testing their 0.045-in.- (1.14-mm-) diameter MIL-101TM electrode products, Dual Shield II 101H4M with 75%Ar-25%CO₂ (C25) shielding gas and Tri-Mark 101-TM with 95%Ar-5%CO₂ (C5) shielding gas, respectively. The 0.045-in.- (1.14-mm-) diameter electrodes were evaluated because they are a commonly used electrode size.

This article reports the results of all chemical, fume, and mechanical testing performed by each manufacturer during systematic development and testing of modified electrode compositions. These results were then compared to the baseline test results for fume emissions and weld metal mechanical requirements.

Experimental Procedure

Weld Metal Requirements

An abbreviated list of selected required properties for the modified electrode welds is provided in Table 1. These requirements are a combination of those provided within Table II, Appendix A, of T9074-BC-GIB-010/0200 (Ref. 1) with a higher yield strength.

All testing was performed with HSLA-100 plate, which was chosen because it is used extensively in aircraft carrier construction and was considered the most difficult plate material being utilized on which to qualify electrodes. The intent was that if modified electrodes could be successfully developed for HSLA-100, the technology could be extended to consumables for other high-strength steels.

Shielding Gas Requirements

Originally, the project was scoped to develop a modified composition for use with argon + 5% CO₂ (C5) shielding gas because this gas has been shown to result in...
in reduced welding fume emissions. To accommodate both manufacturers, the scope widened to include either C5 or argon + 25% CO₂ (C25) shielding gas, at the manufacturers’ discretion.

Baseline Testing

ESAB, Hobart Brothers, and NMC evaluated currently available FCAW electrodes using HSLA-100 steel and C25 shielding gas for fume emissions, airborne Mn levels, and mechanical property data. Combining these data with historical data and initial trials in the project (Ref. 2) provided a baseline against which to measure resulting improvements. Key results are summarized in Tables 2 and 3. The Environmental Protection Agency (EPA) AP-42 emissions factors (Ref. 4) was used as a discriminator during electrode development. The EPA AP-42 technique provides more reproducible results because it captures the total fume emission off the electrode and eliminates welder, environmental, and fume-extraction variables. Fumes were collected using AWS F1.2, Laboratory Method for Measuring Fume Generation Rates and Total Fume Emission of Welding and Allied Processes (Ref. 5). The EPA AP-42 results for baseline testing of the existing MIL-101TM products are provided in Table 3. Based on the results of fume emissions, airborne Mn levels and mechanical property data collected during the baseline efforts, the following conclusions were reached.

• Dual Shield II 101H4M (ESAB product) has historically met NAVSEA Technical Publication T9074-BC-GIB-010/0200.
• Depending on the welding conditions and fume extraction methods, Dual Shield II 101H4M is capable of producing airborne Mn levels above 200 μg/m³.
• Dual Shield II 101H4M produced 50% lower Mn welder exposure levels when using C5 shielding gas, but produced excessive porosity under common shipyard fabrication conditions.
• Tri-Mark 101-TM (Hobart Brothers product) met NAVSEA Technical Publication T9074-BC-GIB-010/0200 and the higher yield strength requirements in high cooling-rate weldments during this baseline effort. During testing of Tri-Mark 101-TM (trade name TM811N3) for another NMC project...

| Table 2 — Time Weighted Average (TWA) Airborne Mn Levels (μg/m³) from Baseline Testing of MIL-101 TM(a) |
|-----------------|-----------------|-----------------|-----------------|
| Fume Type       | 0.045-in. (1.14-mm) | Average for 0.045-in. (1.14-mm) | 0.045-in. (1.14-mm) |
| Mn              | 52              | 74              | 240             |
(a) Welded at different times in a laboratory setting with no specific fume extraction method.

| Table 3 — Baseline Mn Fume Emission Data Using the EPA AP-42 Emission Factor and 75%Ar/25%CO₂ Gas as Provided by ESAB and Hobart Brothers |
|-----------------|-----------------|-----------------|-----------------|
| 101TM Manufacturer | Size in. (mm) | Welding Parameters | Fume Generation Rate (g/min) | % Mn Fume on Filter | Mn Fume Generated (g/h) | Total Fume (kg/ea electrode) | Mn Fume (10^-1 kg electrode) | EPA AP-42 Emission Factor |
| ESAB            | 0.045 (1.14)    | 225 A/26 V       | 0.559            | 11.36            | 3.8             | 8.4             | 9.54             |                      |
| ESAB            | 1/16 (1.6)      | 260 A/26 V       | 0.857            | 11.84            | 6.1             | 11.9            | 14.08            |                      |
| Hobart Brothers | 0.045 (1.14)    | 250 A/27 V       | 1.25             | 6.93             | 5.2             | 12.87           | 8.9              |                      |
Ref. 6, the Charpy V-notch toughness values did not meet requirements at either 0° or –60°F (–18° or –51°C) at the high cooling rate in 2-in. (51-mm) HSLA-100.

- Tri-Mark 101-TM produced airborne Mn levels below 200 μg/m³ (mean of one Hobart Brothers and two NMC test results: 66.5 μg/m³) using C25 shielding gas and in a laboratory-controlled environment.

### Technical Approach

Hobart Brothers started with a dual C5/C25 shielding gas approach for the modified electrode development and then switched to C25 shielding gas. ESAB concentrated on C25 shielding gas throughout its electrode development process. ESAB concentrated on achieving the target fume emissions and then measuring the resulting mechanical properties. Hobart Brothers took the reverse approach and concentrated on measuring mechanical properties of plates welded at low cooling rates (LCR) and then measuring the resulting fume emissions. High weld-metal cooling rates (HCR) usually are desirable from a mechanical property standpoint for these electrodes; therefore, low cooling rates would simulate a worst case scenario. Both manufacturers performed their testing with welds on 3⁄4-in.-thick (19-mm) HSLA-100.

### ESAB Approach

After establishing the baseline fume data, ESAB modified its 0.045-in.- (1.14-mm-) diameter Dual Shield II 101H4M electrode to reduce Mn in the electrode to ultimately reduce Mn emissions. In an attempt to maintain mechanical properties, ESAB increased other alloying elements, including nickel (Ni). Ni was also monitored in the fumes to ensure that the fume emissions for Ni did not significantly increase and counter the benefits of reduced Mn emissions. ESAB then tested the new electrodes for deposited chemical composition, fume emissions, and fume composition. When the results were promising, ESAB fabricated standard quality conformance weldments to check for compliance with mechanical property requirements. Based on the results, ESAB adjusted the electrode compositions and formulated additional lots.

### Results and Discussion

#### ESAB Results

ESAB attempted to reduce Mn fume emission by reducing the electrode Mn content. The effects of weld metal Mn on both the amount of Mn in the fumes (Mn as percent of solids collected) and the mechanical properties are shown in Figs. 1–5. As shown in Figs. 1 and 2, reduced electrode Mn content was directly proportional to reduced Mn levels in the fumes; however, both weld-metal yield strength and CVN toughness were impaired — Figs. 3–5. The scatter in the yield strength — Fig. 3 and CVN toughness (Figs. 4, 5) are attributed to the effects of other simultaneous alloy modifications made to compensate for the reduction in Mn. However, these data demonstrate the importance of Mn in achieving the required mechanical properties in high-strength steel weld metals.
After extensive trials, ESAB developed two lots, NR-1748 and NR-1749, which represented its best effort to achieve the lowered level of Mn fumes. The weldments were made at both low cooling rate with 55 kJ/in. (2.2 kJ/mm) heat input and 225°–275°F (107°–135°C) preheat/interpass temperature, and at high cooling rate (HCR) with 30 kJ/in. (1.2 kJ/mm) heat input and 125°–150°F (52°–66°C) preheat/interpass temperature as required by Technical Publication T9074-BC-GIB-010/0200 (Ref. 1). These parameters are shown in Table 4. A summary of the results of testing these compositions is shown in Table 5 along with the requirements. While the LCR tests met impact toughness requirements, they failed to meet the required yield strength. For the HCR tests, the yield strengths were acceptable, but the weldments failed to meet the tensile elongation and impact toughness at 0°F (~18°C) requirements. In addition, fume rates for both lots marginally did not meet the goal of 50% reduction in Mn fumes. Therefore, neither NR-1748 nor NR-1749 fully met the requirements listed in Table 1.

### Table 4 — NAVSEA Requirements for Qualification Test Weldments for MIL-101TM Electrodes

<table>
<thead>
<tr>
<th>Plate Thickness, in. (mm)</th>
<th>High Cooling Rate, (HCR)</th>
<th>Low Cooling Rate, (LCR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/4 (19)</td>
<td>3/4 (19)</td>
<td></td>
</tr>
<tr>
<td>Position</td>
<td>1G (flat)</td>
<td>3G (vertical)</td>
</tr>
<tr>
<td>Heat Input, kJ/in. (kJ/mm)</td>
<td>30 ± 5 (1.19 ± 0.2)</td>
<td>55 ± 5 (2.18 ± 0.2)</td>
</tr>
<tr>
<td>Preheat/interpass temperature, °F (°C)</td>
<td>125/150 (52/66) (HY-80/100)</td>
<td>225/275 (107/135)</td>
</tr>
</tbody>
</table>

### Table 5 — ESAB Best-Effort Mechanical Properties and Mn Fume Generation (NR-1748 and NR-1749)(a)

<table>
<thead>
<tr>
<th>Lot</th>
<th>FGR(b) (g/min)</th>
<th>Mn Fume Generated (g/h)(c)</th>
<th>Yield Strength, ksi (MPa)</th>
<th>Elongation in 2 in. (51 mm) (%)</th>
<th>Charpy V-notch @ 0°F (–18°C), ft-lb (J)</th>
<th>Charpy V-notch @ –60°F (–51°C), ft-lb (J)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NR-1748-A</td>
<td>0.480</td>
<td>2.00 (–47%)</td>
<td>86.6 (597)</td>
<td>24</td>
<td>43 (58)</td>
<td>43 (58)</td>
</tr>
<tr>
<td>NR-1748-B</td>
<td>0.513</td>
<td>1.97 (–48%)</td>
<td>86.9 (599)</td>
<td>25</td>
<td>50 (68)</td>
<td>44 (60)</td>
</tr>
<tr>
<td>Required</td>
<td>(–50%)</td>
<td>88–110 (606–758)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(a) Values in bold did not meet the minimum requirements.
(b) FGR = Fume Generation Rate.
(c) Based on 3.8 g/h baseline in Table 3.

### Table 6 — Mechanical Properties and Mn Fume Generation for Hobart Brothers Optimum Electrode Using C5 and C25 Shielding Gases(a)

<table>
<thead>
<tr>
<th>Lot</th>
<th>Shielding Gas</th>
<th>Mn Fume Generated (g/h)(b)</th>
<th>TWA Mn exposure, (µg/m³)</th>
<th>Yield Strength, ksi (MPa)</th>
<th>Elongation in 2-in. (51 mm), (%)</th>
<th>Charpy V-notch 0°F (~18°C), ft-lb (J)</th>
<th>Charpy V-notch –60°F (~51°C), ft-lb (J)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VB-3-008</td>
<td>C5</td>
<td>3.01 (–42%)</td>
<td>67</td>
<td>102.0 (703)</td>
<td>21.2</td>
<td>56 (76)</td>
<td>39 (53)</td>
</tr>
<tr>
<td>MR-1-004</td>
<td>C25</td>
<td>4.77 (–8%)</td>
<td>Not measured</td>
<td>105.3 (726)</td>
<td>20.6</td>
<td>53 (66)</td>
<td>28 (38)</td>
</tr>
<tr>
<td>Fabco</td>
<td>C25</td>
<td>Not measured</td>
<td>Not measured</td>
<td>99.6 (866)</td>
<td>20.1</td>
<td>77 (104)</td>
<td>31 (42)</td>
</tr>
<tr>
<td>Required</td>
<td>–50% min.</td>
<td>&lt;200</td>
<td>88–110 (606–758)</td>
<td>18 min.</td>
<td>60 (81) min.</td>
<td>35 (47) min.</td>
<td></td>
</tr>
</tbody>
</table>

(a) Values in bold did not meet the minimum requirements.
(b) Based on 5.2 g/h baseline in Table 3.
Hobart Brothers formulated a series of electrodes that included a 40% and an 80% reduction in Mn content within the electrode, an attempt to eliminate a particular Mn compound, evaluation of a different slag system product, and substitution and reduction of Mn in a different form. None of these electrodes produced acceptable mechanical properties; therefore, no fume emission testing was performed for these latter compositions. The best performing electrode for mechanical properties was Fabco 110K3-M, a release for the commercial industry. This electrode contained Hobart Brothers’ more typical alloy system, including Mn at the traditional level; however, the electrode barely fits within the chemistry limits for the MIL-101TM classification. Mechanical testing was performed on a weldment made at LCR conditions with C25 shielding gas. As shown in Table 6, yield strength, tensile elongation and CVN at 0°F met the requirements; however, the CVN at –60°F was unacceptable for military applications. Therefore, no fume emission testing was conducted on this electrode.

Summary

Both electrode manufacturers put forth significant effort to develop modified electrode products that met both fume emission and mechanical property requirements. ESAB used the approach of optimizing the compositions to achieve a 50% reduction in Mn fume emissions, then measuring the resulting mechanical properties. Hobart Brothers used the opposite approach of testing the worst case scenario for mechanical properties, then focusing on reducing fume generation levels. Neither ESAB nor Hobart Brothers was able to develop a modified MIL-101TM electrode capable of meeting both the fume emission goal and mechanical property requirements. While ESAB came close with one electrode design, the margin was too narrow given the normal variability expected in mechanical properties that are typically achieved in production weldments. This underscores the importance of Mn in achieving both strength and notch toughness in high-strength steel weld metals. However, this effort has provided valuable data and information that may lead to developments of other FCAW electrodes with reduced Mn fume emissions.

Acknowledgments

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References

Focus on global growth and have a world of fun at the 2009 WEMCO Annual Meeting in San Diego.

Think globally. Act pampered.

WEMCO, a Standing Committee of the American Welding Society, is committed to collaborating with fellow industry leaders to stay relevant and dynamic in this the ever-changing global economy. On February 26-28, 2009, WEMCO executives will spend several days at the Rancho Bernardo Inn Golf Resort and Spa, in San Diego, Calif., analyzing:

- Industry globalization and economic potential in emerging markets
- Trends and related issues of private labeling
- Issues surrounding rapid growth and expansion

A world of information on global opportunities

WEMCO understands the importance of networking with fellow industry leaders to promote the welding industry, and encourages its growth and development. Each year, the WEMCO Annual Meeting continues to bring together top-level executives from major welding equipment manufacturers throughout the United States and Canada. In 2009, some of the featured presenters will include Dick Couch, president & CEO of Hypertherm, and Chris Ebeling, VP & general manager of Linde Canada, Ltd. Also joining WEMCO will be the highly-anticipated Alan Beaulieu of the Institute for Trend Research. Beaulieu’s delivery of his economic forecast has proven accurate, as well as entertaining.

We cordially invite executives of welding equipment/products manufacturing companies to join WEMCO on February 26-28 to represent their organizations. The networking opportunities are immense, and the information is invaluable. Read some of the feedback from past attendees:

- “The best such conference that I have ever attended.”
- “Great meeting. Excellent speakers.”
- “Great program. Just the right mix we needed.”
- “Terrific program content, relevant topics, interesting speakers.”
- “The program was excellent all the way through. I wish other associations were as good.”

How to register

Attendance fees are $720 per attendee, and $225 for spouses and guests. WEMCO has also secured a group rate with the Rancho Bernardo Inn of $250 per room, per night, plus applicable taxes. Go to the WEMCO website (www.aws.org/wemco) to download your 2009 Registration Form today. Forms can be submitted via e-mail at wemco@aws.org, or via fax to (305) 442-7451. Deadline to register for the 2009 WEMCO Annual Meeting is January 26, 2009.

For further information about the annual meeting, please contact Natalie James-Tapley at (800) 443-9353, ext. 444, or via e-mail at tapley@aws.org.

Note: Guests eligible for WEMCO membership may attend only one WEMCO Annual Meeting before joining the committee.
The Experts Speak out on Issues Facing Our Industry

AWS Counselors offer career advice and relate their views and what can be done about America’s manufacturing future

BY HOWARD WOODWARD

AWS Counselors represent the captains of industry in the welding and manufacturing scene. Here they offer their sage observations and business advice on the major issues confronting the men and women working in or about to enter the U.S. welding, brazing, and construction industries.

Warren G. Alexander, a professional engineer in the construction of bridges and large buildings, said, “The most important issue facing the United States of America is that we don’t produce enough of our own products. That applies to bridges, automotive products, electronic devices, and everything in between. Even when we design it here, it’s generally built somewhere else where labor is cheaper. We have lost and continue to lose our critical production capabilities. This loss will have a more immediate effect on our security and well being than global warming and reductions in affordable energy.”

David Nangle, vice president, The Lincoln Electric Co., and subsidiary president of Harris Products Group in Ohio, agrees with Alexander. He said, “One of the most important issues is companies try to cut costs by purchasing products from unknown or unproven sources of supply in third-world countries. In addition, manufacturers are looking for lower labor costs by moving operations or sourcing products from countries such as these without full consideration of quality, the costs associated with excess inventory, and reliable delivery.”

Kenneth E. Richter Sr. has served as a high school welding instructor, product development engineer, product and marketing manager, and president of four companies. After 45 years in the industry, he credits his high school welding instructor Carl H. Turnquist for making welding so interesting he made it his career. Richter said, “Failing to educate high school students and challenging them to pursue careers in welding is an issue currently facing our industry. I suggest obtaining a college degree in welding engineering as an excellent base for almost any career in welding.” In his opinion, people entering the job market might consider a career in sales of welding equipment, gases, and consumables since this field offers great potential for growth.

Matt Lucas, a welding, brazing, and heat treating consultant at Belcan Corp., Cincinnati, Ohio, who previously spent 31 years at GE Aviation, has been involved with welding most everything from high pressure vessels to aircraft engines but considers his area of expertise the brazing of high-temperature alloys. He recognizes the extreme shortage of both brazing engineers and brazers and the escalating costs of brazing filler metals, especially those made from copper, silver, gold, and platinum. He thinks it is important for AWS to be actively involved in blending all of the world’s brazing specifications into one international standard.

Lucas advises those entering the welding/brazing fields “to think globally, and... work to achieve a solid education and obtain the meaningful qualifications including CWI, PE, IWE, and qualified welder.” He stresses the importance of following procedures for process control and keeping accurate records if you want to change for the better. Lucas also said he wants to dispel the myth that brazed joints are not strong. “The proper braze joint geometry and filler metal selection will result in a joint that is stronger than the base metals. Brazing and soldering offer great potential for growth. As exotic, difficult-to-weld base metals are developed, brazing and soldering will be used more widely, placing brazing engineers and technicians in greater demand.”

Jerry Utricht, president, WA Technology LLC, Floreence, S.C., an expert in submerged arc and gas metal arc welding, is concerned about submerged arc welding of heavy sections. “Many of these weldments are in the area of transmission pipe manufacture, power plant fabrication including nuclear plants, petrochemical, vessels, bridges, penstocks, and similar products. Since the early 1980s, the United States is no longer a world leader in this type of fabrication. However, there is a resurgence with the advent of the need for new energy sources and the rebuilding of our infrastructure such as bridges. “Large fabrications of heavy sections are required for wind towers, electric power plants including nuclear, petrochemical plant expansions, ethanol production and storage, and offshore drill rigs and support products and bridges. All of these are currently needed in the United States. The skills and expertise to produce these needs has to be redeveloped.”

Lee Kvidahl, a welding engineering expert with Northrop Grumman Ship Systems, Pascagoula, Miss., said, “The most important issue for welding in shipyards is the experience and skill levels of the welders. This has become an even greater challenge due to the lack of the availability of skilled welders. For someone who is considering entering this field, my advice is to go for it. Shipbuilding is an exciting industry for the various careers required for ship construction welding operations. Whether as a welding engineer, welder, welding instructor, welding inspector, welding designer, or welding metallurgist, shipbuilding is a rewarding career. Building a ship requires expertise in multiple applications including structural, piping, sheet metal, and specialty skills for operating some of the automatic equipment.”

Kvidahl said, “The best welding tip I can provide is do not rely solely on your own talents to make a difference in your business. Include the advice and information from everyone involved in an issue whether it is a new application, new process, troubleshooting a problem, etc.” He recommended, “Communicate with...
everyone with expertise — welders, inspectors, equipment suppliers, distributors, and others within your network who may be able to assist. In the long run, taking time to collect the best information and advice will save time and money for your business.”

Kvidahl was eager to point out that, “I believe that a common misunderstanding is that welding in a shipyard is solely one of hard work, that is dangerous, and dirty to the extent that only those with limited opportunities would work there.” Not so, he said, “There are a great variety of very rewarding occupations required in the shipbuilding industry. Yes, it requires hard work with much physical labor involved, but when the product of this labor leaves the yard heading out to sea, it is all worth it.” Kvidahl contends that, “Welding engineering provides a good career path” that can begin in a shipyard then later progress to other challenging engineering positions in industry.

Ron Pierce, chairman of WESCO Gas & Welding Supply, Inc., Prichard, Ala., has passed many welding tests and certifications over the years. He believes the most important issue currently facing industry is the “great shortage of welders and welding professionals,” citing the need to fill an estimated 200,000 welding jobs in the next few years. He is certain there are unlimited job opportunities, many of which offer top salaries. Pierce said, “The image of welding is far better than most people realize. Much satisfaction can be achieved in seeing ships, planes, boats, buildings, structures of all kinds being put together properly using welding.”

He advises newcomers to the industry to be properly prepared. “Get the formal education plus hands-on welding experience to understand what the welding pool can achieve.” He thinks, he added, “Welding and actual learning to weld and pass various tests has given me a foundation that I’ve used throughout my professional career, which stands more than 50 years.”

Herb Cable, CEO of Weld Tooling Corp., Pittsburgh, Pa., specializes in mechanization and automation of welding and cutting operations. He recognizes there is a shortage of skilled welders and sees great opportunities in the welding industry. His advice is to learn correct weld preparation and fitup in order to make quality welds.

Wayne J. Engeron, a CWI and CWE with The Engeron Technology Group, Inc., Stone Mountain, Ga., is a brazing expert who is also involved in all types of welding from an inspection and certification standpoint. He notes, “There is a serious lack of persons who understand the brazing process and can train in-plant personnel. I suggest that any person who becomes interested in learning welding also try to find an instructor who can teach them the basic knowledge and techniques for brazing. This will provide a larger market for your talents when seeking employment.”

Engeron urges newcomers to the field to “concentrate on learning the technical aspects of the processes that you work with.” He notes that while manual skill levels are important, it is usually the person who possesses the technical knowledge who moves into the higher-paying jobs and supervisory positions.

Ernest Levert, a senior staff manufacturing engineer at Lockheed Martin Corp., believes it is essential for the U.S. “to produce new and better products. Industries must grow so they can be competitive with the international welding community. The world is always changing, and so must the welding companies and industries.”

Rudolph Murray, president, H & M Steel, Jacksonville, Fla., is an educator who believes skills development and research are necessary to move the industry ahead. Workers should strive to increase their skills to a higher level of technology and abide by safety requirements. Society as a whole, Murray said, “does not comprehend the in-depth importance of welding.” He feels the industry’s greatest future potential lies in the green power and space technology fields to conserve the nation’s energy and environment.

Ralph E. Long, an international educator, has expertise in applied metallurgy and quality assurance and has served six years as chairman of the IIW Commission XIV, Welding Education and Training.

“I can always learn something useful when visiting a welding facility regardless of its size or setting,” he noted. “Every shop has some unique feature that you can apply elsewhere.” He laments that welding is unjustly perceived by some people as dirty or dangerous. “Welding,” Long said, “provides benefits beyond a good income. Get the appropriate education then acquire experience,” he advises.

Jeff Noruk is a robotics and automation expert who is also involved with education and training activities. He’s convinced many small- to medium-size companies should consider automating their welding operations to remain competitive in the world market. Noruk stresses getting a good education and a solid diploma or degree in welding and becoming “active in AWS, FMA, and RIA committees and conferences where you’ll learn more about the technology and the people who are developing it.”

For newcomers to the robotics field, Noruk said, “The robotic equipment is all pretty good today, so it is more important to concentrate on picking the right project, the right integrator, and assembling a strong team to be successful. Automation is the field to be in,” he adds, “because there will continue to be a shortage of welders in our country, which means we need to automate like Japan has done to stay competitive.”

Jack R. Barckhoff of Barckhoff Welding Management Corp. works with companies to help them develop and apply systematic approaches to make their welding operations more productive and profitable. He concludes that U.S. companies doing welding need to be more productive to compete successfully in the world markets. In Barckhoff’s opinion, welding is not art, it is a scientific process. “You can control a science; you cannot control an art,” he said. An understanding of the impact of all welding variables by the involved personnel is essential for complete control of the processes. The brightest future in welding is in management, said Barckhoff. “It offers both the best career opportunities and best opportunity for real impact on the operating results of any company that has welding as one of its core processes. Once the basics and foundation are established,” he added, “the opportunity to move a company with the necessary technology transferred to the shop floor, a company is ready for robotics and automation.”

James F. Harris has a broad founda-
tion in the fossil and nuclear power, refining, and petrochemical industries with emphasis on welding, material science, failure root cause analysis, inspection, teaching, and management. He sees a dire “need for well-educated, skilled, and dedicated professionals across the broad spectrum of welding and joining technology.”

“Learning,” he said, “is a journey, not a destination. Continuing education is critical to the success of a person’s career.” Harris urges newcomers to seek the counsel of a mentor — an experienced welding industry professional you can speak with about your career and help guide you in making favorable decisions. A favorite approach to problems is to “always begin a root cause analysis with the technology basics. Many times it is the simple things that cause us the greatest problems.”

Harris faults poor communications as a common problem in industry. “One must understand that communication is two ways. Until the communication loop is completed, communication has not been accomplished. Without communication, the desired outcome will probably never be realized. Harris thinks welding offers “tremendous opportunity and growth. Many people I have known started as welders and now are inspectors, educators, supervisors, managers, or engineers.”

Don Hastings, former CEO of Lincoln Electric Co., enthusiastically recalls his beginning in welding equipment sales as a field representative — “and I enjoyed every moment.” His job involved him with shipyards, structural fabricators of bridges, high-rise buildings, pipelines, farm and construction equipment, automotive manufacturers, and military producers. “It was truly challenging, rewarding, and fun.” Hastings branched off into working with welding supply distributors where he trained and motivated their personnel to sell products — “Again, rewarding and fun,” he said.

Omer W. Blodgett, an AWS Fellow, looked back on his career as a renowned structural steel welding expert, author, and teacher and said, “I am 90 years old and still working after 63 years with The Lincoln Electric Co.

“My advice to the younger generation is that once you are out of school don’t stop learning. Actually, that’s when learning starts and, hopefully, will continue the rest of your life.”

Blodgett urges every man and woman in industry “to get involved with a local chapter of an engineering society — AWS, ASCE, ASME, AISC, etc., and take an active part in it.” Also, he advised, “Continue to take courses, and attend seminars and conventions. Read your engineering journals. Write and publish engineering papers. If possible, get on a specification-writing committee to help guide your engineering profession.”

Later in life, he became involved in hiring, training, and motivating recent college graduates to become effective sales representatives. “This was the most fun of all,” he recalled. He notes that the company he joined after college had manufacturing facilities in three countries outside the United States. Today, that company has more than 25 manufacturing sites and facilities worldwide and is expanding. Hastings concluded, “There is tremendous opportunity in entering the welding industry both here in the United States and internationally.”

Don Hastings
Much has been written about the health risks of weld fumes, the various contaminate collection methods, and OSHA requirements/limits for worker exposure. Dust or fume collectors with pulse jet cartridge filters are the preferred method of cleaning the air because of their collection efficiency. The particle size of weld fume is generally in the 0.3 to 0.7 micron size range. For hexavalent chromium (Cr(VI)), the OSHA limit is now 5 micrograms (0.005 mg/m³).

For today’s welding operations, nanofiber filtration offers an efficient and cost-effective way to go because weld fume and other matter smaller than one micron can be controlled. This article explains nanofiber filtration technology and its operational and cost savings benefits.

**Nanofiber Technology**

If you look at any cartridge filter media through high magnification, you will see open spaces or “holes.” The smaller the “holes,” the better the media will be in capturing fine particulate. The best way to do this is to use the smallest fibers possible. A nanofiber is 1/1000 of a micron — Fig. 1. Just how small are these fibers? Consider that there are 25,400 microns in an inch. The lower limit of visibility with the naked eye is 40 microns, and the average pore openings in your skin are 10 microns. As such, an extremely thin nanofiber surface layer on a cartridge filter is capable of capturing submicron particles.

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Depending on the cartridge filter manufacturer, a very fine nanofiber layer will be between 0.3 and 1 micron thick and be placed over a cellulose substrate that is typically 0.016 in. thick. This is equivalent to placing one sheet of copy paper (nano layer) on top of 900 to 1000 sheets of copy paper (substrate).
Comparing Filter Options

The three main types of standard cartridge filters are cellulose, cellulose blended with a synthetic fiber (referred to as blended cellulose), and cellulose filters with a nanofiber layer. Some cellulose and blended cellulose filters consist of one homogenous layer of media. These filters are true depth-loading filters. As air moves through the filter, particulate becomes embedded deep within the filter, restricting airflow and shortening filter life.

Some cellulose or blended cellulose filters currently on the market have an outer layer of melt-blown fibers added to increase the filter's efficiency and life. The principle is the same as adding a nanofiber layer — to provide more surface loading so the filter is easier to pulse clean. The difference is in the diameter of meltblown fibers vs. nanofibers and the depth of the layer.

Melt-blown fiber diameters measure around 10 microns — Fig. 2. Nanofiber diameters can be more than 100 times thinner, ranging from 0.07 to 0.15 micron. These very thin synthetic fibers are produced using an innovative electrostatic process. The tiny openings are efficient in filtering particles less than 1 micron from the contaminated air stream.

The layer of melt-blown fibers is about 100 times thicker than a nanofiber layer — Fig. 3. Because nanofiber is effective at capturing the smallest weld fume particles, only a very thin coating, about 0.1 to 0.5 micron thick, is needed. A meltblown layer is about 50 microns thick. This added thickness traps dust particles that are difficult to dislodge during the cleaning cycle.

Pore size distribution is another difference between melt-blown and nanofiber layers. In a melt-blown layer, fibers of varying sizes entangle and overlap. This entanglement creates pores up to 40 microns in diameter throughout the deep layer. Nanofibers create small pores in uniform size on the filter surface. This feature minimizes penetration of particulate into the substrate, lowering pressure drop and extending filter life.

Nanofiber Technology Fits OSHA Regulations

The nanofiber cartridge filter layer prevents almost all submicron particulate from penetrating through and into the substrate. The initial filter efficiency is 99.999% on 0.5-micron particulate. Weld fume is typically 0.3 to 0.7 micron in size. An efficiency of 99.999% will yield a discharge of 0.252245 micrograms/m3, which is significantly better than the required 5 micrograms/m3 required for welding on stainless steel and the generation of hexavalent chromium (Cr(VI)) fumes. The use of nanofiber filtration makes it possible to achieve these results on a consistent, repeatable basis. Non-nanofiber filter cartridges are unable efficiently to capture submicron contaminate. They allow much of the fine particulate to pass through the filter and back into the air.

Longer Filter Life Equals Fewer Filter Replacements

Cellulose and blended cellulose filters range in price from $50 to $75 per cartridge. Filters using a nanofiber layer are in the $100-$110 range. While a lower initial purchase price may seem attractive, the savings change when you factor in the costs are shown in Table 2. The calculation was based on a collector running 4160 h/yr at 19,000 ft3/min.

Table 1 — Cost Comparison for One Year

<table>
<thead>
<tr>
<th>Filter Type</th>
<th>80/20 Cellulose Blend</th>
<th>Cellulose w/Nanofiber</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchase Price per Cartridge (approx. list price)</td>
<td>$65</td>
<td>$105</td>
</tr>
<tr>
<td>Filter Life</td>
<td>6 months</td>
<td>12 months</td>
</tr>
<tr>
<td>Filter Changes/yr</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Total Purchase Cost</td>
<td>$4160</td>
<td>$3360</td>
</tr>
</tbody>
</table>

Table 2

Table 2 — Pressure Drop Comparison

<table>
<thead>
<tr>
<th>Filter Type</th>
<th>Average of 4160 h/yr at 19,000 ft3/min.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melt-blown Fiber</td>
<td>0.85 h/yr</td>
</tr>
<tr>
<td>Nanofiber</td>
<td>0.52 h/yr</td>
</tr>
</tbody>
</table>

Maintaining a Balance

The ideal filter media maintains filtering efficiency while increasing its permeability. The more permeable, or porous, a filter is, the easier it is to pull air through the filter. In industry terms, there is less of a pressure drop. This translates to a smaller blower and less horsepower requirements, providing an energy cost savings.

The idea of efficiently filtering out microscopic particles while being as permeable as possible may sound like a contradiction. Historically, filter manufacturers have struggled with this balance. Some make the media pore sizes smaller to increase efficiencies, but this results in a higher pressure drop. Others add a meltblown layer to a cellulose substrate. The smaller pore sizes of the melt-blown layer increase efficiency, but adds additional depth to the media, restricts air flow, and increases pressure drop.

A nanofiber surface layer provides high filtering efficiency. The nanofiber coating does all the work, so the substrate's purpose is primarily structural. That substrate can be highly permeable, resulting in the perfect combination of the lowest possible pressure drop with the highest possible filtering efficiency.

With a reduced pressure drop, the nanofiber system can use a smaller fan, reducing electrical costs. An example of the costs are shown in Table 2. The calculations were based on a collector running 4160 h/yr and energy costs of 11 cents/kWh (2007 prices).
Improved Compressed Air Usage

Compressed air is one of the most expensive utilities in a plant and for an air pollution control system. About eight horsepower of electricity is used to generate one horsepower of compressed air. Over time, the additional usage from a depth loading filter media can add up to substantial cost. If airflow is 20.4 standard ft³/min at six pulses/min, the compressed air cost with a system using a blended cellulose filter would be approximately $1279. For comparison, the compressed air cost for a system using nanofiber would be about $191.

Reduced Workplace Emissions

A nanofiber surface layer removes fine particles from the air and reduces the amount of dust released back into the workplace during the pulse jet cleaning process. When weld fume is pulsed off a filter, the vast majority accumulates in the collection bin. An unavoidable by-product of the pulse jet cleaning process is that a small percentage of the particulate will be released back into the atmosphere. Because a filter with a nanofiber layer pulses less often, total outlet emissions are reduced.

Understanding MERV Ratings

The most commonly used indicator of filter efficiency is the minimum efficiency reporting value (MERV). The higher the MERV rating (1 to 20), the better the filter is at removing particulate, especially very small particulate, from the air. The differences in filtering efficiencies between nanofiber, cellulose, and blended cellulose media were recently determined through independent lab testing.

A new filter with nanofiber technology from United Air Specialists has a MERV 15 rating. This means the filter is at least 85% efficient at capturing particles 0.3 to 1.0 micron, and more than 90% efficient capturing particles 1.0 micron or larger. Efficiencies of a MERV 13 filter drop to 75% for particles 0.3 to 1.0 micron. MERV 10 filters are only rated to capture particles 1.0 micron and larger.

The MERV rating is certified by independent lab tests per the ASHRAE standard 52.2-1999, the most current industry-accepted measurement of filter efficiency and ability to capture submicron particles. These tests are done with “new, out-of-the-box” filters.

While MERV is an accurate measure of efficiency, filters should not be selected on just MERV alone. Other criteria, such as pressure drop, cleanability, compressed air usage, and filter life are important in determining a filter’s total performance and life cycle cost.

The best way to determine filter performance for your welding operation is to consult an expert, test the filters in your equipment, and ask for referrals from others in your industry.

Total Savings

The total cost of using a cartridge filter with nanofiber layer is shown in Table 3. The example is based on using a 32-cartridge system operating for 4160 h/yr at 19,000 ft³/min.

<table>
<thead>
<tr>
<th>Table 2 — Comparison of Energy Costs for One Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cartridge Filter</td>
</tr>
<tr>
<td>Airflow ACFM</td>
</tr>
<tr>
<td>Operating Delta P</td>
</tr>
<tr>
<td>Motor HP</td>
</tr>
<tr>
<td>Brake HP</td>
</tr>
<tr>
<td>Annual Energy Use</td>
</tr>
</tbody>
</table>

Note: Based on collector running 4160 h/yr and energy costs of 11 cents/kWh (2007 prices)

<table>
<thead>
<tr>
<th>Table 3 — Total Life Cycle Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchase Cost of Filters</td>
</tr>
<tr>
<td>Annual Energy Use</td>
</tr>
<tr>
<td>Compressed Air Use</td>
</tr>
<tr>
<td>Total Life Cycle Cost</td>
</tr>
<tr>
<td>Total Savings</td>
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</table>

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Welding clothing has come a long way in the past 40 years. Previously, welders wore the same protective clothing as other trades workers. The mindset was, “If leather is good enough for the blacksmith, it’s good enough for the welder.” Thankfully, those days are gone.

### Importance of Wearing the Appropriate Attire

Steel mills rarely use leather protection anymore unless it is in conjunction with other clothing materials. For secondary protection, new materials are coming to light all the time. Aluminized fabric is common, and many new materials are now used in the welding trade, each requiring special care. It is essential to follow the manufacturer’s care instructions precisely, which vary from garment to garment.

Another big change for welders is recognition of the hazards of electric arc ignition of clothing in the National Fire Protection Association’s standard NFPA 70E, which means that it’s been discovered that there is danger to the wearer, regardless of who is performing the task. This indicates the need for personal protective equipment (PPE) on the job, because welders have been killed operating disconnects and plugging in welding equipment. NFPA 70E requires flame-resistant clothing at a weight of HRC 2 (8 cal/cm²) for such tasks.

Fortunately, this common welding clothing weight increases workers’ safety. The welding arc is of much lower intensity and is more predictable than the arc from the electrical feed. So welders who weren’t previously required to wear flame-resistant (FR) clothing now have to do so while operating disconnects or plugging in welding equipment.

Though some companies are finding engineering methods to reduce potential arc flash energy from connecting welding plugs and operation of disconnects, no arc flash specialist worth his or her salt recommends anything less than daily FR wear. This kind of protective clothing prevents ignition, and in the vast majority of

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**How to Properly Care for Flame-Resistant Garments**

**BY HUGH HOAGLAND**

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Though some companies are finding engineering methods to reduce potential arc flash energy from connecting welding plugs and operation of disconnects, no arc flash specialist worth his or her salt recommends anything less than daily FR wear. This kind of protective clothing prevents ignition, and in the vast majority of

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**HUGH HOAGLAND** (hugh@arcwear.com) tests electric arc clothing and personal protective equipment in his companies ArcWear.com and e-Hazard.com, Louisville, Ky., along with providing training and hazard assessment services. For more information on Walls FR Protective Workwear, Cleburne, Tex., visit www.walls.com or call Sandy Finkelstein at (800) 433-1765.

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the cases, eliminates fatalities and often severe injuries.

Therefore, it’s vitally important to take proper care of these potentially lifesaving garments in order to maintain their protective qualities.

Mark Saner, technical manager for Workrite Uniform Co., said, “Proper care of FR garments is an important part of any FR clothing program. Workrite’s broad range of customers successfully use both home and commercial laundering to clean their FR clothing.”

Another national FR expert, vice president and general manager of Walls FR Workwear, Sandy Finkelstein, notes that the most critical thing for properly cleaning protective clothing is to precisely follow the laundering instructions on the garment. “At Walls, we have done a great deal of research on FR fabric care, and we strive to make sure protective garment instructions are clear and easy to follow,” said Finkelstein.

Rules to Follow for Various Types of Materials

To maintain safety garment integrity, the following general laundering guidelines are recommended, but the best plan is to always follow the manufacturer’s garment care information carefully.

Aluminized Clothing

The heat reflective ability of aluminized clothing can be reduced when the garment is stained or soiled, but can usually be cleaned with a light detergent. (Aluminized PPE is used for high splatter welding, but other materials are becoming more common in the workplace.) Lou Ott of Gentex, a large supplier of aluminized materials, suggests the following to ensure protective qualities of reflective clothing:

- Do not store the garment wet or with any chemical contaminants.
- Store clothing on hangers, with ample hanging space to prevent the fabrics from creasing or cracking. If folded, the folds should be loose on aluminized garments. Do not sit on a folded garment.
- Sponge off dirt and soot by using mild soap and water. Dry aluminum surfaces with a clean dry cloth. Rub gently to avoid removing the aluminum.
- Grease stains can normally be removed with dry cleaning solvents. (Note: Isopropanol or perchloroethylene will react with the metal in proximity suits, and may etch the aluminum surface.) After using solvents, clean the clothing with water and wipe dry. Allow the garment to hang in a ventilated location at room temperature until dry.
- Do not machine wash.

Wool and Wool Blends

Wool and wool blends are the most common materials used in the aluminum industry. A. J. Charnaud, Inc.’s ALuSAFE®, Oasis™ from TenCate (formerly Southern Mills), and PR97™ from Melba Industries are types of fabrics for protection from aluminum. These materials are secondary protection for potential splash or are worn under primary garments, and may be used for welding especially when welders are working in the vicinities of molten aluminum. The garments made from these fabrics are much more comfortable than those of old but do require special care. Unlike most protective garments, it is acceptable to launder wool garments with soap and dry them at lower temperatures.

Leather

While use of leather is still common (in whole or in part), leather has issues regarding comfort and weight. Using leather in high wear areas can make sense, but the individual welder may find better materials depending on the work situation and practices. From an arc- or flame-resistant perspective, the leather should be kept free of oils.

Undergarments

Certain types of undergarments can make a slag incident very dangerous. Newer “wicking” materials melt and are not usually recommended. In fact, they are banned if made of polyester, nylon, acetate, polypropylene, polyethylene, or other melting fibers, unless these materials are arc or flash fire-rated under the American Society for Testing and Materials (ASTM) International’s ASTM F1506, Standard Performance Specification for Flame Resistant Textile Materials for Wearing Apparel for Use by Electrical Workers Exposed to Momentary Electric Arc and Related Thermal Hazards, or NFPA 2112, Standard on Flame-Resistant Garments for Protection of Industrial Personnel Against Flash Fire.

Flame-Resistant Cotton

While flame-resistant cotton has long been a staple of welding clothing, old-fashioned and lower cost cotton today may actually be dangerous. Though they may pass a flame low level flame test, if they do not meet ASTM F1506 or NFPA 2112, they are not guaranteed for the life of the garment and the FR may wash out in as little as 25 washings.

Tips for Cleaning Protective Garments at Home

Sandy Finkelstein of Walls FR offers the following “Dos and Don’ts for Protective Garment Home Laundering,” which concur with the most common recommendations in the industry:

Don’t

- Use fabric softener on FR garments in the washer. (Acts as a fuel.)
- Use fabric softener sheets in the clothes dryer. (Acts as a fuel.)
- Use bleach on FR garments. (Can destroy fabric integrity.)
- Wear garments that are grossly contaminated by oils, paints, solvents, or chemicals that leave a combustible residue on the fabric.
- Apply insect repellents containing DEET to garments. (Acts as a fuel.)
- Apply any chemicals directly to the FR garment, including spray starch.

Do

- Wash FR clothing separate from the home laundry to avoid transferring contaminants or non-FR fibers to the FR garment. This form of hydrocarbon loading may decrease the protective value of the garment. (No documented government study is currently available, but one company’s internal anecdotal research is commonly cited that states protection is reduced by about 3% when FR garments are laundered with non-FR cotton clothing.)
- Use warm water and any liquid or dry detergent that does not contain bleach.
- Dry the garment on medium or low heat.
- Launder the garments when they become visibly contaminated with any grease, oil, hydraulic fluid, petroleum product, paint, or chemical.
- Follow manufacturer’s washing instructions printed on the garment’s label.
- Hang the garment to dry in a well-ventilated area. (Diesel fuel, smoke or oil, hydraulic fluid, petroleum product, paint or chemical. Acts as a fuel.)
- Use fans if necessary.

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Special care by the end user needs to
be exercised when using FR cottons. Most “welding greens” (a common term for FR treated cottons used in welding, often green dyed to avoid worker pilfering) claim flame resistance for 25 washes, but this is a very low level flame resistance. If they meet the previously mentioned standards, they should last for more than 25 washings, but it’s far safer and better to choose something with compliance to 100 washings. Note: “Welding greens” may be appropriate for welding, but not for electric arc and may not comply with NFPA 70E. Check the garment label for an arc rating, which is a good indication they have been properly tested.

FR Cotton/Nylon

Flame-resistant cotton/nylon is commonly referred to as 88/12 blends. Three materials on the market today meet the 100 wash test requirement for flame resistance: Walls FR I tex BanWear; Indura UltraSoft® by Workrite Uniform (and others); and ammonia-free FR material from Milliken Amplitude, also available from Workrite. BanWear and Indura UltraSoft are providers in the steel and many other industries for arc-rated materials that are commonly used for welding clothing, in conjunction with sleeves made of other materials. These blends also need special care.

Initially they cost about 20% more than other materials, but many of these blends have twice the wear life, which is a real savings to the end user.

Carbonized Material Blends

CarbonX®, Carbtx, and other carbonized material blends have the advantage of being flame resistant, arc rated, and a great shedder of most molten metals. Some of these materials are more commonly used in undergarments, but one General Motors job site replaced regular FR cotton coverall sleeves with Carbtx ones sewn on in the place of the cotton. This eliminated the need for wearing extra sleeves over the regular garment. The Carbtx sleeves won an R&D 100 Award and increased worker comfort and compliance, because donning the new coverall means the protective sleeves are always on the worker without the added weight of an oversleeve.

Kevlar® and Twaron® are commonly used in blends for welding clothing but not normally alone, because metal sticks to aramids alone. For welding, most companies avoid Nomex®, Conex, PBI, and other aramid materials, even though they are very flame resistant. Some blends, however, do have unique properties, so consider ones like Lenzing/Twaron, CarbonX/Twaron, Lenzing/Kevlar, Coton/Kevlar, CarbonX/Kevlar, and Carbtx/Kevlar, commonly used in welding materials under name brands like Tuffweld®, CarbonX, and Carbtx. These materials need little special care. Simply follow the ASTM standard mentioned in the next section or the manufacturer’s instructions for laundering and care.

Washing Outfits Correctly

ASTM has long had a standard for industrial laundering of FR garments (initially proposed by the Industrial Laundering Association), and a new universal standard for home laundering is in the final stages. Many users choose an industrial launderer for convenience, ease of use, and peace of mind, but this isn’t always necessary. Flame-resistant or arc-rated garments are normally guaranteed for the life of the garment, and home laundering has been shown to be effective in maintaining the integrity of the garment’s flame and arc resistance.

The proposed Standard Guide for Home Laundering Care and Maintenance of Flame, Thermal and Arc Resistant Clothing will give guidance for home laundering and common advice most workers need to know when home laundering. This standard is facing a final vote in ASTM F23, which is the ruling committee for the industrial laundering standard ASTM F1449 - 08, Standard Guide for Industrial Laundering of Flame, Thermal, and Arc Resistant Clothing.

Employers should consider the National Institute for Occupational Safety and Health (NIOSH) recommendations on clothing soiled with hazardous chemicals at work. Hazardous chemical clothing is usually laundered by the employer; or, if washed at home, is recommended to be laundered separately from the family wash. Some companies choose industrial or on-site laundering to limit liability, and some chemicals are too hazardous to ever take home. The industrial hygiene or safety department makes this determination in most companies. But home laundering is more common than industrial so proper evaluation of the work site soils is critical as well as employee training.

The proposed ASTM Standard Guide for Home Laundering Care and Maintenance of Flame, Thermal and Arc Resistant Clothing will likely be approved in the next round of ASTM meetings, but until this is available, most companies use manufacturer’s recommendations.

Final Point

Following these instructions should give America’s welders the arc and flame resistance they need for safety and extend the life of their garments.
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For Info go to www.aws.org/ad-index
Dirty shop? Slippery floors from accumulation of welding fume? Employees breathing suspected carcinogens? These are only a few of the many good reasons to clean up your shop air.

Cleaner air in the welding shop, manufacturing plant, or thermal spray operation helps operators to avoid breathing injurious fumes, helps prevent hazardous spots on floors, and helps keep surrounding equipment clean and functioning. Collecting fume, removing it from the air, and directing clean air back into the plant is one of the best ways to work toward a cleaner plant. This article discusses three steps toward cleaner plant air.

Capture

Basically, there are two ways to capture welding fume, overspray, dust, and other airborne particulate: ambient collection and source capture.

Ambient Collection

Ambient collection can be successful in maintaining low concentrations of fume, mist, or dust, but it usually is only employed when source capture is not feasible. Ambient collection involves one or more ceiling-mounted fume collectors that clean the surrounding air via filtration then discharge the cleaned air back into the workspace.

The primary advantage of an ambient collection approach is that it is inexpensive; however, there are several disadvantages to this form of capture.

1. Since the circulation of filtered air is above their heads, welders, who are bent over their projects, continue to breathe in a concentration of fume produced during welding.
2. Ambient systems only clean a minimal portion of a room’s volume at any given time. Depending on the airflow, it may take days or weeks to clean and recirculate all of the plant air.
3. Ambient systems are inefficient and incur more energy usage because the system must run constantly to be effective for the volume of plant/room air being treated.

Source Capture

Source capture is the most effective way to capture the largest percentage of weld fume, dust, and mist. This method employs capture hoods positioned properly at the welding area to capture the fume, mist, or dusts. Ducts then carry the fume, mist, or dust away. One or more collectors are used to filter the contaminants from the air so it can be returned to the plant.

Typically, a capture hood is positioned 12–18 in. from the weld area, such that the fume is taken immediately away before passing through the worker’s breathing zone. Hood positioning and the distance from the hood face to the weld are critical. The welder must be diligent in keeping the hood close to the weld to be effective. If the hood is repositioned twice as far from the source, it will take four times the air to provide the same capture performance for the same fume.

In a source capture system, the typical capture velocity at the welding zone is 150 ft/min for low toxicity welding. This low ve-
Fig. 2 — When installing a unit to collect fume from several welding stations, get the proper sized ductwork, collector and fan.

Locity is sufficient to ensure that the fume and smoke particles are captured. For a flanged typical hood with a cross-section area of around 2 ft², the flow requirement would be approximately 1320 ft³/min.

While the initial cost to implement a source capture system is believed to be the primary disadvantage to this capture method, there are several advantages to this method. With the proper hood design and positioning, and with good quality filter media in the collector, high cleaning efficiency can be achieved with little or no accumulation of potentially combustible dust on surrounding surfaces. Also, using one collector for each weld station will lower energy costs because the collector and fan may be turned off when the station is not in use. And, finally, welders will breathe cleaner air because the hood captures the fume before it has an opportunity to get into the welder's breathing zone.

Source capture systems, such as individual weld fume collectors, can be effective with a single fume collector servicing each weld station — Fig. 1. These collectors are typically portable, allowing greater adaptability for different uses. They consist of a compact fume collector with an adjustable arm for optimal positioning above the weld point.

Another approach is to install a larger collector connected to several weld stations (Fig. 2); however, sizing the ducting, collector, and fan to appropriately fit the job is the key. A central system is typically located outdoors with ducts running to each welding station. This allows many users to utilize the same duct collector. Each station will have either rigid ducts with a fixed extraction hood or an adjustable fume arm that can be used to position the extraction hood to increase capture efficiency.

**Carry**

Effectively carrying the fume to the collector is the next step. When removing fume, mist, and dust, “effectively” means having an airflow strong enough to keep airborne particulate moving, so it cannot drop back down the hood or somewhere inside the ductwork.

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**Understanding MERV Ratings**

Since the late 1990s, the minimum efficiency reporting value (MERV) rating system based on ASHRAE Standard 52.2-1999 has been deemed the most accurate scale for determining a cartridge filter’s initial efficiency and ability to filter submicron dust particles. MERV ratings illustrate a filter’s efficiency based on particle size (Fig. 3), whereas previous standards measured efficiency based on particle weight. Why the change in standards? Because the testing equipment has improved and MERV ratings became possible. Modern manufacturers today need advanced filtration technology such as Donaldson Torit’s Ultra-Web® to capture smaller submicron particulate (0.3–1.0 micron). MERV ratings that indicate efficiency based on particle size pinpoint a filter’s efficiency in capturing smaller dust particles with much greater accuracy.

Independent lab tests of Ultra-Web, cellulose, and blended media have revealed differences in the MERV efficiency ratings for the various types of filter media. For instance, Ultra-Web filter media rates at a MERV 13 on the 20-point efficiency scale, and is considered a pre-high-efficiency particulate air (HEPA) media suitable for filtering submicron and larger dust. Typical blended media filters have a lower MERV 10 rating and some cellulosed media filters rate lower at MERV 8 efficiency. This is important because MERV 10 filters are rated to capture dust particles in the 1 to 3 μm size and MERV 8 filters are only rated to capture larger 3–10 μm size particles. Since nearly every application generates some submicron dust, a higher MERV-rated filter provides better assurance that smaller particles are being captured, along with the larger ones. Bottom line — your air is cleaner.

**More MERV May Not Always Be Better**

While MERV 13 meets the efficiency demands of most applications and there is little difference between the efficiency of MERV 13 and MERV 15, some applications do call for higher efficiency. The company makes higher performance filters to meet those demands. However, there should be some caution exercised when choosing a filter with a MERV rating higher than 13. While delivering higher initial efficiency, filters with ratings greater than MERV 13 can have shorter filter life and consume more energy due to higher pressure drop during pulse cleaning. Therefore, the cost savings benefits can be less as filters may need to be replaced more often.

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**The MERV Comparison Table**

![The MERV Comparison Table](Larsen Feature:Layout 1 10/7/08 10:14 AM Page 43)
For typical weld fume applications, where fume enters the duct above the hood, you need to maintain a minimum transport velocity of 2500 ft/min to ensure there is no drop out of fume in the duct.

To ensure adequate airflow is maintained in any system, choose a collector with a fan that exhausts a volume sufficient for all weld stations at once. Begin with this simple formula: $Q = VA$

$Q = VA$ [ft$^3$/min = Velocity x Area]

Example: If you know you need 2000 ft$^3$/min, and you want to maintain 2500 ft/min in your duct, then $2000 \div 2500 = 0.8$ ft$^2$ (12-in. duct).

On the reverse, if you have a 12-in. duct and you want to maintain 2500 ft/min, you have $2500 \times 0.7854 = 1964$ ft$^3$/min.

Work with your dust collector supplier to select an appropriate sized collector. Tables of various ducts are available in the industrial ventilation manual, Ventilation and the American Conference of Governmental Industrial Hygienists, and will be helpful in selecting duct components. Visit www.acgih.org/home.htm for more information.

After installation, check the actual system air flows and record the various static pressures measured at key system points. Then, over time, recheck the static pressures to ensure the system is still functioning properly.

**Contain**

The final key to good containment or fume removal is a high-efficiency filter. The three most commonly used types of filters for weld fume include

- Static filter systems;
- Electrostatic precipitators; or
- Self-cleaning collectors with cylindrical filters.

Static systems simply collect the fume-laden air. These filters are not designed to be cleaned and reused; instead, the dirty filters are simply replaced. Static systems, therefore, rely on low fume levels to allow reasonable filter life.

Electrostatic precipitators (ESPs) work well initially, but the collection efficiency diminishes as dust accumulates on the plates and charging wires prior to cleaning. ESPs can fill up quickly and be hard to clean. It is also worth noting that ESPs must typically be oversized in order to maintain a reasonable efficiency prior to servicing.

Self-cleaning fume collectors with cylindrical filters offer the most performance advantages for the containment/filtration stage. The collector is sized for constant airflow and the cylindrical filter contains ample filter media, which holds high quantities of fume particles. While fume particles are typically small — less than a micrometer ($\mu$m) in size — high efficiency filter media can capture these particles. This type of fume collector is capable of using compressed air to automatically self-clean. The operator just sets a differential pressure switch to activate the cleaning when a preselected differential pressure is reached. The cleaning mechanism runs only when needed.

**In the End**

Welding procedures and metals may produce toxic fume. You want the exhaust air coming out of the fume collector to be as clean as possible, especially if you are retuning the air into your workspace. Remember the three Cs — capture, carry, and contain — to provide a cleaner work environment for increased worker comfort, safety, and productivity.
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COMING EVENTS

ASNT Fall Conf. & Quality Testing Show. Nov. 10–14. Charleston Convention Center, Charleston, S.C. For complete information or to register, visit www.asnt.org/events/conferences/fc08/fc08.htm.


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

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JOM-15, 15th Int'l Conf. on the Joining of Materials, and 6th Int'l Conf. on Education in Welding. May 3–6, 2009, Helsinør, Denmark. Contact JOM Institute, jom_aws@post10.tele.dk.


AeroMat® 2009 Conf. and Expo. June 7–11, 2009. Dayton Convention Center, Dayton, Ohio. Contact ASM Customer Service (800) 336-5152, ext. 0; customerservice@asminternational.org; or visit http://asmcommunity.asminternational.org/content/Events/aeromat09/.


Educational Opportunities


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


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

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EPRI NDE Training Seminars. EPRI offers NDE technical skills training in visual examination, ultrasonic examination, ASME Section XI, and UT operator training. Contact Sherryl Stogner, (704) 547-6174; sstogner@epri.com.
9-Year Recertification Seminar for CWI/SCWI

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<tr>
<th>Location</th>
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For current CWIs and SCWs needing to meet education requirements without taking the exam, if needed, recertification exam can be taken at any site listed under Certified Welding Inspector.

Certified Welding Supervisor (CWS)

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<th>Location</th>
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CWS exams are also given at all CWI exam sites.

Certified Radiographic Interpreter (CRI)

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<td>Miami, FL</td>
<td>Mar. 9-13</td>
<td>Mar. 14</td>
</tr>
<tr>
<td>Indianapolis, IN</td>
<td>Apr. 20-24</td>
<td>Apr. 25</td>
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<tr>
<td>Miami, FL</td>
<td>Jun. 22-26</td>
<td>Jun. 27</td>
</tr>
<tr>
<td>Houston, TX</td>
<td>Jul. 27-31</td>
<td>Aug. 1</td>
</tr>
</tbody>
</table>

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

Certified Welding Educator (CWE)

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

Senior Certified Welding Inspector (SCWI)

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

Code Clinics & Individual Prep Courses

The following workshops are offered at all sites where the CWI seminar is offered (code books not included with individual prep courses): Welding Inspection Technology (general knowledge and prep course for CWI Exam-Part B), and D1.1 and API-1104 Code Clinics (prep courses for CWI Exam-Part C).

On-site Training and Examination

On-site training is available for larger groups or for programs customized to meet specific needs of a company. Call ext. 455 for more information.

International CWI Courses and Exams

AWS training and certification for CWI and other programs are offered in many countries. For international certification program schedules and contact information, please visit http://www.aws.org/certification/international.html

AWS Certification Schedule

Certification Seminars, Code Clinics and Examinations

<table>
<thead>
<tr>
<th>Location</th>
<th>Seminar Dates</th>
<th>Exam Date</th>
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<tbody>
<tr>
<td>Corpus Christi, TX</td>
<td>EXAM ONLY</td>
<td>Nov. 22</td>
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<tr>
<td>Sacramento, CA</td>
<td>Nov. 30-Dec. 5</td>
<td>Dec. 6</td>
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<tr>
<td>Spokane, WA</td>
<td>Nov. 30-Dec. 5</td>
<td>Dec. 6</td>
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<tr>
<td>Syracuse, NY</td>
<td>Nov. 30-Dec. 5</td>
<td>Dec. 6</td>
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<tr>
<td>St. Louis, MO</td>
<td>EXAM ONLY</td>
<td>Dec. 6</td>
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<tr>
<td>Miami, FL</td>
<td>Dec. 7-12</td>
<td>Dec. 13</td>
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<td>Reno, NV</td>
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<td>Jan. 11-16</td>
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<tr>
<td>Jacksonville, FL</td>
<td>EXAM ONLY</td>
<td>Jan. 10-15</td>
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<td>Baltimore, MD</td>
<td>EXAM ONLY</td>
<td>Mar. 31-3</td>
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<tr>
<td>Long Beach, CA</td>
<td>EXAM ONLY</td>
<td>Mar. 31-</td>
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<tr>
<td>Corpus Christi, TX</td>
<td>EXAM ONLY</td>
<td>May 21-26</td>
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<td>Rochester, NY</td>
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<td>Jun. 7-12</td>
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<tr>
<td>Anchorage, AK</td>
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<td>Jun. 7-12</td>
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<tr>
<td>Portland, OR</td>
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<td>Jun. 7-12</td>
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<tr>
<td>Boston, MA</td>
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<td>Jun. 7-12</td>
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<tr>
<td>Phoenix, AZ</td>
<td>EXAM ONLY</td>
<td>Jun. 7-12</td>
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<tr>
<td>York, PA</td>
<td>EXAM ONLY</td>
<td>Jun. 7-12</td>
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</tbody>
</table>

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

Certified Welding Inspector (CWI)

<table>
<thead>
<tr>
<th>Location</th>
<th>Seminar Dates</th>
<th>Exam Date</th>
</tr>
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<tbody>
<tr>
<td>Corpus Christi, TX</td>
<td>EXAM ONLY</td>
<td>Mar. 29-Apr. 3</td>
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<tr>
<td>Sacramento, CA</td>
<td>EXAM ONLY</td>
<td>Mar. 29-Apr. 3</td>
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<tr>
<td>Corpus Christi, TX</td>
<td>EXAM ONLY</td>
<td>Apr. 11</td>
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<td>Spokane, WA</td>
<td>EXAM ONLY</td>
<td>Apr. 13</td>
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<td>Cleveland, OH</td>
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<td>Birmingham, AL</td>
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<td>Apr. 20</td>
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<tr>
<td>York, PA</td>
<td>EXAM ONLY</td>
<td>Apr. 25</td>
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</tbody>
</table>

For information on any of our seminars and certification programs, visit our website at www.aws.org/certification or contact AWS at (800/305) 443-9353, Ext. 273 for Certification and Ext. 455 for Seminars. Please apply early to save Fast Track fees.

This schedule is subject to change without notice. Please verify the dates with the Certification Dept. and confirm your course status before making final travel plans.
Growing Young Welders — Ohio 4-H Style

By Richard Harris, District 10 director

The roots for the AWS Workforce Development program can find nourishment in Ohio 4-H Clubs. The top 9- to 18-year-old welders from the various county competitions struck their arcs at the Ohio State Fair last August to compete for prizes and a chance to represent Ohio for national honors at Purdue University in September.

The Ohio 4-H program started in 1994. Since then, more than 500 4-H members, some with more than five years of experience, have competed at the state level.

“We started the welding program at the club level with shielded metal arc welding,” said Larry Heckendorn, an instructor and 4-H contest coordinator at The Ohio State University (OSU), and past District 7 director. “Our next project manual will cover oxyfuel welding and cutting. Later will come manuals for flux cored, gas metal, and gas tungsten arc welding. We utilize Boy Scouts working on their metallurgy merit badges to test the drafts of our manuals. We want the books technically right, but written so the youth understand the material.”

AWS Sections and welding distributors have actively nurtured the growth of welding in 4-H Clubs throughout Ohio.

“Many of these youth come back to compete multiple years,” said Randall Reeder, P.E., associate professor and extension agricultural engineer at OSU. “Also, younger brothers and sisters continue a family interest in welding. That says a lot about the popularity and value of our 4-H welding program. For example, Kurtis Croft, an age-group winner this year, is the younger brother of a former national welding winner.”

During the contest, participants gain points by demonstrating safe handling, selection, and application of equipment and supplies. All participants make the following welds: a 3-in. double square groove weld, 1-G position, and a 3-in. double fillet weld, 2-F position. They use a shielded metal arc welding (SMAW) power source, 0.025-in.-thick low-carbon steel, and 0.125-in.-diameter E-6011 electrodes.

The contest is divided into two classes: projects larger than a 3 × 6-ft door, and the other for smaller projects. Each class has five age divisions between 9 and 18 years old. The judges select one individual in each class, who is at least 14 years old, to compete at the National 4-H Engineering Challenge in September at Purdue University.

The AWS Columbus Section presented a clock trophy to the top performer from each class. Lincoln Electric Co. donated welding machines and reference books as prizes to the winner from each age category in both classes.

The following 4-H members earned 2008 awards at the Ohio State Fair.

In the Small Project Class Anna Wenning earned the right to represent Ohio in the National 4-H Welding Contest. Matthew Klopfenstein won a clock trophy and a welding machine. The highest scorers in each age group included Nicholas Edinger (9–10); Kurtis Croft (11–12); Jared Bright (13–14); Joshua Robinson (15–16); Adam Brietkrenz (15–16); and Anna Wenning (17–18).

The Outstanding of the Day awards (the top 20% of entries) went to Kurtis Croft, Walker Davenport, Jared Bright, Lonnie Westfall, Jacob Lozano, Joshua Robinson, and Adam Brietkrenz.

In the Large Project Class, Jake Zwayer advanced to the National 4-H Welding Contest. The top welders in each age group and winners of welding machines included Eric Nichols (13–16) and Kayla Luzadder (17–18). The Outstanding of the Day awards went to Kayla Luzadder, Jessica Willet, and Eric Nichols.

Judges, from local schools, weld shops, distributors, Edison Welding Institute, and AWS Sections, critiqued contest weldments, project manuals, project weldments, and optional weldments, plus the answers to ten oral questions on general welding knowledge and materials based on the 4-H SMAW Project Manual.

The event sponsors included Lincoln Electric, Praxair, Airgas, DeLille, Linde, Valley National Gases, Hamilton Tank, Ohio Steel Industries, Central Ohio Welding, Ohio 4-H, and the OSU Department of Food, Agricultural, and Biological Engineering. Praxair provided welding helmets and support supplies and Hamilton Tank donated base metal cut to size.

For more information on 4-H activities, contact Larry Heckendorn or Randall Reeder, The Ohio State University Department of Food, Agricultural and Biological Engineering, (614) 292-1731. For more information and photos, visit www.4engineering.osu.edu.
Tech Topics

New Standards Projects

Development work has begun on the following two revised standards. Directly and materially affected individuals are invited to contribute to their development.


**Standards for Public Review**


AWS was approved as an accredited standards-preparing organization by the American National Standards Institute (ANSI) in 1979. AWS rules, as approved by ANSI, require that all standards be open to public review for comment during the approval process. The above two standards are open for public review until the dates shown. Draft copies may be obtained from Rosalinda O’Neill, ext. 451, roneill@aws.org.

**Standard Approved by ANSI**

- **C1.5:2009, Specification for the Qualification of Resistance Welding Technicians.** Revised standard. Approved 9/16/08.

Technical Committee Meeting


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Member-Get-A-Member Campaign

Shown are the September 18 standings for the 2008–2009 Member-Get-A-Member Campaign. See page 65 of this Welding Journal or visit www.aws.org/mgm for campaign rules and prize lists. If you have any questions regarding your member proponent plans, call the Membership Dept., (800) 443-9353, ext. 480.

**Winner’s Circle**

- **Sponsored 20+ new members.** The superscript indicates the number of times the member has achieved Winner’s Circle status since June 1, 1999.
  - J. Compton, San Fernando Valley
  - E. Exell, Mobile
  - J. Mertzhal, Peru
  - G. Taylor, Pascagoula
  - L. Taylor, Pascagoula
  - B. Mikeska, Houston
  - R. Peasee, Detroit
  - W. Shreve, Fox Valley
  - M. Karagoulis, Detroit
  - S. McGill, NE Tennessee
  - T. Weaver, Johnstown/Altoona
  - G. Woerner, Johnstown/Altoona
  - R. Wray, Nebraska
  - M. Haggard, Inland Empire

**President’s Roundtable**

- Sponsored 9–19 new members. P. Betts, Mobile — 12

**President’s Club**

- Sponsored 3–8 new members.
  - W. Rice, Tri-State — 5
  - J. Compton, San Fernando Valley — 4
  - R. Newman, Maine — 4
  - C. Becker, Northwest — 3
  - R. Ellenbecker — 3
  - M. Rahn, Iowa — 3
  - M. Wheat, Western Carolina — 3

**President’s Honor Roll**

- M. Boyer, Detroit — 2
- B. Donaldson, British Columbia — 2
- F. Hendrix, New Jersey — 2
- R. Johnson, Detroit — 2
- J. Padilla, Cusatuinl Izcalli — 2
- J. Polson, L.A./Inland Empire — 2
- J. Smith, North Texas — 2
- A. Stute, Madison-Beloit — 13
- D. Taylor, Kern — 13
- R. Hutchinson, L.B./Orange Cty. — 12
- R. Evans, Siouxland — 11
- R. Norris, Maine — 9
- J. Boyer, Lancaster — 8
- N. Carlson, Idaho/Montana — 7
- S. MacKenzie, Northern Michigan — 7
- D. Zabel, Southeast Nebraska — 7
- D. Howard, Johnstown-Altoona — 6
- D. Kowalski, Pittsburgh — 6
- J. Reed, Ozark — 5
- C. Schner, Wyoming — 5
- J. Roberts, Sacramento — 4
- D. Vranich, North Florida — 4
- B. Halillia, New Orleans — 3
- D. Hamilton, Chattanooga — 3

**Student Member Sponsors**

- Sponsored 3 or more students.
  - A. Rowe, Philadelphia — 36
  - T. Moore, New Orleans — 32
  - D. Berger, New Orleans — 30
  - B. Benyon, Pittsburgh — 28
  - E. Norman, Ozark — 26
  - D. Schnalzer, Lehigh Valley — 22
  - R. Munns, Utah — 19
  - D. Pickering, Central Arkansas — 17
  - R. Rummel, Central Texas — 13
  - A. Stute, Madison-Beloit — 13
  - D. Taylor, Kern — 13
  - R. Hutchinson, L.B./Orange Cty. — 12
  - R. Evans, Siouxland — 11
  - R. Norris, Maine — 9
  - J. Boyer, Lancaster — 8
  - N. Carlson, Idaho/Montana — 7
  - S. MacKenzie, Northern Michigan — 7
  - D. Zabel, Southeast Nebraska — 7
  - D. Howard, Johnstown-Altoona — 6
  - D. Kowalski, Pittsburgh — 6
  - J. Reed, Ozark — 5
  - C. Schner, Wyoming — 5
  - J. Roberts, Sacramento — 4
  - D. Vranich, North Florida — 4
  - B. Halillia, New Orleans — 3
  - D. Hamilton, Chattanooga — 3

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District Director Awards Announced

The District Director Award program provides a means for District directors to recognize individuals who have contributed their time and outstanding effort to the affairs of their local Sections and/or Districts.

**District 4 Director Roy Lanier** has nominated:
- Robert Simpson, advisor, Rowan-Cabaruss C. C.
- Randy Owens — Carolina
- Kent Coleman — Charlotte

**District 7 Director Don Howard** has nominated:
- Uwe Aschemeyer — Cincinnati
- Ken Colardo — Cincinnati
- George Seese — Johnstown-Altoona
- Joseph Sickles — Johnstown-Altoona
- Todd Parker — Wheeling
- Peter Kinney — Pittsburgh

**District 9 Director George Fairbanks** has nominated:
- William ‘Bill’ New — Morgan City

**District 14 Director Tully Parker** has nominated:
- Mike Anderson — Indiana

**District 21 Director Jack Compton** has nominated:
- Mark Bell — San Diego

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52 NOVEMBER 2008
District 1
Russ Norris, director
(207) 604-9262
rmorris@maine.rr.com

BOSTON
AUGUST 26
Activity: The Section held a board meeting hosted by Chairman Jim Shore. Richard Moody gave the secretary’s report. Gary Hylan reported on the Section’s financial situation, and Bob Lavole presented information on the Section’s upcoming tours. Jack Paige reported on the Section library, and District 1 Director Russ Norris made a presentation on the District 1 conference business. The meeting was held at Artisan Industries in Waltham, Mass.

MAINE
SEPTEMBER 11
Activity: The Section held an executive board meeting at Verrillo’s Restaurant in Portland, Maine. Chair Scott Lee announced the Pipefitters Local #716, Augusta, Maine, will start conducting the SkillsUSA welding testing for the state. Also discussed were the upcoming CWI seminars and tests. Russ Norris, District 1 director, discussed district and national news and details for the Las Vegas welding show. Attending were Mark Legal, Southern Maine C.C.; Joe Champagne and Darren Snodgrass, Pipefitters Local #716; Adam Fallon, Lincoln Electric; Bob Bernier and Fran Piccirillo, Valley National Gas; Scott Lee and Dick Gregoire, Metso Paper; and Jeff Fields, Bath Iron Works.

District 2
Kenneth R. Stockton, director
(908) 412-7099
kenneth.stockton@pseg.com

YORK-CENTRAL PA.
AUGUST 15
Activity: The Section hosted its annual Woody Rowland Memorial Golf Outing at Cool Creek Country Club in Wrightsville, Pa. The event attracted 120 participants. Ed Calaman coordinated the event and recruited golfers and hole sponsors. The first-place winners were Mike Flory, Jim Turner, Art Hendrix, and Mike Smyser.

District 3
Alan J. Badeaux Sr., director
(301) 753-1759
abadeaux@ccboe.com

District 4
Roy C. Lanier, director
(252) 321-4285
rlanier@email.pittcc.edu

Shown at the Boston Section board meeting are Chairman Jim Shore (seated) and (standing, from left) Richard Moody, Gary Hylan, Bob Lavole, Vice Chair Tom Ferri, and Jack Paige.

Shown at the Maine Section program are (seated, from left) Mark Legal, Joe Champagne, Adam Fallon, Bob Bernier, and Scott Lee. Standing, from left, are Dick Gregoire, Fran Piccirillo, Darren Snodgrass, District 1 Director Russ Norris, and Jeff Fields.
Shown at the York-Central Pennsylvania Section golf outing are the first-place team members (from left) Mike Flory, Jim Turner, Art Hendrix, and Mike Smyser.

Shown at the Florida West Coast Section program are Chairman Al Sedory (left) and speaker Dalton Spivey.

Topic: Grinding media used in welding and cutting operations
Activity: The Section raffled off gift cards donated by Home Depot and Lowe’s to raise money for the Section’s scholarship funds. The program was held at Frontier Steakhouse Cattle Co. in Tampa, Fla.

District 6
Neal A. Chapman, director
(315) 349-6960
weldingengineer@inbox.com

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

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

District 9
George D. Fairbanks Jr., director
(225) 473-6362
fits@bellsouth.net

District 9 Conference
JUNE 14
Activity: The New Orleans Section hosted the District 9 conference. George Fairbanks, District 9 director, chaired the meeting. In attendance were officers from the New Orleans, Mobile, Pascagoula, and Baton Rouge Sections.

District 5
Steve Mattson, director
(904) 260-6040
stevemattson@bellsouth.net

FLORIDA WEST COAST
SEPTEMBER 10
Speaker: Dalton Spivey, company sales representative
Affiliation: Saint-Gobain Abrasives

Members of the New Orleans, Mobile, Pascagoula, and Baton Rouge Sections attended the District 9 conference in June.

Florida West Coast Section members and guests are shown at the September meeting.

Sepalor: Grinding media used in welding and cutting operations
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District 7
Don Howard, director
(814) 269-2895
howard@ctc.com

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

District 9
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(225) 473-6362
fits@bellsouth.net

District 9 Conference
JUNE 14
Activity: The New Orleans Section hosted the District 9 conference. George Fairbanks, District 9 director, chaired the meeting. In attendance were officers from the New Orleans, Mobile, Pascagoula, and Baton Rouge Sections.

Mobile
SEPTEMBER 11
Speaker: Jim Hurley, southeast regional
NEW ORLEANS
SEPTEMBER 10
Activity: The Section held its executive board meeting at New Orleans Pipe Trades Local #60. Topics on the agenda included setting meeting dates and sponsors, finalizing the student welding competition arrangements, and planning for the Section’s 11th annual fishing rodeo. In attendance were Matt Howerton, chair; Donald Berger, vice chair; Aldo Duron, secretary; John Pajak, treasurer; Bruce Hallila, Paul Hebert, and Tony Demarco, past chairs; Kenneth Caliva, property chair; and Cris Gotangco, fishing rodeo chairman.

District 10
Richard A. Harris, director
(440) 338-5921
richaharris@alltel.net

Columbiana CCTC Student Chapter
SEPTEMBER
Activity: The Columbiana County Career and Technical Center Student Chapter members elected their slate of officers for the new term. Named were Jake Win- don, chairman; Seth Steele, vice chair; Kia McDevitt and Chelsea Yarwood, treasurers; Paul Parker and Brittany Kanos, secretaries; Pat Buchanan and
Shown are the Columbiana CCTC Student Chapter members in the Level 2 class.

Shown are the Columbiana CCTC Student Chapter members in the adult class.

Shown at the Detroit Section program are (from left) Fronius presenters Wes Doneth, Franz Dietachmair, Stephanie Fratwell, and Gerald Obritzberger with John Bohr.

Dylan Wolford, publicity chairs; Vince Jarvis, member chairman; and Tyler Farmer and Rachel Falk, SkillsUSA representatives.

District 11
Efthios Siradakis, director
(989) 894-4101
ef.siradakis@airgas.com

DETROIT
SEPTEMBER 11
Activity: Fronius USA LLC, Brighton, Mich., hosted the Section’s scholarship awards presentation program for 160 attendees. The Fronius presenters included Stephanie Fratwell, Gerald Obritzberger, and Wes Doneth who discussed the company’s welding equipment advances and solar technology. Section members Don Maltz, Rod Bereznicki, and John Bohr presented the scholarships to John Ribisky, Jason Russel, Leland Kienbaum, Nicholas Schuster, Alan Kirchhoff, Tom West, Travis Woiderski, Isaiah Scott, Nathan Gladsmith, Cody Decker, Amanda Rhei, Tom Bartolomucci, Steve Bieniek, Eric Koster, Mike Fitzpatrick, Charlie Mauris, Bryan DeCorte, Randi Gelisse, Hjoshua Dittmar, Jared Nevel, James Marden, Rod Bereznicki, John Bohr, Steven Hart, T. J. Bradley, Ryan Mulcahy, and Brian Peterson. In attendance were Jeff Hardesty, Ferris State University (FSU) professor; Jeff Carney, advisor to the FSU AWS Student Chapter; and Section Chair Mike Karagoulis. Highlights of the program included demonstrations of the company’s Delta spot welding, tandem welding, plasma cold wire welding, and a new GMA process, cold metal transfer welding, for use with steel and aluminum.

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

LAKESHORE
SEPTEMBER 12
Speaker: Lynn Mead, regional applications consultant
Affiliation: Praxair
Topic: Controlling welding fumes
Activity: The dinner and meeting were held at Redekers Rustic Inn in Kellnersville, Wis.

MADISON-BELOIT
SEPTEMBER 17
Speakers: Bruce Halvorson, QA manager, Marinette Marine Corp; and John Hinrichs, VP technology, Friction Stir Link, Inc.
Topic: Friction stir welding applications
Activity: The program was held at the Coliseum Bar in Madison, Wis., with Chair Ben Newcomb presiding. Attending were Jim Harrison, program chair and technical representative; Jim Pfeil, membership chair; Bill Dawson, treasurer; Dan Gibbs, publicity chair; Mark Prosser, Burt Wheeler, Willie Pietrizick, Larry Bower, and Dave Burrow.

MILWAUKEE
SEPTEMBER 18
Activity: The Section members met at Miller Park for a behind-the-scenes tour of the construction of the unique fan-shaped retractable roof. The project employed 165 welders who clocked 74,000 welding hours. Randy Bruch, president of Steelwind Industries, a major contractor for erecting the roof, led the tour. Assisting Bruch were Steelwind VP Jason Geiger; Sam Hall, fabrication manager; Jim Potter, senior estimator/sales; Scott Howard, sales; and Yahya Elnatour, purchasing/project manager.

UPPER PENINSULA
SEPTEMBER 3
Activity: The Section executive board members held a planning meeting to set the calendar for the new year. Tom Topper was presented the Private Sector Educator Award.

SEPTEMBER 16
Activity: The Upper Peninsula Section members toured Cruisers Yacht Co. in Marinette, Wis., to study the manufacture of its Cruisers and Rampage lines. Included was the fabrication of aluminum fuel tanks, stainless steel deck rails, and numerous other parts along with the fabrication and outfitting of the hulls.

CHICAGO
AUGUST 17
Activity: Technical Chairman Craig Tichelar hosted the Section’s AWS Safari to the Brookfield Zoo for 51 attendees. Chairman Hank Sima presented Tichelar with a plaque in appreciation for his services as chairman.

AUGUST 20
Activity: The Chicago Section held a board meeting at Bohemian Crystal Restaurant in Westmont, Ill., to discuss District conference topics, new members for the board, treasurer’s report, and plans for the next season’s programs. Attending were Chairman Hank Sima,
Vicky Landorf, Marty Vondra, Pete Host, Cliff Iftimie, and Eric Krauss.

SEPTEMBER 10
Activity: The Chicago Section members held its program at Nelson Stud Welding in Bridgeview, Ill. Jon Sues presented a talk then conducted a tour of the facility.

Illinois Central College Student Chapter
APRIL 18
Activity: The Peoria Section’s Student Chapter participated in the Illinois State SkillsUSA welding contest held in Springfield, Ill. Tom Campen, a Student Chapter member, won the college class gold medal, a plaque, plus a check from the James F. Lincoln Arc Welding Foundation to help defray his expenses to attend the national welding contest in Kansas City, Mo. Eric Ockerhausen is advisor for the Student Chapter.

Shown during the Chicago Section’s Brookfield Zoo outing are (from left) Craig Tichelaar, Chair Hank Sima, Treasurer Marty Vondra, Bob Zimny, and Jeff Stanczak.

Shown at the August Chicago Section board meeting are (seated) Vicky Landorf and Marty Vondra. Standing (from left) are Pete Host, Chairman Hank Sima, Cliff Iftimie, and Eric Krauss.

Shown at the Chicago Section September program are (from left) Pete Host, Don Merker, Scott Alison, Keith Zeilenga, John Kotrba, speaker Jon Sues and Chair Hank Sima.

Speaker Jon Sues (left) is shown with Hank Sima, Chicago Section chairman, at the September program held at Nelson Stud Welding.

Tom Campen displays the gold medal, plaque, and check he earned by taking first place in the college class Illinois State SkillsUSA welding competition.

District 14
Tully C. Parker, director
(618) 667-7795
tparke@millerwelds.com

District 15
Mace V. Harris, director
(612) 861-3870
macevh@aol.com

District 16
David Landon, director
(641) 621-7476
dlandon@vermeermfg.com
The Iowa Section members studied the manufacture of row crop planters during their tour of Kinze Manufacturing in September.

Shown are some of the attendees at the North Texas Section program.

IOWA
SEPTEMBER 9
Activity: The Section members toured Kinze Manufacturing, Inc., in Williamsburg, Iowa, to study the construction of large row crop planting machines and grain auger wagons that can handle 1050 bushels.

NEBRASKA
SEPTEMBER 11
Speaker: Barry Blessing
Affiliation: Midwest Laboratories, Inc.
Topic: The company's steel X-ray system
Activity: The program was held at Midwest Laboratories in Omaha, Neb., a provider of analytical services for agriculture, environmental, feed, and fuel projects. Following the talk, Blessing demonstrated the inspection equipment.

District 17
J. J. Jones, director
(940) 368-3130
jjones@thermadyne.com

NORTH TEXAS
SEPTEMBER 16
Speaker: Tim Ulnski, regional manager
Affiliation: Wolf Robotics
Topic: Welding heavy, thick metal parts
Activity: More than 110 people attended this program, held at Humperdinks in Arlington, Tex., Miller Electric provided the door prizes.

Tim Ulnski (left) receives a speaker appreciation gift from Rob Tessier, North Texas Section chairman.

Shown at the Nebraska Section program are (from left) Chair Karl Fogleman, speaker Barry Blessing, and Monty Rodgers.
Shown at the Puget Sound Section program are Vice Chair Ken Johnson (center) with speakers Joe Mackin (left) and Tom Twedt.

SPOKANE
September 13
Activity: The Section hosted its third annual golf tournament at Deer Park Golf Course in Deer Park, Wash. Eleven four-member teams participated in the event that was followed by a luncheon and presentation of door prizes. The Oxarc team, Ryan and Dave Baranowitz, Tyson Martin, and Greg Mann, took first-place honors.

District 20
William A. Komlos, director
(801) 560-2353
bkoz@arctechllc.com

District 21
Jack D. Compton, director
(661) 362-3218
jack.compton@canyons.edu

LONG BEACH/ORANGE COUNTY
September 18
Speaker: Andy Foster
Affiliation: Oxygen Services Co.
Shown at the San Francisco Section program are (from left) Dale Flood, District 22 director; Section Chair Liisa Pine; and speaker Gene Lawson, AWS president.

San Francisco past chairs included (from left) Tom Smeltzer, Richard Hashimoto, Andre Lopez, Sharon Jones, Dale Phillips, and Doug Williams.

San Francisco Section Chair Liisa Pine and speaker Gene Lawson, AWS president, along with other attendees.

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

FRESNO
April 12
Activity: The Section hosted the SkillsUSA competition at Ironworkers Local 155 in Fresno, Calif., with Robert Fain, training coordinator, serving as facilitator. About 50 contestants participated with a dozen judges evaluating their work on blueprint reading, brazing, cutting, and welding. Fain dubbed Shawn Perkins with the nickname Rosie the Riveter in honor of the contributions women have made to the construction industry.

SAN FRANCISCO
September 3
Speaker: Gene Lawson, AWS president
Affiliation: ESAB Welding Products

Activity: The American Welding Society (AWS) technical committees are made up of individuals just like you. They come from a wide array of industries, backgrounds, areas of experience, and education. Committee members are motivated to participate by a desire to contribute to the body of technical information which has provided professional expertise, authority, and stability to the welding industry through AWS since the year 1919.

These Technical Committees are integral to the welding industry. The committee members produce nationally recognized standards industry including the D1.1, Structural Welding Code — Steel, B2.1 standard on welding procedure and performance qualification, the A5 filler metal specifications, and about 200 other standards that require periodic review.

For example, the D10K Subcommittee on Welding of Titanium Piping seeks volunteers to assist in the revision of D10.6, Recommended Practices for the Gas Tungsten Arc Welding of Titanium Piping and Tubing. Contact Brian McGrath, (800) 443-9353, ext. 311; bmcgrath@aws.org.

The G2C Subcommittee on Nickel Alloys is currently seeking volunteers to assist in the development of G2.1, Recommended Practices for the Joining of Wrought Nickel-Base Alloys. Contact Stephen Borrero, (800) 443-9353, ext. 334, sborrero@aws.org.

Find out more about how you can get involved and contribute your knowledge to AWS Technical Committee activities at www.aws.org/technical, or call the AWS Technical Department at (800) 443-9353, ext. 340, and ask to speak to someone about joining a technical committee. At the Web site you can view a complete list of the Technical Committees to assist you in matching your interests with an appropriate committee.

Experience What Technical Committee Membership Can Do for You
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England OilField Services, Inc.
265 Windy-Lynn Rd.
England, AR 72046
www.englandoil.com
Representative: Jason Dickson
England OilField Services, Inc., utilizes both time-tested and cutting-edge methods and techniques to meet the needs of a rapidly growing customer base in the fabrication industry. Its specialties are meeting client demands for quality and on-time delivery with a down home feel and competitive pricing.

Affiliate Companies
Aceros Prefabricados S.A.
Section 8336, PO Box 02-5289
Doral, FL 33102
Alta Tecnologia en PND S.A. de C.V.
Nahuatlacas MZ 82 L-12 BLS
Col Ajusco Deleg Coyoacan
Mexico City, D.F. 04300, Mexico
Constructora Cima Cia., Ltd.
Urb Balcon Del Norte #111
AV Occidental Y Diego Vasquez
Quito Pichincha, Ecuador
EEI Corporation
12 Mangahan St. Bgy, Bagumbayan Libis
Quezon City 1110, Philippines
J & M Hardware & Locksmiths, Inc.
19 E. 21st St., New York, NY 10010
Metro Steel and Pipe
932 E. Main St., Leesburg, FL 34748
Promaquina S.A. de C.V.
Ave. Miguel Aleman 300
Col Nova Apodaca Nuevo Leon
66605, Mexico

Supporting Companies
ECKA Granules of America
500 Prosperity Dr.
Orangeburg, SC 29115
E. K. Machine Co., Inc.
671 S. Main
Fall River, WI 53932
M-Tech (Multi Technology) Pvt. Ltd.
22 Km. Off Ferozepur Rd.
Lahore, Punjab 54176, Pakistan
Quell Industrial Services
615 Elm St.
Portland, TX 78374
Welco Services, Inc.
1426 13th Ave.
McPherson, KS 67460

Educational Institutions
A. C. Jones
1902 N. Adams
Beeville, TX 78102
Bill Priest Institute
1402 Corinth St.
Dallas, TX 75215
Holbrook H. S.
1008 8th Ave.
Holbrook, AZ 86025
North Point H. S. for Science, Technology & Industry
2500 Davis Rd.
Waldorf, MD 20603

Membership Counts

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<tr>
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<td>Educational</td>
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<tr>
<td>Student + transitional members</td>
<td>4,744</td>
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<tr>
<td>Total members</td>
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Submit Your Choice for the Robotic Welding Award

December 31 is the deadline for submitting nominations for the 2009 Robotic and Automatic Arc Welding Award. The award includes a plaque and a $1500 honorarium. The nomination packet should include a summary statement of the candidate’s accomplishments, interests, educational background, professional experience, publications, honors, and awards. Send your nomination package to Wendy Sue Reeve, awards coordinator, 550 NW LeJeune Rd., Miami, FL 33126. For more information, contact Reeve at wreeve@aws.org, or call (800/305) 443-9353, ext. 293.

In 2004, the AWS D16 Robotic and Automatic Arc Welding Committee, with the approval of the AWS Board of Directors, established the Robotic and Automatic Arc Welding Award.

The award was created to recognize individuals for their significant achievements in the area of robotic arc welding. This work can include the introduction of new technologies, establishment of the proper infrastructure (training, service, etc.) to enable success, and any other activity that has significantly improved the state of a company and/or industry.

The Robotic Arc Welding Award is funded by private contributions. This award is presented at a special ceremony during the FABTECH International & AWS Welding Show held each fall.
Nominees for National Office

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

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

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

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

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

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

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

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

E-mail the letter to Gricelda Manalich, gricelda@aws.org, c/o Gerald D. Uttrachi, chair, National Nominating Committee.

The next meeting of the National Nominating Committee is scheduled for October 2008. The terms of office for candidates nominated at this meeting will commence January 1, 2010.

Honorary Meritorious Awards

The Honorary-Meritorious Awards Committee makes recommendations for the nominees presented for Honorary Membership, National Meritorious Certificate, William Irrgang Memorial, and the George E. Willis Awards. These awards are presented during the FABTECH International & AWS Welding Show held each fall. The deadline for submissions is December 31 prior to the year of awards presentations. Send candidate materials to Wendy Sue Reeve, secretary, Honorary Meritorious Awards Committee, wreeve@aws.org; 550 NW LeJeune Rd., Miami, FL 33126. Descriptions of the awards follow.

William Irrgang Memorial Award is awarded each year to the individual who has done the most over the past five years to enhance the American Welding Society’s goal of advancing the science and technology of welding.

This award consists of a $2500 honorarium and a certificate. It is presented during the FABTECH International & AWS Welding Show held each fall. The award is administered by the American Welding Society and sponsored by The Lincoln Electric Co. to honor the late William Irrgang.

George E. Willis Award is awarded each year to an individual who promotes the advancement of welding internationally by fostering cooperative participation in areas such as technology transfer, standards rationalization, and promotion of industrial goodwill.

The award consists of a $2500 honorarium and a certificate. It is presented during the FABTECH International & AWS Welding Show held each fall. The award is administered by the American Welding Society and sponsored by The Lincoln Electric Co. to honor George E. Willis.

Honorary Membership Award is presented to a person of acknowledged eminence in the welding profession, or who is accredited with exceptional accomplishments in the development of the welding art, upon whom the American Welding Society sees fit to confer an honorary distinction. Honorary Members have full rights of membership.

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

International Meritorious Certificate Award is given in recognition of significant contributions to the welding industry for service to the international welding community in the broadest terms. The awardee is not required to be an AWS member. Multiple awards may be given. The award consists of a certificate and a one-year AWS membership.

AWS Publications Sales

Purchase AWS standards, books, and other publications from World Engineering Xchange (WEX), Ltd. orders@awspubs.com; www.awspubs.com Toll-free (888) 935-3464 (U.S., Canada) (305) 824-1177; FAX (305) 826-6195

Welding Journal Reprints

Copies of Welding Journal articles may be purchased from Ruben Lara.

(800/305) 443-9353, ext. 288; rlarua@aws.org

Custom reprints of Welding Journal articles, in quantities of 100 or more, may be purchased from
FosteReprints
Claudia Stuchowiak
Reprint Marketing Manager
866-879-9144, ext. 121
claudia@foste-reprints.com

AWS Foundation

AWS Foundation, Inc., is a not-for-profit corporation established to provide support for educational and scientific endeavors of the American Welding Society. Information on gift-giving programs is available upon request.

Chairman, Board of Trustees
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Director, Solutions Opportunity Squad
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550 NW LeJeune Rd., Miami, FL 33126
(305) 445-6628; (800) 443-9353, ext. 293

General Information:
(800) 443-9353, ext. 688; vpinsky@aws.org

AWS Mission Statement

The mission of the American Welding Society is to advance the science, technology, and application of welding and allied processes, including joining, brazing, soldering, cutting, and thermal spraying.

It is the intent of the American Welding Society to build AWS to the highest quality standards possible. The Society welcomes your suggestions. Please contact any staff member or AWS President Gene E. Lawson, as listed on the previous page.
JOIN FORCES WITH 54,000 OTHER INDUSTRY PROFESSIONALS
FOR CAREER ADVANCEMENT, MEMBERS’-ONLY DISCOUNTS, NETWORKING OPPORTUNITIES, UP-TO-DATE INFORMATION, EDUCATIONAL ADVANCEMENT, PROFESSIONAL DEVELOPMENT, AWARD-WINNING INDUSTRY PERIODICALS, PUBLICATIONS, TECHNICAL RESOURCES, CERTIFICATION PROGRAMS AND THE OPPORTUNITY TO BE PART OF THE INDUSTRY’S PREMIER MEMBERSHIP ORGANIZATION.

...AND THAT’S JUST THE BEGINNING.

American Welding Society
Since 1919, the American Welding Society (AWS) has been a multifaceted, nonprofit organization with a goal to advance the science, technology and application of welding and related joining disciplines. From factory floor to high-rise construction, from military weaponry to home products, AWS continues to lead the way in supporting welding education and technology development to ensure a strong competitive and exciting way of life for the world.

JOIN TODAY BY CALLING 800-443-9353, EXT. 480 OR ON-LINE AT WWW.AWS.ORG
Metals & Alloys UNS Book Updated with New Features

The 11th edition of Metals & Alloys in the Unified Numbering System (UNS) is available as a 600-page, soft-cover, 8½ × 11-in. book or online. New features include 4500 new trade names and seven new fields of chemical element search capabilities for the online version. Included are more than 5000 UNS numbers, 11,800 trade names and alloy designations, and 13,300 specification cross references. The UNS provides a means of correlating many internationally used metal and alloy numbering systems currently administered by societies, trade associations, and individual users and producers of metals and alloys. The book can help users achieve the necessary uniformity for efficient indexing, record keeping, data storage and retrieval, and cross referencing. The specifications referenced include those from AWS, AA, ASME, ASTM, CDA, ISO, NACE, and SAE. The prices are $195 for the book, $390 for the online version, and $495 for both editions purchased at the same time.

ASTM International
www.astm.org
(610) 832-9585

Full Line of Flap Discs Detailed in Brochure

A 24-page, full-color brochure illustrates and describes the company’s Polifan® flap discs featuring high stock-removal rates with superior surface finish, PS-Forte universal line for general purpose trade and industrial use, and the SG-Elastic performance line for professional trade and industrial applications. Also pictured are the Combidisc® Mini-Polifans in 2- and 3-in. diameters that grind faster and last longer than regular coated discs, and Polivic® nonwoven abrasive flap discs for fine grinding, cleaning, and finishing stainless steel parts. More than 200 different flap discs are presented in a selection of sizes, grains, grits, and arbor hole versions. Provided are guides for selecting the most cost-effective product for particular applications, various product selection charts, and safety information. The PDF brochure can be downloaded from the company’s Web site.

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

SAW Products Pictured

A new catalog features the company’s complete lines of submerged arc welding equipment, wire, and fluxes. Shown are fused, bonded, active, and neutral fluxes and a wide range of wires and bands for welding and hardfacing in carbon steel and stainless steel. Extensive information is provided on how to select the correct wire and flux for specific applications.

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

Products for a Cleaner and Safer Workplace Pictured

Viewable online, the Pigalog® Web catalog features 474, full-color, well-illustrated pages of products for controlling routine and emergency industrial leaks and spills plus a wide variety of personal safety clothing and industrial equipment. A comprehensive index simplifies finding the products of interest. Items pictured include a wide variety of absorbent pads, mats, cloths, adjustable retaining dykes, and products for containing oil, machine drips, caustics, biohazards, acids, water, and other industrial fluids safely. Shown are rain suits, boot covers, glasses, face shields, respirators, hearing protection, lighting, fall-protection harnesses and lifelines, drench showers,

Book Explains How to Read Weld Shop Drawings

The 180-page, hard-cover book, How to Read Shop Drawings, serves as an introductory text for students and employees new to manufacturing with specific attention to welding. Described as a comprehensive overview of how to read and interpret industry shop drawings, the book discusses how each shop drawing is read and illustrates the shapes, sizes, and parts of an object, as well as how those parts will fit together. The main points of discussion include three-viewed drawings, drawing to scale, auxiliary views, weld joints, and welding symbols. The book, priced at $10, may be ordered online.

James F. Lincoln Arc Welding Foundation
www.jflf.org
(216) 481-8100

NEW LITERATURE

Full Line of Flap Discs Pictured

A 24-page, full-color brochure illustrates and describes the company’s Polifan® flap discs featuring high stock-removal rates with superior surface finish, PS-Forte universal line for general purpose trade and industrial use, and the SG-Elastic performance line for professional trade and industrial applications. Also pictured are the Combidisc® Mini-Polifans in 2- and 3-in. diameters that grind faster and last longer than regular coated discs, and Polivic® nonwoven abrasive flap discs for fine grinding, cleaning, and finishing stainless steel parts. More than 200 different flap discs are presented in a selection of sizes, grains, grits, and arbor hole versions. Provided are guides for selecting the most cost-effective product for particular applications, various product selection charts, and safety information. The PDF brochure can be downloaded from the company’s Web site.

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eyewash stations, and additional products too numerous to mention.

New Pig
www.newpig.com
(800) 468-4647

Lifting Magnets Pictured

How to Choose and Use Lifting Magnets is a 24-page brochure designed to assist industry professionals in selecting the most appropriate lifting magnet to meet specific application requirements. A comprehensive overview of the topic is presented using text, pictures, diagrams, and charts to guide the reader in selecting the right lifting magnet to make quick work of steel handling.

Eriez®
www.eriez.com
(888) 300-3743

Guide Assists Compliance with D1.8 Seismic Code

The D1.8 Seismic Supplement Welding Manual provides a user-friendly general overview of the AWS D1.8, Structural Welding Code — Steel Seismic Supplement, and specifically addresses welded connection details, materials selection, and testing, fabrication, and workmanship and inspection issues. The manual also discusses welding-related requirements for buildings designed to resist seismically induced loads and includes updates to Seismic Provisions made by the American Institute of Steel Construction as well as new standards for welding-related requirements developed by the American Welding Society’s D1 Structural Welding Committee and D1L Subcommittee. The manual was written in part by Duane Miller, first vice chair, AWS D1 Structural Welding committee, and chair, Seismic Welding Subcommittee. Call to request a copy.

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

Hi-Tech Gas Detector Described in Brochure

A four-page, full-color brochure highlights the company’s new XD single gas detector featuring rugged, portable construction with IP66/67 rating, data logging and docking, automatic test, and a calibration system, plus a wide range of user-selectable options. The units are designed to detect H2S, CO, O2, PH3, Cl2, NH3, and HCN. Designed to withstand the most adverse conditions, the literature details how the units warn of the gas hazards present using a liquid crystal display.

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

Welding Electrodes Detailed in Catalog

An 88-page catalog provides detailed information on more than 150 welding electrode products including descriptions, classifications, shielding gases, welding positions, characteristics, typical mechanical properties, typical deposit compositions, and applications. Products include flux cored and metal cored carbon-steel, low-alloy, stainless steel, nickel alloy, and hard-facing welding electrodes. The well-organized table of contents makes it easy to find the products desired. Included is information on a comprehensive line of tubular welding electrodes including electrode compatibility charts, welding parameters, agency approvals, and packaging options. The catalog can be viewed and downloaded from the Web site.

Select-Arc, Inc.
www.select-arc.com
(800) 341-5215

Welding Supplies Featured in Master Catalog

A full-service distributor of maintenance, repair, operating, and production supplies has released its master catalog featuring a welding section and 4200 new products added to its regularly stocked inventory. The catalog is offered free to distributors in the transportation, manufacturing, government, and natural resources markets. Call for a copy of the catalog, or visit the Web site to learn more about the company’s operations.

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For info go to www.aws.org/ad-index
Koike Aronson Names VP

Koike Aronson/Ransome, Inc., Arcade, N.Y., a supplier of cutting and positioning equipment for the metalworking industry, has named Stephen R. Morris executive vice president of operations. Previously, Morris served the company as operations manager.

Parlec Appoints VP

Parlec, Inc., Rochester, N.Y., a provider of CNC tooling, work holding, and presetting solutions, has named James Pierce vice president of operations. Pierce has more than 20 years of experience with manufacturing companies in the Rochester area.

UltraFit Taps Sales VP

UltraFit Manufacturing, Mississauga, Ont., Canada, a supplier of complex, custom-bent tubular products for the automotive, medical devices, furniture, and recreational products industries, has named Tim Creasy vice president — sales and marketing. Creasy previously served in senior positions at Beltraine Solutions, the precision machined parts industry, and the in-
One of the most discussed topics and sources of misunderstanding involves joining dissimilar materials by welding. Vendors probably receive more phone calls with questions on this subject than any other. The traditional welding codes are nearly silent on the issue. Many companies do not have—or have lost—expertise in this area. The most difficult-to-weld challenges—including various material combinations involving aluminum, creep-enhanced ferritic steels, nickel alloys, titanium, copper, ceramics, and more—will be covered. New chemistries are coming to the aid of existing filler metals, making them more amenable to dissimilar metals welding. Advances in ultrasonic and laser brazing, projection and consumable bit resistance welding, friction stir welding, hot-wire GTAW, controlled short-circuit transfer GMAW, explosion welding, and magnetic pulse welding will also be discussed in terms of their successful application to the joining of dissimilar materials.

Joining Dissimilar Metals Conference
Orlando, Florida / March 3–4, 2009

To register or to receive a descriptive brochure, call (800) 443-9353 ext. 455, (outside North America, call 305-443-9353), or visit www.aws.org/conferences
PROFESSIONAL PROGRAM ABSTRACT SUBMITTAL
Annual FABTECH International & AWS Welding Show
Chicago, IL – November 15-18, 2009

Submission Deadline: March 13, 2009
(Complete a separate submittal for each paper to be presented.)

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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.

☐ Check the category that best applies:

☐ Technical/Research Oriented  ☐ Applied Technology  ☐ Education

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

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

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

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

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

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

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

Return this form, completed on both sides, to
AWS Education Services
Professional Program 2009
550 NW LeJeune Road
Miami FL 33126
FAX 305-648-1655

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Underwater Welder Training from an Engineer’s Prospective

This first-hand account of an intensive ten-day underwater wet welding program details the skills learned ranging from theoretical preparation to testing of welds

BY UWE ASCHEMEIER

My adventures in underwater wet welding began with a phone call. The American Welding Society had been asked to find a speaker to talk about underwater welding for a German Welding Society (DVS) seminar, so I called Kevin Peters, president of Miami Diver, Inc., Miami, Fla.

While discussing the possibilities of a joint talk with him, he asked, “Why don’t you come down here to Miami and participate in our Hydroweld wet welding training program?” I agreed right away.

As a welding engineer trained in Germany, I went through an apprenticeship program and I learned how to weld. So, I believed, it shouldn’t be too difficult for me to weld underwater. On top of this, working also as a commercial diver I thought it should really be a walk in the park. Having dived in all kinds of environments, from potable water to sewage, I viewed this opportunity as just taking my welding skills to a familiar underwater environment.

What Miami Diver Dedicates Itself To

A member of the Subsea Solutions Alliance, Miami Diver specializes in underwater ship services offering repair and maintenance solutions worldwide. Trained service personnel with specialized equipment perform maintenance and highly specialized repairs underwater on predominantly floating structures anywhere in the world. These structures include merchant, naval, and passenger vessels, semisubmersibles, Floating Production, Storage and Offloading (FPSO)/Floating Storage and Offloading unit (FSO), and barges.

In order to retain their position as a world leader in the field of underwater ship services, the company recognizes the need to maintain a highly skilled, competent workforce. It has a policy to ensure its personnel are provided with the latest,
state-of-the-art training opportunities, including specialist training in underwater shaft seal replacement, propeller straightening, and underwater welding.

**The Basics of Educating Welder Divers**

The modular courses offered by Hydroweld last for ten days and are intended to train commercial divers to the standard required to pass a Welder Performance Qualification (WPQ) to AWS D3.6M:1999, *Specification for Underwater Welding*, to Class ‘B’ welds and, where applicable, to Miami Diver Class ‘A’ procedures. The WPQ is witnessed by Lloyds Register (LR), which also issues the certification. Lloyds Register is a major classification society, and certification issued by them is generally accepted by other classification societies worldwide.

The course objective is to train welder divers who are serious about pursuing a career in wet welding or who wish to improve on their current wet welding capabilities and gain a recognized wet welding qualification.

Established in 1987, in West Midlands, Great Britain, Hydroweld develops wet welding consumables, processes, and techniques, and training programs as well as consultancy, personnel, and services with the aim of significantly improving the quality and reputation of wet welding. The modular nature of the courses is in recognition of the time required to develop the wet welding skills in each position and/or joint configuration. With wet welding predominantly completed in the vertical or overhead position, modules one and two concentrate on these positions and lead on to more difficult positions such as 5F pipe to plate and further to butt joint/groove welds.

The courses systematically guide students through various tasks designed to improve their wet welding skills and provide a sound foundation for subsequent tasks. With the philosophy that ‘practice makes perfect’ and with some guidance, the courses have a realistic time frame in order for even some of the less naturally capable students to succeed. However, it is not an attendance course and students are subject to failure should they not meet the standard. Student numbers are limited to ensure maximum water time is achieved.

While no previous underwater welding experience is necessary, an understanding of topside welding, both theoretical and practical, is a significant advantage to any student wishing to enroll. This knowledge helps the student progress more rapidly though the courses and increases the likelihood of satisfactorily completing the welder performance coupons to the standard required by AWS D3.6M:1999.

The courses are open to both individual commercial divers and diving contractors. Commercial diving contractors who wish to sponsor a number of welder divers on a project-specific wet welding course are welcome to discuss their individual requirements. These requirements may also include the development and qualification of welding procedures in addition to the qualification of wet welders to the specific welding procedures.

**Identifying Four Weld Classes**

The AWS D3.6, *Specification for Underwater Welding*, was first published in 1983 to establish a standard reflecting state-of-the-art technology relative to underwater welding and to provide those with a requirement for underwater welding a choice of weld quality, on a fitness-for-purpose basis. As with all AWS/ANSI documents, the specification is revised on a regular basis (approximately every five years) to keep up with modern technology. The AWS D3.6 specification sets out four classes of welds identified as A, B, C, or O. These classes are broadly defined as follows:

- **Class ‘A’ welds**, which are intended to be comparable with above-water welds by virtue of specifying comparable properties and testing requirements.
- **Class ‘B’ welds**, which are intended for less critical applications where lower ductility, greater porosity, and larger discontinuities can be tolerated.
- **Class ‘C’ welds**, which are intended for applications where load bearing is not a primary consideration and that satisfy lesser requirements than Class A, B, and O.
- **Class ‘O’ welds**, which must also meet the requirements of another code or specification.

The AWS D3.6 specification details a list of essential variables, which are addressed and recorded during the development of the welding procedures. These variables take into consideration the joint configuration, base metal, filler metal, position, weldment temperature, electrical characteristics, technique, and environment — Fig. 1. The specification also details the nondestructive and destructive procedures required to qualify welds to the standard.
Wet welding is often seen as a poor relation of conventional dry welding with some justification. Although wet welding can produce results to Class 'A' surface quality welds, the process is discredited by diving contractors unfamiliar with the technology taking on projects, including ship repairs, that frequently result in unacceptable weld defects and, in some cases, weld failure. This failure or unacceptability is then seen by clients who then are subsequently reluctant to accept wet welding for anything other than noncritical, temporary repairs.

**Advantages of Underwater Wet Welding**

It is with the above in mind that we can turn to the importance of wet welder training and certification. In today's world with an ever-increasing requirement for traceability, quality assurance, and quality control, it should be possible to virtually eliminate or at least minimize the risk of unacceptable wet welding. In the offshore oil and gas industry, generally there is always a requirement for proof of competency, training, and qualification, yet in the shipping industry it is often a case of whoever is available at the time the work needs to be performed.

Underwater wet welding for repairing large structures submerged in the sea is often much more economical than the alternative of building a hyperbaric containment structure around the weld locations in order to perform welding in a dry environment.

The wet welding process is the most versatile, cost effective, and widely used method of repairing and modifying steel structures underwater. The process is used extensively in the offshore oil and gas industry, for applications such as replacement and modifications to structural members, strengthening project and new installations. Most of this wet welding is subject to class approval and generally requires the qualification of wet welding procedures and welder qualifications. In civil engineering, permanent repairs and strengthening of structural piles on bridges and jetties as well as dock walls are also completed using the wet welding process.

**Day-by-Day Details of the Program**

The class took place in Miami in February at the corporate office of Miami Diver. Hydroweld shares part of the facilities: a classroom, shop area to prepare test specimens, and the heart of the training facility, a 35,000-gal training tank — Fig. 2. The 20-ft-diameter tank provides three workstations, allowing three divers to weld at one time. The instructor can watch and critique each welder through an observation window of about 1 ft in diameter at each welding station. He can communicate with each welder through a head set and microphone.

Students learn to master coupon preparation and wet welding in the 3F (vertical fillet weld) position in the controlled environment.

The program is scheduled for 10 days. I thought, “Ten days … who needs ten days to learn how to weld two pieces of steel together with a fillet weld in the vertical position?” After the program was over, I completely understood the need for ten days. There were nine wet welders-to-be in the class from such places as the United States, Canada, and the Caribbean.

The first day we got familiar with the facility and equipment, and received extensive theoretical training in underwater wet welding. The instructor, Michael Pett, taught us the theory of welding underwater, including introductions to the equipment, safety aspects, and underwater welding techniques.

The second day the nine welders rotated in groups of three: One group welded underwater, one group operated the communications stations, and one group prepared the weld specimens — Fig. 3. Every two and a half to three hours the rotation was switched, which is one reason for the ten days, since each welder only practices underwater up to three hours per day. Any longer, student concentration drops off and, in some cases, cold sets in.

The first task was to weld beads on plate — first just stringer beads, then a pad across the plate. This relatively simple task enabled students to familiarize themselves with the setup underwater, to deposit a considerable number of welding electrodes, and provide the instructor with a guide to the general capability of each student.

On the third day, the task was to weld fillet welds 12 in. long on a ¼-in.-thick cruciform specimen (see lead photo). During my 30 years in the welding field, I have firmly held to the rule that vertical welding on structural steel is performed in an upward progression. With some exception, such as the root on pipes, sheet metal, or to repair undercut on welds on structural steel, you never weld downward. I had to learn that it is opposite un-
derwater and that travel speed is different. When welding downhill topside (as in nonstructural applications), you generally have to weld quickly to be ahead of the weld pool; underwater, travel speed is much slower due to the rapid cooling of the slag and weld metal. Just about everything is more critical and precise underwater — the heat generated by the arc is more constricted and every movement of the electrode, such as a wobble, will be seen in the finished weld. Travel speed is critical as is electrode angle and bead positioning.

First we learned how to weld the root pass on the cruciform, which was a big challenge for me. It seemed for the first few days in the tank I was unable to accomplish the given task; mastering control over the tip of the electrode was difficult resulting in incomplete side wall fusion, cavities in the weld, and burning more holes than depositing weld metal into the joint. Initially the amperage for a ⅜-in.-diameter shielded metal arc welding (SMAW) rod was 150 A.

I continued to practice welding the root pass with a ⅛-in.-diameter rod into ¼-in. material. While the other welders were making progress, I was not. On the fourth day, those who mastered the amperage of 150 A and were producing constant acceptable welds had their amperage increased to 160 A. I was still producing holes in my welds though.

On the fifth day, for those who mastered the increased root amperage, they started to weld a second and third pass. I still stuck with my root pass.

Pett was very patient with me. He put on his headset with his microphone, watching me the entire time through the observation window, and never gave up on me.

The sixth day was basically the same as the other days, increasing the amps on root and cover passes for those who mastered the previous parameters and were producing constant acceptable welds. But not me. Pett even had a stool in front of my observation window at this point — Fig. 4.

The seventh day, Pett took me into the welding booth where we produced the samples, and I demonstrated to him that I can produce a sound specimen in the dry — Fig. 5. We discovered that the problem was my vision. Since there is limited room in the diving hat for glasses, we usually don’t dive with glasses, but use cheater lenses on the outside of the hat attached to the weld lens holder. We decided to jerry-rig my glasses and wear them in the diving hat. Problem solved. When the rotation reached me for welding underwater, I was able to control the pool and to produce satisfactory root and cover passes. I felt much better than I had the days before.

The eighth day I caught up with the divers using ½-in. cruciform plates and increased the amperage for the root pass to 175 A and for the cover passes 150 A. The ninth day we increased the amperage again, this time to 180 A, and left the capping runs the same at 150 A.

The tenth day was test day — Figs. 6, 7. We had about one hour of practice time in the tank to weld the test specimen according to AWS D3.6, Fig. 5.8 (⅛-in. fillet weld, ⅛-in.-thick material, 12 in. long). The test was witnessed by Lloyds Register. After welding the specimen, I came out of the water and presented it to Pett and the inspector from Lloyds. They didn’t seem too impressed with my welding skills. After discussions, they agreed to accept it visually, but the break test results caused me to fail due to incomplete root penetration. I had to go back in the water. The second run proved to be much more successful. I remembered the tips Pett had given me the previous days, and I applied them during the test. This time the results were satisfactory for the visual and break test. The macros showed very deep penetration with no defects.

Concluding Thoughts

Now I understand why the training is scheduled for ten days. To produce AWS D3.6 Class ‘B’ welds underwater is not as easy as it seems. It requires the welder to adopt new welding techniques and to be very patient. The ten days of the course also makes sense, since each welder has only 2.5 to 3 hours of practice time each day in the tank.

Acknowledgment

As a welding engineer and a commercial diver, this was a very challenging and educational experience. I am very grateful for all the help Michael Pett provided me and the invitation from Kevin Peters to be a part of this wonderful opportunity. I hope I will get the call one day to put my newly acquired skills to work.
Ohio State Engineering Students Take on the Moonbuggy Challenge

The tight design constrictions imposed on the designers of the original Moonbuggy forced the students to explore novel construction techniques

BY SARA CANALE, MIKE WISE, AND NICK BALZER

The Great Moonbuggy Race, held at the U.S. Space & Rocket Center in Huntsville, Ala., has been an engineering competition for the past 15 years.

The competition challenges teams of students to design and build a lunar terrain navigation vehicle that addresses a series of engineering criteria similar to the problems faced by the original Moonbuggy design team.

In addition, this competition makes physical demands on the team members during the competition. The team mustfully assemble their Moonbuggy then pedal it through a 0.7-mile simulated lunar terrain course in the shortest possible time. The design challenge represents the best technical approach toward engineering a Moonbuggy that can navigate the lunar terrain course.

This year was the first year for The Ohio State University (OSU) Engineering Department to enter a Moonbuggy vehicle — Fig. 1. The ten-member team consisted entirely of currently enrolled welding engineering students. The Moonbuggy's components were designed and constructed by students, with assistance from the College of Engineering's Industrial Systems and Engineering Machine Shop and Ripley Metal Works. This year's Moonbuggy was funded by sponsorship from Acute Technological Services, Inc., and John Deere.

The contest rules require that the Moonbuggy must carry two drivers, one male and one female, and no body part of either passenger may be closer than 15 inches to the ground. The vehicle must also be able to navigate through 17 obstacles including rugged moon-like craters, rocks, lava ridges, and inclines. Also, the vehicle must be equipped with the following features: a simulated TV camera, simulated high-gain antenna, two simulated batteries, fenders over each wheel, simulated electronic controls, and the national or a school flag.

In order to successfully complete the course, several systems had to be utilized. There were specific demanding requirements for the Moonbuggy. The most challenging is that the entire vehicle must fold up into a $4\times4\times4$-ft box with all of its parts attached. Moreover, the Moonbuggy must be hand carried 20 ft, so components must be lightweight and versatile.

The first step was the construction of the frame — Fig. 2. The material selected for the frame was 4130 chrome-moly tubing with 0.028- to 0.035-in. wall thicknesses, chosen for its superior strength-to-weight ratio. The frame consisted of an 8-ft-long triangular frame supported by four OSU laser cut bulkheads, one at each end, and two in the center — Fig. 3.

In order to fit inside the 4-ft cube, the frame needed to fold at the center; which was achieved by constructing a hinge utilizing the two internal bulkheads. The frame was welded by several members of the team using the manual gas tungsten arc (GTA) process with ER70S-2 filler metal. To assure good fitup, the tubes were all hand notched using a hole saw, angle grinder, or die grinder to yield a fit with a very small root opening. Next was construction of the drivetrain and suspension.

Power was supplied to both the front and rear wheels via independently powered chain-driven systems. Both systems consisted of a set of pedals, a seven-speed internal shifting hub, and a variable-length driveshaft to compensate for the
excessive flexing of the suspension. The driveshaft was made by taking two different pieces of square tubing that were of different sizes. They were assembled so that one slides into the other, providing the needed movement. The front drivetrain also included dual disc brakes, a custom differential, and a hinging pedal mount.

The pedal mount was made using a piece of tubing and fabricating a gusset system that allows for the tube to hinge and fold flat against the frame, while providing enough strength for the rider to pedal with full force.

The final part of the drivetrain was computer-aided designed, billet machined, 6061-T6 aluminum bearing carriers. The front bearing carriers also acted as a steering knuckle, which allowed for easy steering alignment.

The front drivetrain was challenging to assemble due to the large number of components in the limited amount of space.

The final weld on the driveshaft was an out-of-position circumferential GTA weld between a 5/8-in. solid bar and a thick-walled U-joint.

The weld was achieved by having a team member actually spin the driveshaft while the GTA torch was held steady; all while trying not to heat the driveshaft enough to melt the bearing seals.

The four-wheel independent suspension allowed for excellent wheel travel, which kept the aggressive mountain bike tires gripping over the extreme obstacles and turns. Last were seats and steering.

The seats were also custom made because the seat backs needed to fold flush against the frame in order to fit inside the 4-ft box. The seat backs were constructed using two parallel tubes spaced 15 in. apart, wrapped in duck cloth material (similar to a director’s chair). Steering consisted of two custom-fabricated rotating handles, a go-cart rack-and-pinion system, and adjustable tie rods.

The Moonbuggy utilized some off-the-shelf parts that were modified to fit the desired application. However, most of the buggy was fabricated from scratch. This includes the frame, suspension control arms, and all of the drivetrain mounting.

The ten-student OSU engineering team (Fig. 4) was presented with the Pit Crew Award for ingenuity and persistence in overcoming problems during the race after cutting ten minutes off their final time between trials. The team also earned the 2008 Rookie Award for the fastest course completion time among newcomers, finishing the course in 8 min, 36 s.
Bauer Fabrication, located in Waterbury, Vt., has been using wire arc thermal spray as an enhanced finishing technique on various fabrication projects for many years — Fig. 1. It is useful for corrosion protection on exterior items such as railings and stairs where normal maintenance coatings are difficult to apply and ineffective without extensive surface preparation. Zinc is applied to a sandblasted substrate that is then top coated with primer and paint. While not all jobs can justify this added expense, many customers are seeing that the benefit of this process will save them from the unsightly corrosion and rusting that inevitably attacks carbon steel, along with the cost of maintenance painting that they would otherwise pay.

Perhaps a more important use of thermal spray as an adjunct to architectural fabrication is coating a less-expensive material such as carbon steel with copper or bronze to achieve corrosion protection and a large improvement in appearance. The process follows essentially the same steps as in coating with zinc with the exception of using primer and paint as a topcoat. Here, the metal sprayed surface is sanded to smooth and highlight the details, treated with a chemical patina to darken or color it, and sealed with a clear topcoat that penetrates the sprayed layer and preserves the desired effect. In this case, customers can perceive a higher value in the

**Novel Thermal Spray Technique Plants the Seed of Artistic Creativity**

*Artwork from murals to sculptures can be produced more quickly using a recently patented method*

**BY ERIC C. BAUER**

Bauer Fabrication, located in Waterbury, Vt., has been using wire arc thermal spray as an enhanced finishing technique on various fabrication projects for many years — Fig. 1. It is useful for corrosion protection on exterior items such as railings and stairs where normal maintenance coatings are difficult to apply and ineffective without extensive surface preparation. Zinc is applied to a sandblasted substrate that is then top coated with primer and paint. While not all jobs can justify this added expense, many customers are seeing that the benefit of this process will save them from the unsightly corrosion and rusting that inevitably attacks carbon steel, along with the cost of maintenance painting that they would otherwise pay.

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**ERIC C. BAUER** (ecb@bauerfab.com) is founder of Bauer Fabrication, Waterbury, Vt. Visit www.bauerfab.com.

**Fig. 1 — Thermal spraying taking place for a recent project.**

**Fig. 2 — The artist’s model, full size (about 3 ft tall), is carved out of white Styrofoam. The material is easy to shape and was adequate for this project, although it doesn’t take the shape in fine detail and is heat sensitive.**

**Fig. 3 — This is a mandrel or structural skeleton made slightly smaller than the foam model. It consists of stainless steel and has an integral base plate so the finished piece can be bolted down. The seed pod skin will be attached to this mandrel using the spray process.**
end product and are happy to get a bronze railing for a less than solid bronze price.

The benefit to the fabricator goes even further because it can use the large selection of available carbon steel shapes and sizes as well as ease of welding and machining to an advantage. For instance, bronze-coated large steel newel posts can be mixed with solid bronze bar balusters to get a great effect. The textures of these two materials will differ and that difference can also be used to advantage.

**Inventing an Innovative Approach: Bauer Art Metal**

Bauer Fabrication developed a new process, Bauer Art Metal (BAM), for which it recently received a U.S. patent. This process involves thermal spraying any metal onto wire mesh to build free-standing objects. It is being used to fabricate items ranging from bronze fountain bowls, art murals, tiles and signage, to large outdoor sculptures and memorials. The BAM process compares favorably to traditional foundry methods in both cost and production time; and, when combined with other fabrication techniques, offers a fresh approach to designing metalwork.

**The Steps of Making a Bronze Seed Figure**

The construction at a large university of an outdoor sculpture designed by Vermont artist Kathryn Lipke-Vigessa is detailed in a sequence of photos. Part of her commission was a large bronze seed in three segments, into the center of which was to be planted a live tree.

Her patterns were carved out of block Styrofoam — Fig. 2. The three separate segments needed to be secured to the ground and supported. A stainless steel skeleton was made for each of the different seed segments that served as a structure for the shell as well as a base plate for anchoring — Fig. 3. Copper mesh was shaped to the pattern on both the front and back halves — Fig. 4A, B. The mesh is easily formed by hand and can be cut and joined to accommodate almost any contour. Each half is then sprayed with zinc to solidify the shape taken from the model. The openings in the mesh readily accept the sprayed zinc, and the mesh becomes encapsulated when sprayed from both sides, lending great strength to the shell. The front and back sections are assembled and sprayed together onto the stainless steel skeleton. Minor grinding makes the seams disappear. The final shape is then sprayed with silicon bronze and highlighted by sanding and polishing — Fig. 5. The bronze surface is treated with a chemical patina to the desired color and sealed with a wax or other topcoat. The completed three seed sections are pictured in Fig. 6.

This whole sequence was completed in less time and at about half the cost of traditional foundry casting.

**Future Prospects**

The BAM process, when used in combination with the other traditional techniques, offers a new approach to fabricating. Bauer Fabrication is utilizing this in its work to achieve a different look and greatly expanded design possibilities.
Oxyfuel Gas Cutting of Steel

Oxyfuel gas cutting is widely used for the severing of carbon and low-alloy steel as well as other iron alloys and some nonferrous metals such as titanium. It is not generally applicable for cutting stainless steels, high-alloy steels, nickel, or cast iron because these metals do not readily oxidize and provide the degree of heat needed to sustain the cutting operation.

Alloying elements have two possible effects on oxyfuel gas cutting of steel. They may make the steel more difficult to cut, or they may give rise to hardened or heat-checked cut surfaces, or both. The effects of alloying elements are summarized in Table 14.3.

When steel is cut with the oxygen jet, a large quantity of heat energy is liberated in the kerf. The depth of the heat-affected zone depends on the carbon and alloy contents, thickness of the base metal, and cutting speed employed. Hardening of the heat-affected zones of steels containing up to 0.25% carbon is not critical in the thicknesses usually cut. Higher carbon steels and some alloy steels are hardened to a degree that the thickness may become critical. Typical depths of the heat-affected zones in oxygen-cut steel are shown in Table 14.4. For most applications, the affected metal need not be removed; however, if it is removed, removal should be by mechanical means.

Table 14.3 — Effect of Alloying Elements on the Resistance of Steel to Oxyfuel Gas Cutting

<table>
<thead>
<tr>
<th>Element</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>Steels up to 0.25% carbon can be cut without difficulty. Steels with a higher carbon should be preheated to prevent hardening and cracking. Graphite and cementite (Fe₃C) are detrimental, but cast irons containing up to 4% carbon can be cut using special techniques.</td>
</tr>
<tr>
<td>Manganese</td>
<td>Steels containing approximately 14% manganese and 1.5% carbon are difficult to cut and should be preheated for best results.</td>
</tr>
<tr>
<td>Silicon</td>
<td>Silicon, in the amounts usually present, has no effect. Transformer irons containing as much as 4% silicon are cut. Silicon steel containing large amounts of carbon and manganese must be carefully preheated and post-annealed to avoid air hardening and possible surface fissures.</td>
</tr>
<tr>
<td>Chromium</td>
<td>Steels with up to 5% chromium are cut without difficulty when the surface is clean. Higher chromium steels, such as 10% chromium steels, require special techniques (see the section “Oxidation-Resistant Steels”), and the cuts are rough when the usual oxyacetylene cutting process is used. In general, carburizing preheat flames are desirable when cutting this type of steel. In addition, the flux cutting and metal powder cutting process enable to be made in the common straight chromium irons and steels as well as in stainless steel.</td>
</tr>
<tr>
<td>Nickel</td>
<td>Steels containing up to 3% nickel may be cut using the conventional oxyfuel gas cutting processes; cuts are satisfactory in steels up to about 7% nickel content.</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>This element affects cutting about the same as chromium. Aircraft-quality chrome-molybdenum steel presents no difficulty. High molybdenum-tungsten steels, however, may be cut only with special techniques.</td>
</tr>
<tr>
<td>Tungsten</td>
<td>The usual alloys with up to 14% tungsten may be readily cut, but cutting is difficult with a higher percentage of tungsten. The limit is approximately 20% tungsten.</td>
</tr>
<tr>
<td>Copper</td>
<td>Copper has no effect in amounts up to about 2%.</td>
</tr>
<tr>
<td>Aluminum</td>
<td>The effect of aluminum is not appreciable unless present in large amounts (on the order of 10%).</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>This element has no effect in the amounts usually tolerated in steel.</td>
</tr>
<tr>
<td>Sulfur</td>
<td>Small amounts such as are present in steels have no effect. With higher percentages of sulfur, the rate of cutting is reduced and sulfur dioxide fumes are noticeable.</td>
</tr>
<tr>
<td>Vanadium</td>
<td>In the amounts usually found in steels, this alloy may improve rather than interfere with cutting.</td>
</tr>
</tbody>
</table>

Table 14.4 — Approximate Depths of Heat-Affected Zones in Steels Cut with Oxyfuel Gas Cutting*

<table>
<thead>
<tr>
<th>Steel Thickness</th>
<th>Low-Carbon Steels</th>
<th>High-Carbon Steels</th>
</tr>
</thead>
<tbody>
<tr>
<td>mm</td>
<td>mm</td>
<td>mm</td>
</tr>
<tr>
<td>Under 13</td>
<td>Under 0.8</td>
<td>0.8</td>
</tr>
<tr>
<td>13</td>
<td>1.32</td>
<td>0.8 to 1.6</td>
</tr>
<tr>
<td>152</td>
<td>3.2</td>
<td>3.2 to 6.4</td>
</tr>
</tbody>
</table>

*The depth of the fully hardened zone is considerably less than the depth of the heat-affected zone.

San Jacinto College, accredited by the Commission on Colleges of the Southern Association of Colleges and Schools to award the associate degree, serves the East Harris County (Houston area), Tex. At the heart of the San Jacinto College learning experience are its three campuses, located to provide easy access for all local citizens. Each campus is staffed with highly qualified instructors who present college-transfer courses, job-preparation courses in technical fields, continuing education courses, and numerous programs designed to meet the needs of the day and evening students (Fig. 1).

The Welding Education Faculty

San Jacinto College Central and North Campuses employ three full-time and about 11 adjunct welding instructors for approximately 450 welding students each semester. Each instructor has a minimum of three years full-time welding experience while most have more than 15.

Bryan Suarez (Fig. 2), Central Campus Welding Department chairman, explained why he entered the welding education field, “When I first started teaching part-time, I was welding at a full-time job during the day and teaching at night. I quickly realized the rewards of teaching when one of my students came to me and said, ‘Thank you for taking the time to help me.’”

“Since that time,” Suarez said, “Many other students have come in, either during class or after completing classes, to inform me of their new welding careers. The satisfaction I received from hearing them describe the impact San Jacinto’s education had on their lives is why I have maintained a position in teaching.

“One reason that San Jacinto College has maintained its reputation for being a high-quality welding educational facility is from the instructor’s knowledge and their passions for teaching,” he said.

Chad Phillips, adjunct welding instructor at the Central Campus, said, “While teaching welding is the goal of the welding department, it’s building character that is the primary goal of education.”

Eddie Foster, North Campus Department chairman, has spent 18 years welding in industry. His time spent “under the hood” has enabled him to gain valuable knowledge in the petrochemical field as a combination welder. “I enjoy teaching,” Foster said, “to pass on the knowledge that was gathered through my years of experience.”

The caring leadership of the instructors at San Jacinto College has enabled them to mentor students both during class and outside of class. Tiburcio Parras III (Fig. 2), full-time Central Campus instructor, often receives calls from past students that he has mentored over the last nine years of teaching. Many students come by or contact him for welding information or to discuss how much he has impacted their lives. “I look at each and every student as not an individual but who is behind them to see them succeed. It’s not just the individual but the wife, kids, or family that they will be providing for,” commented Tiburcio. “My greatest satisfaction is to see them succeed in life.”

Welding Educational Offerings

The San Jacinto College Welding Department is geared toward developing the skills of students with little or no experience in welding to where they can fulfill their career choice by earning a certificate or degree in welding. With the increase in welding employment opportunities in the Houston area that offer attractive salaries, more and more people are choosing welding as a successful and rewarding career.

The college offers a two-year Associate of Applied Science (AAS) degree program, as well as one-year Certificate of Technology and occupational certificate options. Students who earn a welding technology AAS degree will receive introductory, advanced, and high-technology skills in welding theory and methods. The college’s AAS program offers a versatile curriculum for all individuals seeking a career in manufacturing, industry or research in related welding professions. Certificates are offered in structural welding, SMAW pipe welding, and combination welding for trainees.

HOWARD M. WOODWARD (woodward@aws.org) is associate editor for the Welding Journal.
seeking certification in the least amount of time. Welding Technology — Sheet Metal is a 504 contact hour continuing education certificate program offered at the college’s North Campus.

The graduation rate of San Jacinto College Welding Technology students participating in either the AAS program or a certificate program has been consistently high. Job placement after graduation is generally at or near 100%.

San Jacinto College offers specific training “exit points” for those students seeking skills in the welding field. With four certificate options and an Associates of Applied Science degree, its course offerings can meet every welder’s training need.

The Structural Welder Certificate is the college’s entry-level program. The courses include Introduction to Shielded Metal Arc Welding (SMAW), Advanced Shielded Metal Arc Welding (SMAW) and any other welding classes, for a total of 15 semester hours equivalent to 384 contact hours. A student may complete this certificate in one semester if he/she comes to college full time. While this is the shortest term for becoming a welder, the demand for a structural welder is not high as demands for other classifications of welders.

The college offers two additional certificates for intermediate-level welder training to include Shielded Arc Certificate includes Introduction to Gas Tungsten Arc Welding (GTAW), Advanced GTAW, Advanced GTAW Stainless Steel, and Introduction to Gas Metal Arc Welding (GMAW). This certificate can be used to obtain positions as GTAW or GMA welders on both plate and pipe (Fig. 3).

The college’s most sought after credential is the Combination Pipe Welder Certificate. It includes four SMA and two GTA welding courses. A person who is enrolled full-time should be able to complete this certificate during two long semesters. Combination welder skills are the preferred welder qualifications throughout industry because they can be certified in the two most common processes, SMAW and GTAW, on both plate and pipe. Even when welding jobs are scarce, which will not be anytime soon, companies are always looking for qualified combination welders to meet any need in an industrial application.

Students who graduate from the program will be skilled and have a good understanding of the related and technical information associated with welding. Graduates should be qualified to pass entry-level certification tests as required by industry.

Each of the certificates is connected. A student who completes the Structural Welder Certificate courses, will only need one additional class — Advanced Pipe — to achieve the SMA Pipe Welder certificate. Students who achieve this certificate only need two additional classes to complete the combination certificate. In other words, achieving the combination certificate also includes the other two.

Students who complete a degree in welding technology can transfer, through an articulation agreement with the University of Houston (main campus) for a B.S. degree in Technology, Leadership and Supervision.

Facilities

San Jacinto College Central has one of the largest welding facilities in Texas. It features 112 welding booths housed in two buildings. The first building includes eight Miller Mark VIII welding machines which service 64 welders, each of which are strictly used for the SMA welding process. Within the 64 booths, remote rheostats are installed to allow each welder to change his/her amperage without stepping out of the booth. The other building houses an additional 48 welding booths which include four Miller Mark VIII machines (32 machines total). The 32 booths, which also feature remote rheostats, are used strictly for the GTA welding process. An additional 16 welding booths include 16 Miller XMT350, multiprocess machines. These machines
are suitable for GTA, SMA, GMA, or FCA welding. Generally, however, these machines are primarily used for the GTAW process due to the high demand by students wishing to become combination welders. Facilities are available for teaching oxyfuel welding and cutting and other related operations — Fig. 5.

**High School Student Opportunities**

San Jacinto College offers a dual-credit welding program in partnership with the local high school. This arrangement allows high school students to attend college classes at night to receive both college credit and high school credit at the same time. There is no cost to the students for tuition for these classes, however, students are required to purchase needed supplies for classes in which they enroll. Some students are able to complete a certificate in welding at the same time they receive their high school diploma.

San Jacinto College also works with the Construction Maintenance and Education Foundation (CMEF) which is a training arm to the Associated Builders and Contractors of Greater Houston (ABC). This foundation sets aside scholarship funds for current high school technical students that allows these students to attend college-level welding classes for a fee of only $25 per class. This opportunity is open to all juniors and seniors at local high schools that currently use the National Center for Construction Education and Research, Contren training materials. Students may attend San Jacinto College in the evenings after school for two years of high school and one year after they graduate. Students who take advantage of this opportunity can be more than half-way toward completing their Associate’s Degree before they graduate from high school. Many of these high school students are employed directly out of high school as structural welders or welders helpers.

**Graduate Success Stories**

Graduates of the welding program include Nick Levier, Antonio Jasso, and Librado Garcia (Fig. 4). Levier has been employed as a single hand and rig welder for the past two years working on pipelines and in refineries as a combination welder. Jasso, who had no previous welding experience prior to attending the college, has been working for the last three years as a combination welder in refineries, and Garcia has worked four years as a combination welder.

**School-to-Work Program**

The College’s welding program is helping San Jacinto College student Fernando Morales achieve his educational and career goals. Morales said, “The welding equipment we get to use in class is outstanding. The welding instructors are very well informed and they are always there for me.” Whenever I had any questions, they were right there by my side to help me perfect my welding skills.

Howard Jackson, adjunct welding instructor at Central Campus, commented, “Now is an excellent time to be a welder. The plants in the Houston area are getting older and need to be refurbished or rebuilt. Welders are in such high demand that after one course, some students are able to go to work at $22 per hour or more.”

**Tuition**

The current tuition rates are based upon the student’s entry status into the welding program. Students entering the program through Continuing and Professional Development (CPD) pay $343 for each welding class, which includes 128 contact hours. Students seeking credit for classes within the welding program pay $343 for a five-credit-hour class at 128 contact hours if they live in district, or $468 for out of district students. Out-of-state and other nonresident rates are $718 for one class.

Also, under Texas law, a college may allow senior citizens 65 years of age and older to enroll in up to six semester hours of credit courses per term without paying tuition. A senior citizen may enroll in up to six hours of credit classes provided there is space available. The student must pay all applicable fees.

The college is tax supported both by the state of Texas and the college district keeping tuition and fees comparatively low. Financial assistance is available to students in the form of scholarships, grants, and loans, and part-time jobs are available on campus.

**After the Storm**

Hurricane Ike took its toll on the college campus, faculty, and student body when it struck the Texas coast on Sept. 13, but the college managed to resume classes and normal business operations on Sept. 29, complete with a plan to get the students through their fall semester on an unchanged academic calendar.

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WELDING JOURNAL 91
Estimating Welding Preheat Requirements for Unknown Grades of Carbon and Low-Alloy Steels

Preheat and interpass temperatures were determined by using HAZ hardness measurements and the estimated martensite transformation temperature

BY R. W. HINTON AND R. K. WISWESSER

ABSTRACT. When the steel grade or composition is unknown, the measurement of oxygen-cut surface maximum heat-affected zone (HAZ) hardness can be an aid in developing or confirming reliable welding procedures. If the chemical analysis of a carbon or low-alloy steel is not available or is not practical to obtain, weld repair or new fabrication welding of a component made of an unknown grade of steel in the field or in the shop is hazardous. A sequence of field or shop oxygen-cut surface hardness measurements is recommended to help ensure the success of this type of weld repair or fabrication. These procedures are for multibead weldments of cast and wrought steel components more than 25 mm (1 in.) in thickness but do not take into account weld joint complexity or hydrogen relief. The development of minimum preheat temperatures and maximum interpass temperatures was demonstrated by a Welder Training & Testing institute (WTTI) test of the maximum oxygen-cut surface heat-affected zone (HAZ) hardness of three unknown grades of steels.

Introduction

Although the weld applications of the enclosed methods presented and discussed can be applied to new carbon and low-alloy steel fabrications, these methods are usually applied to weld-repair applications and broken components provided that these are not components that require code weldments. In general, the higher the carbon and alloy contents of carbon and low-alloy steels, the higher the preheat temperatures required (Ref. 1). However, when the combined carbon and low-alloy contents are relatively high (5% maximum total content) for steels, the nearly complete (90%) martensite transformation temperature for that steel can be below the preheat temperature and subsequent interpass temperatures. If the preheat and interpass temperatures are high relative to a low 90% martensite transformation temperature for that steel, substantial retained austenite in the HAZ can occur. When the weldment cools, retained austenite can transform to martensite to produce high residual tensile stresses and an increased probability of delayed cracking. For example, the measured as-quenched hardness of steel, the reported 90% martensite transformation temperature ($M_{90}$), and the calculated carbon equivalent (CE) listed in Table 1 and 2 were taken from actual data reported in Ref. 2. The grades of steels listed in Tables 1 and 2 show that higher low-alloy composition content and higher carbon content (higher CE) result in higher as-quenched hardness and a lower $M_{90}$ temperature. Steel grades listed in Table 1 and 2 that are difficult to weld include AISI 4340, 1050, 6150, 8660, and 4360.

More accurate welding procedures for unknown steel grades can be developed by oxygen cutting the unknown steel at ambient or room temperature using standard through-thickness oxygen-cutting settings, by removal of the oxide scale from the oxygen cut surface and by making a small or shallow hardness measurement on the steel to obtain the maximum hardness of the oxygen-cut surface. Note that large indentation hardness measurements, such as a 10-mm-diameter Brinell impression, are not recommended because the maximum hardness of an oxygen-cut surface is just below the thin (usually 0.004-in.-deep) decarburized layer below the oxygen-cut oxide scale. This method is not presented to replace welding procedures that take into account steel joint size and complexity or hydrogen relief where the steel grade, certified composition, or check composition of the steel is available. For example, weld repair of a critical component that has failed in service and cannot be immediately replaced with a spare component could rely on an ambient oxygen-cut and maximum surface hardness determination of potential repair weldability. When the steel grade or composition is unknown, the determination of oxygen-cut surface maximum HAZ hardness can be an aid in developing or confirming reliable welding procedures. These procedures do not apply to code-welded steel applications where code-related weld repairs are required. For examples of code welding requirements, see Refs. 3–7.

Experimental Procedures

In order to demonstrate the method of obtaining hardness equivalent (HE) weld-
ing procedures proposed herein, three grades of steel billets saw cut to 1-in. lengths. Accurate checks of chemical compositions of these three billets are listed in Table 3. The hot-rolled AMS 6414 (modified AISI 4340) steel billet had 4 1/2-in. square cross sections. The as-cast ASTM A36 and ASTM 616 Grade 60 billets had 5-in. square cross sections. These billet samples were “cold-stamp” identified as A, B, and C and sent to the Welder Training & Testing Institute (WTTI) as unknown steel samples.

A welding instructor, with student observers, oxygen-cut one sample from each of the three grades of steel at ambient temperature to produce two half pieces of smooth 1-in.-thick steel. The oxygen-cut oxide scale on the surface was lightly ground away. The oxygen-cut half-sample with a parallel uncut surface was placed in a Rockwell hardness tester. Rockwell A hardness was measured using a 60-kg load with a diamond Braille indenter to produce shallow, small hardness indentations on the oxygen-cut surface.

After a number of shallow, small indentation hardness measurements were made on the first surface, other shallow (0.004-in.-deep) grinds were made with a flat grinder and additional hardness measurements were made and tabulated. These hardness results were correlated between the maximum oxygen-cut HAZ hardness converted to Brinell hardness (Ref. 8) and the chemical carbon equivalent.

### Table 1 — Welding Preheat Parameters Estimated from End-Quenched Maximum Hardness

<table>
<thead>
<tr>
<th>AISI Grade</th>
<th>Measured(b)</th>
<th>Reported(c)</th>
<th>Composition(d)</th>
<th>End Quenched(e)</th>
<th>Estimated(f)</th>
<th>HEQ Preheat(g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maximum (As quenched) Hardness BHN</td>
<td>90% (M90) Martensite Temperature °C (°F)</td>
<td>Carbon Equivalent CE</td>
<td>90% (M90) Hardness Equivalent HEQ</td>
<td>90% (M90) Martensite Temperature °C (°F)</td>
<td>Temperature °C (°F)</td>
</tr>
<tr>
<td>1019</td>
<td>293</td>
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<td>0.32</td>
<td>0.36</td>
<td>378 (712)</td>
<td></td>
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<td>0.50</td>
<td>347 (660)</td>
<td>(h)</td>
</tr>
<tr>
<td>4317</td>
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<td>335 (635)</td>
<td>127 (261)</td>
</tr>
<tr>
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<td>338 (640)</td>
<td>0.51</td>
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<td>295 (563)</td>
<td>206 (405)</td>
</tr>
<tr>
<td>1320</td>
<td>420</td>
<td>293 (560)</td>
<td>0.62</td>
<td>0.60</td>
<td>303 (548)</td>
<td>156 (313)</td>
</tr>
<tr>
<td>1340</td>
<td>534</td>
<td>266 (510)</td>
<td>0.69</td>
<td>0.71</td>
<td>270 (518)</td>
<td>191 (344)</td>
</tr>
<tr>
<td>4140</td>
<td>578</td>
<td>271 (520)</td>
<td>0.74</td>
<td>0.77</td>
<td>250 (482)</td>
<td>242 (468)</td>
</tr>
<tr>
<td>5140</td>
<td>601</td>
<td>271 (520)</td>
<td>0.72</td>
<td>0.77</td>
<td>240 (464)</td>
<td>250 (482)</td>
</tr>
<tr>
<td>4340</td>
<td>578</td>
<td>210 (410)</td>
<td>0.77</td>
<td>0.77</td>
<td>240 (464)</td>
<td>250 (482)</td>
</tr>
<tr>
<td>1050</td>
<td>601</td>
<td>249 (480)</td>
<td>0.81</td>
<td>0.81</td>
<td>240 (464)</td>
<td>250 (482)</td>
</tr>
<tr>
<td>6150</td>
<td>684</td>
<td>232 (450)</td>
<td>0.86</td>
<td>0.93</td>
<td>240 (464)</td>
<td>250 (482)</td>
</tr>
<tr>
<td>8660</td>
<td>690</td>
<td>143 (290)</td>
<td>0.95</td>
<td>0.94</td>
<td>200 (392)</td>
<td>232 (416)</td>
</tr>
<tr>
<td>4360</td>
<td>722</td>
<td>193 (380)</td>
<td>1.14</td>
<td>0.98</td>
<td>185 (365)</td>
<td>337 (638)</td>
</tr>
</tbody>
</table>

(a, b, c) Reported compositions for carbon equivalents, maximum water-quenched end of bar hardness and 90% complete martensite transformation temperatures were taken from Ref. 2. Steel compositions from Ref. 2 are listed in Table 2.

(d) $CE = C + (Mn + Si)/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15$. Compositions from Ref. 2.

(e) $HEQ = (BHN-44)/667$.

(f) $M_{90} = 510°C - 0.45 (maxmium as-end-quenched BHN)$.

(g) Minimum preheat temperature (PH) = $450°C + (HEQ - 0.42)$ From Ref. 2 data.

(b) No metallurgical preheat was necessary to retard the HAZ cooling rate because the HEQ was below 0.47. A surface heat to 200°F to remove surface moisture is recommended.
lent for each grade.

The same WTTI welding instructor welded the three steel grades that were V-grooved from 1-in.-thick samples using the welding procedures, including interpass and preheat temperatures, from the correlation of maximum oxygen-cut HAZ hardnesses and carbon equivalents. The maximum interpass temperature from the maximum oxygen-cut HAZ hardness was determined from the correlation of Jominy bar as-quenched hardness and 90% martensite completion temperature (Table 1).

The basis for the correlation between maximum oxygen-cut HAZ hardness and an estimate of weldability of the flame-cut steel with sufficient steel mass for cooling on either side of the oxygen-cut is the similarity of the weld/base metal HAZ of this same steel. A normal, smooth, oxygen-cut through-thickness that progresses without hesitation will produce a large prior austenite grain size near the melted surface, will dissolve most of the carbides in this hot zone, and upon rapid cooling as the oxygen-cut goes further will transform this hot zone to martensite. Cooling transformation diagrams for a variety of steels are shown in Ref. 9. Similar HAZ behavior of base steel occurs when heated to a near-melting temperature near the molten weld metal except a lower cooling rate and lower HAZ hardness occurs when the base steel is preheated prior to welding or during multiple temper-bead welding.

Results

Steel Composition and Preheat for Welding

In general, the higher the carbon content in a steel, the more difficult the steel is to weld, especially at ambient temperatures because of HAZ cooling rates. For example, AISI 1020 (0.20% carbon content) welds can be welded without preheat except to dry the surface of moisture with a surface preheat of 200°F. In contrast, AISI 1050 (0.50% carbon content) steel is difficult to weld and requires a relatively high preheat temperature throughout the base steel to reduce the cooling rate and potential hardness in the HAZ of the base metal. A high preheat temperature reduces the hardness of the HAZ by reducing the cooling rate and the amount of hard martensite in the HAZ. The as-water-quenched maximum hardness (Ref. 2) of various grades of steel subjected to a Jominy bar end quench is listed in Table 1. In general, the Jominy bar as-water-quenched maximum hardness is higher than the oxygen-cut surface maximum hardness of the same steel. The longer

Table 2 — Chemical Compositions of Steels

<table>
<thead>
<tr>
<th>AISI Grade(a)</th>
<th>C</th>
<th>Mn</th>
<th>Ni</th>
<th>Cr</th>
<th>Cu</th>
<th>Mo</th>
<th>V</th>
<th>CE(b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1019</td>
<td>0.17</td>
<td>0.92</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>0.32</td>
</tr>
<tr>
<td>USS T1</td>
<td>0.15</td>
<td>0.92</td>
<td>0.50</td>
<td>0.32</td>
<td>0.46</td>
<td>0.06</td>
<td>0.59</td>
<td></td>
</tr>
<tr>
<td>4317</td>
<td>0.17</td>
<td>0.57</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>0.53</td>
</tr>
<tr>
<td>8620</td>
<td>0.18</td>
<td>0.79</td>
<td>0.52</td>
<td>0.56</td>
<td>0.19</td>
<td>0.50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4130</td>
<td>0.33</td>
<td>0.53</td>
<td>0.90</td>
<td>0.18</td>
<td>0.63</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1320</td>
<td>0.20</td>
<td>1.88</td>
<td>0.54</td>
<td>0.21</td>
<td>0.62</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8630</td>
<td>0.30</td>
<td>0.80</td>
<td>0.55</td>
<td>0.21</td>
<td>0.62</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1340</td>
<td>0.43</td>
<td>1.58</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>0.69</td>
<td></td>
</tr>
<tr>
<td>4140</td>
<td>0.37</td>
<td>0.77</td>
<td>0.98</td>
<td>0.21</td>
<td>0.74</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5140</td>
<td>0.42</td>
<td>0.68</td>
<td>0.93</td>
<td>—</td>
<td>0.72</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4340</td>
<td>0.42</td>
<td>0.78</td>
<td>1.79</td>
<td>0.33(c)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1050</td>
<td>0.50</td>
<td>0.91</td>
<td>—</td>
<td>—</td>
<td>0.65</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6150</td>
<td>0.53</td>
<td>0.67</td>
<td>0.93</td>
<td>0.18</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8660</td>
<td>0.59</td>
<td>0.89</td>
<td>0.64</td>
<td>0.22</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4360</td>
<td>0.62</td>
<td>0.64</td>
<td>1.79</td>
<td>0.32(d)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(a) Compositions reported in Ref. 2 in percent by weight. Silicon contents were not reported except for 4360 (0.67 Si modified).
(b) CE = C + (Mn + Si)/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15 in percent by weight.
(c) — Element not reported in Ref. 2.
(d) Element concentration is higher than maximum specified for AISI grade.
time that the Jominy bar is held in the furnace prior to the water end-quench procedure increases Hardenability and maximum hardness by producing larger prior austenite grain size, more complete solid solution of carbides, and a higher cooling rate than those conditions and parameters in an oxygen-cut HAZ.

### Steel Composition and Carbon Equivalent

In addition to higher carbon in steel producing higher as-quenched hardness and higher HAZ hardness, other alloying elements in steel, such as, manganese, nickel, chromium, molybdenum, vanadium, and copper produce higher hardness at lower cooling rates in the HAZ shown by all the Jominy bar hardenability and maximum hardness results presented in Ref. 2. Cooling transformation diagrams for a range of carbon steels and low-alloy steels shown in Ref. 9 demonstrate steel’s Hardenability by showing the lowest cooling rate for a particular grade of steel to transform to martensite. In contrast to the wide range in Hardenability, the thermal conductivity of carbon and low-alloy steels that relate to heating and cooling (oxygen cutting) parameters is similar within a narrow range of thermal conductivity. Therefore, higher preheats for welding to promote lower cooling rates and lower hardness in the HAZ are needed for low-alloy steels with medium carbon contents (0.3 to 0.4% carbon), such as SAE or AISI 4130, 4340, and 8630 steels.

Steel’s weldability is represented by the carbon content and alloy elements that are combined as a carbon equivalent (CE) in wt-% in Refs. 3 and 4 as follows:

\[
CE = C + (\frac{Mn + Si}{6}) + (\frac{Cr + Mo + V}{5}) + (\frac{Ni + Cu}{15})
\]

### Table 3 — Check Compositions and Carbon Equivalents (CE) of Steels A, B, and C Studied in This Investigation

<table>
<thead>
<tr>
<th>Steel ID</th>
<th>Steel Grade</th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>Ni</th>
<th>Cr</th>
<th>Mo</th>
<th>V</th>
<th>Cu</th>
<th>CE(a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>AMS 6414</td>
<td>0.41</td>
<td>0.27</td>
<td>0.72</td>
<td>1.82</td>
<td>0.85</td>
<td>0.25</td>
<td>0.09</td>
<td>0.12</td>
<td>0.942</td>
</tr>
<tr>
<td>B</td>
<td>ASTM A36</td>
<td>0.15</td>
<td>0.33</td>
<td>0.64</td>
<td>0.11</td>
<td>0.13</td>
<td>0.05</td>
<td>—</td>
<td>0.43</td>
<td>0.384</td>
</tr>
<tr>
<td>C</td>
<td>ASTM A616</td>
<td>0.36</td>
<td>0.25</td>
<td>1.08</td>
<td>0.09</td>
<td>0.12</td>
<td>0.03</td>
<td>0.02</td>
<td>0.35</td>
<td>0.645</td>
</tr>
</tbody>
</table>

(a) Carbon equivalent (CE) = C + (Mn + Si)/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15.

### Table 4 — Carbon Equivalents (CE) and Flame-Cut Surface Heat-Affected Zone Maximum Hardnesses of Steels A, B, and C

<table>
<thead>
<tr>
<th>Steel</th>
<th>Carbon Equivalent (CE)</th>
<th>Max. HRA HAZ Hardness, (BHN)(b,c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.942</td>
<td>82.0 (679)</td>
</tr>
<tr>
<td>B</td>
<td>0.384</td>
<td>62.9 (255)</td>
</tr>
<tr>
<td>C</td>
<td>0.645</td>
<td>73.0 (420)</td>
</tr>
</tbody>
</table>

(b) Conversion to Brinell hardness (BHN) from measured Rockwell A (HRA) hardness on the HAZ surface (Ref. 8).

The preheat and interpass temperatures should not be above the 90% martensite (M90) transformation temperature of the base steel because in completed large weldments the additional martensite transformation from retained austenite can take place during cooling to increase shrinkage from final welding and promote HAZ or weldment cracking.

A good least-squared straight line (method of determining the best representation) fit of the martensite (M90) transformation temperature vs. the as-quenched maximum Brinell hardness (Max EQ BHN) listed in Table 1 from Ref. 2 is shown in Fig. 1, and the relationship is listed below

\[
M_{90} = 510°C - 0.45 \text{ Max EQ BHN}
\]

Major chemical compositions of the steels tested and reported in Ref. 2 are listed in Table 2 and the composition carbon equivalents (CE) are listed in Tables 1 and 2. When the M90 vs. the composition CE data points for that steel is plotted in Fig. 2, a least-squared straight-line fit results in a good correlation

\[
M_{90} = 464°C - 277 \text{ CE}
\]

### Table 5 — Martensite Transformation and Preheat Temperatures

<table>
<thead>
<tr>
<th>Steel Grade</th>
<th>Carbon Equivalent (CE)</th>
<th>Max. HRA HAZ Hardness, (BHN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.942</td>
<td>82.0 (679)</td>
</tr>
<tr>
<td>B</td>
<td>0.384</td>
<td>62.9 (255)</td>
</tr>
<tr>
<td>C</td>
<td>0.645</td>
<td>73.0 (420)</td>
</tr>
</tbody>
</table>

(c) Concrete reinforcing bar specification.
WELDING RESEARCH

Table 5 — Maximum Hardness of Base Steel Heat-Affected Zone (HAZ) Next to Fusion Line

<table>
<thead>
<tr>
<th>Steel</th>
<th>Maximum HAZ Hardness, DPH(a) (BHN) Next to Weld</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>321 (304)</td>
</tr>
<tr>
<td>B</td>
<td>222 (212)</td>
</tr>
<tr>
<td>C</td>
<td>242 (230)</td>
</tr>
</tbody>
</table>

(a) Measured diamond pyramid hardness (DPH) or Vickers hardness using a 500-g load on a polished and etched cross section (Refs. 8, 11).

Discussion with Examples

Welding Procedure Designed from Maximum Oxygen-Cut Surface HAZ Hardness

1) Choose a welding electrode or wire to produce an as-welded deposit of weld metal that is hardness compatible with the measured base metal hardness. Descriptions of hardness tests and the correlation between hardness and tensile strength of carbon and low-alloy steels are found in Ref. 11.

2) Estimate the following welding parameters from the measured maximum hardness (Brinell hardness number) of the oxygen-cut HAZ:

A. Composition carbon equivalent (CE) = Hardness Equivalent (HE):
   \[ HE = \frac{(Max \ HAZ \ BHN + 54)}{769} \]

B. Estimate from measured maximum oxygen-cut HAZ hardness the 90% martensite (M₉₀) completion transformation temperature
   \[ M₉₀ = \frac{510° - 0.45°C}{0.42} \]

Discussion

Field or Shop Measurements to Determine Maximum Oxygen-Cut Surface HAZ Hardness

1) Use a portable hardness device for large components or a shop bench hardness device for a smaller component or a 1/2-in.-thick oxygen-cut section from a larger component, and take measurements on a ground number 100-grit or finer surface. Also, measure the base metal hardness of the failed component or the new weld fabrication.

2) If possible, in field repair, visually determine the cause of failure, such as product quality, corrosion-assisted or wear-assisted overload, or fatigue. Report these observations to the owner-operators before proceeding to weld repair to alleviate, if possible, these conditions in the future.

3) At ambient or room-temperature oxygen cut a 13-mm (1/2-in.) or thicker section from the base metal using a normal continuous through-thickness oxygen-cutting procedure. Adjust the oxygen flow to produce a smooth, continuous through-thickness oxygen cut of the component section. Avoid checking maximum HAZ surface hardness where there was evidence of either dwell, backup, or weave during the oxygen-cut. The thickness and width of the oxygen-cut area should be at least 13-mm (1/2-in.) thick to ensure substantial cooling from the oxygen-cut face. Sufficient steel mass on both sides of the oxygen cut, such as 13 mm (1/2-in.) or more, is required to promote adequate cooling after the flame has passed. The oxygen cut produces HAZ hardness in the base metal that is similar but usually harder than the HAZ next to a weld bead on that same steel.

4) Grind the scale and a small decarburized metal to a depth of approximately 0.1 mm (0.004 in.) from the more massive side of the oxygen-cut surface and measure the maximum hardness on the HAZ on the component with a portable hardness unit. Use the highest hardness value measured. Do not average these values. Alternatively, a substantial size of the oxygen-cut piece can be ground flat and parallel on the backside of the oxygen cut to measure its the maximum hardness in a shop hardness tester. The surface preparation for maximum oxygen-cut HAZ hardness should be ground to a number 100-grit or finer finish.

5) Measure and record the individual hardness on three or more locations with either electronic or shop hardness units to produce small and shallow indentations. Lightly regrind the previously ground oxygen-cut surface to remove approximately 0.1 mm (0.004 in.) and repeat the hardness measurements until a single maximum hardness value is identified in the previous surface measurement. Convert the maximum hardness measurement to a Brinell hardness number (BHN) via ASTM E140 (Ref. 8) after the maximum hardness is determined. Only the maximum hardness of the steel's martensitic microstructure is determined by this method of rapid cooling the oxygen-cut HAZ. This procedure is not designed to measure the steel's hardenability or ability to transform to martensite at a minimum cooling rate that is different for different types of steel as shown in Ref. 9.

Example 1. Estimations from maximum HAZ hardness of 440 BHN are

\[ HE = \frac{(440 + 54)}{769} = 0.64 \]

\[ M₉₀ = \frac{510° - 0.45°C}{0.42} = 211°C \]

\[ PH = \frac{450°C \sqrt{(0.64 - 0.42)}}{32°F} = 312°C (594°F) \]

Note that the 211°C (412°F) preheat is acceptable because it is below the 90% martensite (M₉₀) completion transformation temperature of 312°C (594°F). The weld interpass temperatures during welding should be kept below this M₉₀ martensite completion temperature. Postweld heat treatment of the weldment (component) may be required for higher carbon and medium carbon low-alloy steels with carbon equivalents or hardness equivalents above a value of approximately 0.5. Examples of some AISI grades of steel with higher carbon equivalents are listed in Table 1. Postweld heat treatment reduces the hydrogen content of the welds and HAZs and reduces the maximum hardness of the HAZ. In some cases, postweld heat treatment improves the cyclic stress fatigue strength of weldments by reducing the magnitude of residual tensile stresses across and along the length of weldments.

Caution

When the 90% martensite completion transformation temperature of the base steel is below the preheat temperature and interpass temperature for a large weldment, delayed cracking can occur from the transformation of retained...
austenite to martensite after the completed weldment has cooled. Therefore, buttering or predepositing first-bead weld metal on the base metal joint surface at a high preheat temperature should be considered on large multibead weldments. After the base metal surface is weld overlaid, cool to below the 90% Martensite transformation temperature of the base steel to complete the weldment.

Example 2. Procedure when the estimated $M_{90}$ temperature is below the preheat temperature for a HAZ hardness of 600 Brinell is as follows:

$$ HE = \frac{(600 + 54)}{769} = 0.85 $$
$$ M_{90} = 510°C - 0.45 (600) = 240°C $$
$$ PH = 450°C \sqrt{(0.85 - 0.42)} = 295°C $$

Use the preheat temperature to make the first-bead weld deposits on the base metal (butter the base metal) and then drop the temperature to below the $M_{90}$ temperature to complete the multibead weldment.

**Welding Unknown Steels A, B, and C**

Steels A, B, and C were welded in 1-in.-thick single-V multibead joints using the hardness equivalent (HE), the $M_{90}$ and the preheat temperature (PH) welding procedures determined from the measured maximum oxygen-cut HAZ hardnesses. The A, B, and C compositions and carbon equivalents (CE) are listed in Table 4. During this study, WTTI staff and the welding instructor doing the work did not know the compositions or grades of Steels A, B, and C. Therefore, this welding exercise was a blind test of measuring the proposed oxygen-cut surface maximum HAZ hardnesses and welding to the following welding procedures. Composition carbon equivalents (CE) and oxygen-cut surface maximum HAZ hardnesses are listed in Table 4 for Steels A, B, and C.

The following welding procedures were based upon the measurements of flame-cut surface maximum HAZ hardnesses and the corresponding carbon equivalents of A, B, and C steels. The following welding procedure designs were as follows:

**Steel A:**

$$ HE = \frac{(679 + 54)}{769} = 0.95 $$
$$ M_{90} = 510°C - 0.45 (679) = 204°C $$

Since a preheat of 200°F would produce excessive radiant heat on the welding personnel located at the weld joint site, Steel A was preheated to 250°F and the base metal joint surface was welded (buttered joint technique). The buttered Steel A was then cooled to below the $M_{90}$ (399°F) temperature and the multibead weldment was completed.

**Steel B:**

$$ HE = \frac{(255 + 54)}{769} = 0.40 $$
$$ M_{90} = 510°C - 0.45 (255) = 395°C $$

Since a preheat of 622°F would produce excessive radiant heat on the welding personnel, Steel B was preheated to 550°F and the base metal joint surface was welded (buttered joint technique). The preheat temperature for a HAZ hardness of 622°F would produce excessive radiant heat on the welding personnel, and the base metal joint surface was welded (buttered joint technique). The preheat temperature for a HAZ hardness of 622°F would produce excessive radiant heat on the welding personnel, and the base metal joint surface was welded (buttered joint technique). The preheat temperature for a HAZ hardness of 622°F would produce excessive radiant heat on the welding personnel, and the base metal joint surface was welded (buttered joint technique).

**Steel C:**

$$ HE = \frac{(420 + 54)}{769} = 0.62 $$
$$ M_{90} = 510°C - 0.45 (420) = 321°C $$

The Steel C weld joint base metal surface was heated to above 200°F to remove surface moisture before welding. Interpass temperature was not restricted because the $M_{90}$ temperature was extremely high at 743°F.

The Steel B weld joint base metal surface was heated to above 200°F to remove surface moisture before welding. Interpass temperature was not restricted because the $M_{90}$ temperature was extremely high at 743°F.

**Conclusion**

In the absence of knowledge of the carbon and low-alloy steel grade or knowledge of a manufacturer’s certified composition of the steel to be weld fabricated or weld repaired, a product check of the steel’s chemical composition may not be practical. In the absence of a confirmed steel grade identification, a welding procedure can be developed for this unknown steel by measuring the oxygen-cut surface maximum heat-affected zone (HAZ) hardness equivalent (HE), by estimating temperature of the 90% martensite completion transformation ($M_{90}$) using the same oxygen-cut surface maximum hardness equivalent (HE). These welding procedures should not be applied to weld repair code-welded steel components.

**Acknowledgments**

The Welder Training & Testing Institute (WTTI) is gratefully acknowledged for its management, staff, and welding instructor’s participation in the application of these proposed welding procedures on three unknown steels. Laboratory Testing, Inc. (LTI), provided the certified check chemical compositions of these three steels.

**References**

8. ASTM International. 03.01 E140 (Tables 1 and 2); 2008
Effect of Martensite Start and Finish Temperature on Residual Stress Development in Structural Steel Welds

The experimental electrodes with lower Cr-Ni contents were found capable of promoting compressive residual stresses in welds

BY M. C. PAYARES-ASPRINO, H. KATSUMOTO, AND S. LIU

ABSTRACT. Martensite start and finish temperatures are very important in structural steel welding because they control the residual stresses in a weld. Tensile residual stresses amplify the effect of applied tensile stress. On the other hand, compressive residual stresses are algebraically added to the applied tensile stresses to result in a lower net stress level experienced by a weld, thus inhibiting crack initiation and increasing the fatigue life of the welded component.

The residual stress state, i.e., whether compressive or tensile, and its magnitude will depend on the expansion that accompanies the austenite-to-martensite transformation and the thermal shrinkage due to cooling. High martensite start temperature and low martensite finish temperature will both minimize the effect of transformation-induced compressive stress generation. To obtain a full martensitic structure in a weld metal within an optimal range of temperatures will depend mainly on the filler metal composition. A new type of welding wire capable of inducing a local compressive residual stress state by means of controlled martensitic transformation at relatively low temperatures has been studied.

In this study, several low-transformation-temperature welding (LTTW) wires have been developed and investigated to determine the martensite start and finish temperatures of the welds. Also studied was the effect of the martensite start and finish temperatures on microstructural development and hardness in single- and multi-pass weldments.

Introduction

It is well known that high tensile residual stresses near a weld decrease the fatigue performance of the weld because these initial stresses, when superimposed on the applied stresses, elevate the overall mean stress (Refs. 1–4). Several procedures have been developed to relieve the tensile residual stresses in welded joints. Postweld heat treatment (PWHT) and shot peening are two common methods used to improve fatigue properties (Ref. 3). Another way to reduce or eliminate undesirable residual stresses in welded parts is to modify the welding process itself. For example, low heat input and small weld pool are known to reduce residual stress.

Physical and mechanical properties such as heat capacity, density, thermal expansion coefficient, and strength of the base metal and filler metal contribute to the magnitude of the residual stresses generated in a weld (Refs. 4–6).

It has long been recognized that phase transformations in steels can radically affect the development of residual stresses. For example, Jones and Alberry (Ref. 7) showed how transformation temperatures influence the evolution of stress as a constrained sample cools from the austenite state. It is significant that their experiments showed that the residual stress at ambient temperature is smaller when the transformation temperature is reduced. Ohta et al. (Ref. 8) designed a welding alloy containing 10% Cr and 10% Ni, with an exceptionally low austenite-to-martensite transformation temperature, $T_{Mf}$. In this alloy, martensitic transformation in an unconstrained specimen starts at about 180°C and ends right at ambient temperature. By contrast, normal steel welding alloys have transformation temperatures around 400°–500°C. As illustrated in Fig. 1A, the net strain on cooling between $T_{Mf}$ and ambient temperature is contraction in the case of the conventional alloy, whereas there is a net expansion for the new welding wire. As such, local tensile residual stress results in the conventional wire and compressive residual stress for the low-Ms alloy at ambient temperature — Fig. 1B.

When fatigue tests were conducted on welded sections, the structures joined using the low-Ms alloy weld metal exhibited much higher fatigue strength (Ref. 8). This improvement of approximately 20% is attributed to the compressive residual stress, which reduces the effective stress range that the structure experiences during fatigue testing (Ref. 8). The achievement is based entirely on the fact that the reduction of the transformation temperature allows the expansion originated from martensite transformation to compensate for the accumulated thermal contraction strains. The improved results and the substantial benefits are expected to bring radical changes in fatigue design philosophies for structural components. This effect has recently been confirmed by Eckerlid et al. (Ref. 9), Martinez Diez (Refs. 10, 11), and Darcis et al. (Ref. 24).

Low-Transformation-Temperature Welding (LTTW) Wires

Martensitic Transformation Approach

The principal decomposition products of austenite during cooling are precipitated phases that include carbides and nitrides, or the polymorphic phases of al-

KEYWORDS

Martensitic Transformation
Martensite Start Temperature
Low Transformation Temperature Welding Electrodes
LTTW Electrodes
Weld Metal Phase Transformations
Compressive Residual Stress
Dilatometric Measurements
Consumable Development
loyed iron, which includes the low-temperature ferrite ($\alpha$) and the diffusionless transformation products, BCT $\alpha$-martensite, and HCP $\varepsilon$-martensite (Ref. 12). The BCT martensite phase can be thought of as a variant of the thermodynamically favored $\alpha$-ferrite, which would have formed from the austenite upon cooling were it not for the severe limitation of the diffusional processes due to fast cooling (Ref. 13). In the absence of ferrite formation by nucleation and growth, austenite undergoes the much more dynamic martensite transformation, involving short-range atomic rearrangements over broad interfaces at high velocity. The diffusionless shear-type martensitic transformation requires considerably greater driving force than the diffusion-controlled growth of ferrite in austenite, due to mechanical shearing of the austenite lattice. Consequently, martensitic transformation usually requires a considerably greater undercooling below the equilibrium temperature, $T_0$, at which the parent and transformed phases are in thermodynamic equilibrium. The relative stability of the austenite phase is very important in order to induce martensitic transformation at a desired temperature or stress level. The strain due to phase transformation can alter the state of residual stress or strain. It is well known that the martensitic transformation of the carburized surface of a steel component puts the surface under compression as a result of the expansion at the surface due to the formation of the lower-density martensite from austenite.

Table 1 — Compositions of the Welds (in wt-%) Produced Using the CSM Experimental Metal-Cored Wires

<table>
<thead>
<tr>
<th>Wires</th>
<th>C</th>
<th>Mn</th>
<th>Cr</th>
<th>Ni</th>
<th>P</th>
<th>Mo</th>
<th>Si</th>
<th>S</th>
<th>Ti</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>0.04</td>
<td>0.89</td>
<td>10.00</td>
<td>0.30</td>
<td>&lt;0.01</td>
<td>0.04</td>
<td>0.20</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>A6</td>
<td>0.08</td>
<td>0.89</td>
<td>14.70</td>
<td>0.27</td>
<td>&lt;0.01</td>
<td>0.04</td>
<td>0.19</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>B5</td>
<td>0.04</td>
<td>0.86</td>
<td>13.00</td>
<td>1.70</td>
<td>&lt;0.01</td>
<td>0.04</td>
<td>0.16</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>C5</td>
<td>0.05</td>
<td>0.41</td>
<td>3.00</td>
<td>13.2</td>
<td>&lt;0.01</td>
<td>0.35</td>
<td>0.22</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>ER70S-3</td>
<td>0.09</td>
<td>1.02</td>
<td>0.05</td>
<td>0.03</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>0.41</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

Table 2 — Transformation Temperatures Measured Using Dilatometry

<table>
<thead>
<tr>
<th>Wire</th>
<th>$\text{Ac}_1$</th>
<th>$\text{Ac}_3$</th>
<th>$\Delta T_\text{f}$ ($T_{\text{Ms}}, T_{\text{F}}$)</th>
<th>$\text{Ac}<em>1$ ($T</em>{\text{Ms}}, T_{\text{F}}$)</th>
<th>$\epsilon_f$ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>800</td>
<td>850</td>
<td>300</td>
<td>284</td>
<td>0.244</td>
</tr>
<tr>
<td>A6</td>
<td>790</td>
<td>815</td>
<td>360</td>
<td>190</td>
<td>0.081</td>
</tr>
<tr>
<td>B5</td>
<td>740</td>
<td>780</td>
<td>300</td>
<td>225</td>
<td>0.416</td>
</tr>
<tr>
<td>C5</td>
<td>635</td>
<td>720</td>
<td>270</td>
<td>120</td>
<td>0.570</td>
</tr>
<tr>
<td>ER70S-3</td>
<td>820</td>
<td>860</td>
<td>645</td>
<td>580</td>
<td>-0.570</td>
</tr>
</tbody>
</table>

(a) $T_{\text{Ms}}$ and $T_{\text{Ms}}$ are for A1, A6, B5, and C5.
(b) $T_{\text{F}}$ and $T_{\text{F}}$ are for ER70S-3.
ferrite and pearlite reactions, as well as other intermediate reactions such as the formation of bainite.

According to transformation characteristics, alloys can be divided into two classes with respect to martensite formation: 1) those that affect the equilibrium austenite decomposition temperature ($T_0$), and 2) those that affect the necessary undercooling below $T_0$, i.e., $\Delta T_m = T_0 - T_{Ms}$ (Ref. 14). $T_0$ is influenced by the chemical composition of the alloy, degree of order, hydrostatic stress (Ref. 15) (classical thermodynamic factors), and $\Delta T_m$, which is influenced by the difficulty of martensite nucleation and growth within the austenite matrix (kinetic, activation factor). The factors that affect the $\Delta T_m$ include external shear stresses and any other products that may affect the resistance of the base austenite lattice to mechanical shear during martensite transformation, e.g., hardening mechanism, point defects, dislocations, and precipitates.

Martensite Formation — Influence of Alloying Elements

The effect of alloying elements on the $T_{Ms}$ temperature has been studied by many researchers. Izumiyama et al. (Ref. 16) showed the effects of individual alloying of 13 elements. Their results showed that Al, Ti, V, Nb, and Co effectively increased the $T_{Ms}$, whereas Si, Cu, Cr, Ni, Mn, and C decreased the $T_{Ms}$ temperature. However, Liu (Ref. 17) reported different effects for some of the elements. He showed that all alloying elements mentioned earlier (Mn, V, Cr, Cu, W, Si), except Al and Co, decreased the $T_{Ms}$ temperature. The different observations are not unexpected since different processing conditions (e.g., austenitizing conditions and cooling rates), austenite grain size, and impurity content will significantly af-
fect the martensite transformation behavior. All these metallurgical factors need to be carefully considered in order to manage the martensite transformation behavior of an alloy.

This paper describes the development and characterization of several LTTW consumables that contained lower combined alloy contents (than the 10% Cr and 10% Ni developed by Ohta et al. (Ref. 8)) for the management of weld residual stresses and improvement of weld joint fatigue properties. Metal cored electrodes were manufactured and welds prepared. The welds were analyzed for chemical composition and specimens were extracted for dilatometric analysis for $T_{Ms}$ determination. The welds were also cross-sectioned for metallography and hardness testing.

**Experimental Procedures**

**Chemical Composition of the Weld**

The CSM-designed filler metal produced ferrite-martensite and ferrite-austenite microstructure. The composition of the welds produced using the four metal-cored welding wires are shown in Table 1.

The chromium and the nickel equivalents of each of the welds were calculated and plotted on the Schaeffler diagram as shown in Fig. 2. A1, A6, and B5 are expected to result in a ferrite–martensite microstructure while C5 is expected to be martensitic with some retained austenite. For comparison, a commercial solid wire, AWS ER70S-3, was also included in the research. Two models were used to calculate the martensite start temperatures of these alloys, the Self-Olson Equation (Refs. 18, 19) and the methodology proposed by Ghosh and Olson (Refs. 20–22). Scanning electron microscopy (SEM) and energy-dispersive spectroscopy (EDS) were used to examine the microstructure as well as alloying element segregation in the welds.

**Dilatometric Measurements**

Dilatometric specimens were extracted from single-pass welds deposited on an A36 grade structural steel using the four experimental consumables and the commercial ER70S-3 wire. The dilatometric measurements were made on a Gleeble thermomechanical simulator (Fig. 3) using 6-mm-diameter and 80-mm-length samples. The small cylinders were heated at the rate of 10°C/s to 1050°C and held at that temperature for 3 min, followed by quenching in a helium jet at the cooling rate of 100°C/s.

<table>
<thead>
<tr>
<th>Wires</th>
<th>$T_{Ms}$ (°C)</th>
<th>$T_{Ms}$ (°C)</th>
<th>$T_{Ms}$ (°C ±400)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>416</td>
<td>334</td>
<td>332</td>
</tr>
<tr>
<td>A6</td>
<td>360</td>
<td>280</td>
<td>325</td>
</tr>
<tr>
<td>B5</td>
<td>301</td>
<td>260</td>
<td>318</td>
</tr>
<tr>
<td>C5</td>
<td>279</td>
<td>175</td>
<td>291</td>
</tr>
<tr>
<td>ER70S-3</td>
<td>620(a)</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

(a) Ferrite transformation start temperature ($T_{fs}$).

---

**Table 3 — Experimentally Measured and Calculated Martensite Start Temperatures of Weld Metal**

![Fig. 5 — Microstructures of A1 in single-pass weld bead and Gleeble specimen. A — Single-pass weld bead; B — Gleeble specimen.](image1)

![Fig. 6 — Microstructures of A6 in single-pass weld bead and Gleeble specimen. A — Single-pass weld bead; B — Gleeble specimen.](image2)

![Fig. 7 — Microstructures of B5 in single-pass weld bead and Gleeble specimen. A — Single-pass weld bead; B — Gleeble specimen.](image3)
Microstructural Development

The specimens were prepared to a mirror-finish using standard metallographic techniques and etched with the Kalling No. 2 reagent (1.5 g CuCl₂ + 33 mL HCl + 33 mL ethanol + 33 mL H₂O) according to ASTM E407 and E340 testing techniques. Photomicrographs were taken using a LE.CO Olympus PMG-3 field microscope, coupled to a PaxCAM camera. Area fractions of martensite and ferrite were measured using the point counting technique.

Microhardness Distribution in the Weldments

Microhardness testing was conducted on transverse cross sections taken from the welds. Measurements were made on a Vickers microhardness scale with a load of 300 g. The objective of this study was to evaluate the hardness of single- and multipass welds; both as-solidified and reheated zones were measured. In the case of multipass welds, measurements were made in the “No-Reheat” (as-solidified) zone, “Once-Reheated” (reheated weld metal) zone, and “Twice-Reheated” (overlapping reheated) zones.

Samples for microhardness testing were first etched to identify the weld fusion zone. Hardness measurements were made across the weld interface at two different distances from the surface of the last bead of the weldments. Indentations were made at increments of 0.3175 mm inside the weld metal. However, the increments between successive measurements were reduced to 0.1588 mm when approaching the reheated zones in order to detect changes in hardness in these areas.

Results and Analysis

Results from the dilatometric analysis and microstructural analysis are presented and discussed in the following.

Dilatometric Analysis

The dilatometric curves and the martensite start temperature data are presented. In addition, the experimentally determined values are compared with the predicted values using the Self-Olson equations and the Ghosh-Olson methodology.

Dilatometric Curves

Figure 4 shows the dilatometric curves for the four designed and conventional wires obtained using the Gleeble thermomechanical simulator. Martensitic transformation occurred in all four designed wires. The martensite start temperature and the relative strain (compressive or tensile) are recorded on each of the figures. Data from the C5 sample was selected for further description and interpretation of the dilatometric measurements. At the beginning of the test, the percent strain was zero. With increasing temperature, the sample began to expand as evidenced by the positive strain. Ferrite-to-austenite transformation (α → γ) began at approximately 635°C and ended at around 720°C, representing a deviation from the equilibrium Ac1 and Ac3 temperatures. The negative slope during α → γ transformation indicates contraction because of the denser atomic packing factor of austenite. After the holding temperature of 1050°C, the sample was allowed to cool down at the rate of 100°C/s and contraction was observed. At 270°C, the slope began to change again indicating that martensite began to form. Up to this point, cooling has amounted to a contraction of about 1.8% (from +1.2 to -1.8).
Assuming that the welded structure was entirely rigid, the contraction of austenite would have resulted in tensile residual stresses. However, with the formation of martensite and its more open body-centered tetragonal (BCT) crystal structure, the contraction reversed to expansion. Finally, at room temperature, the strain reached around zero.

The martensite transformation start temperature ($T_{Ms}$) is identified as the temperature at which the slope changed from positive to negative during cooling. Similarly, the martensite transformation finish temperature ($T_{Mf}$) can be identified as the temperature when the negative slope turned to positive. Even though it is not necessary for all the austenite to decompose into martensite at $M_f$ to control residual stress, the magnitude of the expansion is important since it is responsible for offsetting the residual tensile stress state that originated from thermal contraction.

Sample C5 exhibited the lowest $T_{Ms}$ temperature and the largest amount of expansion. The expansive strain also remained at room temperature. These results indicate that compressive residual stresses can be induced in the vicinity of the weld metal in a welded joint produced using the C5 welding wire.

Martensite transformation initiated in sample A1 at 390°C and the amount of expansion was around 0.5% (from –0.3% to 0.2%). Nevertheless, the martensite transformation completed at a relatively high temperature, around 284°C. Thus, a part of the effect of expansion would be offset by subsequent cooling and contraction of thermal origin. The overall strain ($\varepsilon_f$) for sample A1, measured from the onset of martensitic transformation to room temperature, was only 0.244% as indicated in Fig. 4. It is clear by comparing sample C5 with A1 that the onset and the end of martensite transformation are just as important as the magnitude of the expansion in controlling the final residual stress state in a welded joint. For comparison, the $T_{Ms}$, $T_{Mf}$, and $\varepsilon_f$ of sample A6 are 360°C, 190°C, and 0.244%, respectively. For sample B5, these values are 300°C, 225°C, and 0.578%. Lower $T_{Ms}$ and $T_{Mf}$, and larger $\varepsilon_f$ will maximize the compressive residual stress in a welded joint.

On the contrary, a phase transformation was observed to start at 645°C and finished at 580°C during cooling in sample ER70S-3. Microscopic observation concluded that ferrite transformation occurred instead of martensite transformation. The lower alloying content of this welding wire certainly supports this observation. After the transformation, cooling has amounted to a contraction of 0.57% and then the strain reached around zero at room temperature. These measurements

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**Fig. 10** — Macrophotograph of weld B5 showing the three layers and six weld beads.

**Fig. 11** — Macrophotograph of the multipass weld B5 with lines designating the different weld zones: as-solidified weld metal, once-reheated zone, and twice-reheated zone.

**Fig. 12** — Microstructures of as-solidified and once-reheated areas. A — As-solidified fifth pass; B — once-reheated fourth pass.

**Fig. 13** — Microstructure of twice-reheated areas in weld A1. A — Twice reheated with the fifth and sixth passes; B — twice reheated with the fourth and sixth passes.
indicate that tensile residual stresses will result in the welded joint. The characteristics of the microstructures will be discussed later.

Table 2 shows the summary of the dilatometric analysis.

Comparison between Measured and Predicted Ms Temperatures

Experimentally measured martensite transformation temperatures (\(T_{\text{Ms}}\)) of the designed wires are listed in Table 3, which also contains the \(T_{\text{Ms}}\) temperatures as estimated using the Self-Olson equation (Refs. 17, 18) and the Ghosh-Olson methodology (Refs. 19–21). The temperature of the conventional wire, ER70S-3, indicates ferrite transformation start temperature (\(T_{\text{Fs}}\)).

As can be seen in Table 3, the Ghosh and Olson methodology appears to better predict the \(T_{\text{Ms}}\) temperatures for these experimental alloys. Since the Self-Olson Equations were derived statistically based on a number of alloys, this equation is expected to provide more accurate results for alloys whose compositions fall within the range of the database.

Weld Microstructure

Comparison of Microstructure between Single-Pass and Gleeble Specimen

Figures 5–8 are micrographs of the single-pass weld beads and the Gleeble specimens from each of the designed wires. All were martensitic in nature. However, the two microstructures, i.e., single-pass weld and Gleeble specimen, are slightly different because the Gleeble specimens were extracted from bead-on-bead (BOB) welds, which experienced multiple thermal cycles.

Figure 9 shows the microstructures of the ER70S-3 single-pass weld bead and the Gleeble specimen. Ferrite clearly predominated in the microstructure. More specifically, acicular ferrite and grain boundary ferrite veining were the two major features observed in the single-pass weld while 100% polygonal ferrite was found in the Gleeble specimen.

The volume percents of the matrix microstructure (white in the figures) and carbides (black or gray) were determined...
using the point counting technique. The results for the single-pass welds and the Gleeble specimens are listed in Table 4.

Hardness profiles were measured on the dilatometric specimens and single-pass weldments. The average hardness readings are listed in Table 5. All readings corresponded to martensitic microstructure. Comparing the hardness test results from the actual single-pass welds, the values of the Gleeble specimens were lower, again due to the multiple thermal cycles experienced.

Microstructure of Multipass Weld Specimens

Characterization of the weld metal and reheated zone microstructures of the welds is described in this section. A macrophotograph of the three layer (six-pass B5) weldment is shown in Fig. 10. The solid lines trace the weld interfaces of each individual bead, identified by numbers; 1 indicates the first bead and 6 indicates the sixth bead. As shown in Fig. 11, the weldment was composed of three zones: a) as-solidified zone marked “As-S,” b) once-reheated zone marked “1-RH,” and c) twice-reheated zone named “2-RH.”

Multipass Weld A1

Figure 12A and B show the as-solidified microstructure in the fifth pass and the once-reheated microstructure in the fourth pass, respectively. The as-solidified weld metal, Fig. 12A, was fully martensitic with a hardness reading of 383 on the Vickers scale. The reheated weld metal in Fig. 12B showed martensite and bainite, with an average hardness of HV292, which is lower than that measured in a fully martensitic microstructure. Bainite formed as a result of tempering.

Figure 13A and B show the microstructures of twice-reheated regions. These microstructures are more bainitic as compared to that of the single-reheated regions. The lower hardness values of 288 and 248 confirm the effect of multiple thermal cycles.

Multipass Weld A6

Figure 14A, B, and C show the micrographs of as-solidified first pass, second pass, and third pass, respectively, all with fully martensitic microstructure. Since carbon is low in these welds, the martensite is lathy in nature.

Different from the first, second, and third pass, the as-solidified fifth and sixth passes did not show 100% martensite in the microstructure. Instead, the martensite appeared as islands in the ferrite matrix as shown in Fig. 15A–C. These morphologies are similar to those reported in the literature, which described the undiluted microstructure of a weld metal of Type 403 martensitic stainless steel that contained 0.11% C, 12.38% Cr, and 0.28% Ni (Ref. 23). The amount of martensite in A6 wire weld was less than that of a type 403 stainless steel weld due to the lower carbon content of A6. The appearance of ferrite together with martensite will be explained in the next section on EDS analysis results.

Figure 16A shows an SEM photograph of the as-solidified first pass. Some isolated carbide particles are observed in the martensitic microstructure. EDS analysis in Fig. 16B showed Cr, Si, Ti, Mn, Al, and
Fe in the carbides. During welding, the first pass is expected to be more affected by dilution from the base steel. As such, the as-solidified first pass weld metal transformed into martensite because of carbon pickup from the base metal. On the contrary, in the later passes, weld metals contained less carbon and therefore martensite plus ferrite microstructures appeared. Figure 16C shows the SEM photograph of the as-solidified fourth pass, in which the effect of dilution was reduced. Larger carbide particles can be observed in the ferrite microstructure than in the first pass. The carbides were composed of Cr, Ti, Mn, and Fe. As a result of carbide precipitation, a carbon-depleted zone is expected to form around the carbides. The lower carbon content would then result in the formation of ferrite around the carbide particles. The ferrite next to the carbide precipitates in Fig. 16C confirms the explanation above.

On the other hand, many oxides composed of Si, Cr, Mn, Al, and Fe were observed in the as-solidified sixth pass in which little dilution of the base steel occurred, as shown in Fig. 16E. With the lower carbon in this region, the microstructure became ferrite and martensite as shown in Fig. 15B. High hardness values (above 300) resulted in these regions when the indent was on the martensite even the regions were reheated. On the contrary, when the indent was on the ferrite matrix, the hardness values would be low.

**Multipass Weld B5**

Figure 17 shows the microstructure of the as-solidified first pass of weld B5. The microstructure is fully martensite with Vickers hardness reading of 308. The high hardness was believed to also be a result of base metal dilution as in the case of weld A6.

**Multipass Weld C5**

Figure 18A and B show the as-solidified microstructure in the sixth pass and the once-reheated microstructure in the fifth pass, respectively. Figure 18A shows a martensitic microstructure with a Vickers hardness value of 368 while the reheated weld metal microstructure in Fig. 18B was bainitic with a hardness reading of HV300-275. The grain boundaries were clearly visible in both microstructures.

Figure 19 is a SEM photograph of the grain boundaries shown in Fig. 18. EDS analysis performed on the grain boundaries in Fig. 19B showed Cr, Mn, and Ni segregation. Chemical etching clearly developed the grain boundaries because of the alloying element segregation.

As expected, weld metal microstructures, whether single pass or multipass, are a result of chemical composition and thermal history. Base metal dilution, in this study, promoted the composition gradient, in particular, carbon, from the first pass to the later passes, as well as the hardness variations. The top beads with lower carbon exhibited a mixture of ferrite and martensite, and lower hardness readings. In terms of residual stress control, single-pass welds that had the correct chemical compositions demonstrated great ability to mitigate tensile residual stresses. Martensite started at a low temperature and ended close to room temperature. The effect of multipass welds on residual stress control is more difficult to assess because of the pass-to-pass chemical composition dilution and the prior bead thermal history. Thus, residual stress control via martensite transformation should be designed for structures with joints that can be accomplished through single-pass welding.
Conclusions

The low-transformation-temperature welding (LTTW) consumables design in this investigation exhibited expansion during cooling in a weld thermal cycle. Therefore, the experimental electrodes with lower Cr-Ni contents are capable of promoting compressive residual stresses in welds. Chemical composition proved to be critical in determining the martensite start temperature and martensite transformation behavior. Base metal dilution regarding carbon must be limited to maximize martensite formation. Weld joints designed to use single beads will be optimal for residual stress control. The major finding of this research is listed below.

• Martensite transformation start temperatures of the four designed wires are 390°C for A1, 360°C for A6, 300°C for B5, and 270°C for C5. The commercial wire, ER70S-3, transforms into ferrite at 645°C.

• Expansive strains developed for the designed wires in the dilatometric testing. The amount of the expansive strains for B5 and C5 are larger than those of A1 and A6. The expansion resulted in a compressive stress state. On the contrary, contractive strains and tensile residual stress resulted for the commercial E70S-3 wire.

• In single-pass welding, the microstructures of the designed wires are martensite due to the high chromium and/or nickel content of the experimental electrodes as well as carbon dilution of the base steel.

• The microstructures of the Gleeble specimen for all designed wires was martensitic.

• The microstructures of multipass A6 welds are martensite in the first to fourth passes, where dilution exerts the greatest effect; those in the fifth and sixth passes are composed of martensite and ferrite.

• The microstructures of multipass B5 welds are mainly martensite. Some alloy elements such as Cr, Ni, and Mn are observed to segregate along the grain boundaries.

• The microstructures of multipass C5 welds are fully martensite with microhardness reading between 350 and 380, even in the reheated regions.

Nomenclature

$e_{\alpha}$ = Thermal expansion coefficient of ferrite
$e_{\gamma}$ = Thermal expansion coefficient of austenite
$T_0$ = Equilibrium austenite decomposition temperature
$T_F$ = Ferrite finish temperature
$T_S$ = Ferrite start temperature
$T_M$ = Martensite transformation start temperature
$T_F$ = Martensite finish temperature
$\Delta T_m$ = Undercooling range for the austenite-to-martensite transformation
$A_c1$ = Temperature at which austenite begins to form during heating
$A_c3$ = Temperature at which transformation of ferrite to austenitic is completed during heating.

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12. **The purpose, function, and nonprofit status of this organization and the exempt status for Federal income tax purposes:** None
13. **Publication Title:** Welding Journal
14. **Issue date for Circulation Data Below:** October 2008
15. **EXTENT AND NATURE OF CIRCULATION:**

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16. **Statement of Ownership will be printed in the November 2008 issue of this publication.**

I certify that the statements made by above are correct and complete:
Andrew Cullison, Publisher
**Editorial Profile**

For those engaged in welding-related activities, *Welding Journal* provides current news, features, research reports, practical data, and advertisements from industry leaders around the world. Also featured are welding-related metalworking activities such as design, testing and inspection, maintenance and repair, and training.

**Other Editorial Features of Welding Journal**

- News of the Industry
- New Products
- New Literature
- Aluminum Q&A
- Welding Workbook
- Washington Watchword
- Brazing Q&A
- Peer-Reviewed Welding Research
- Book Reviews
- Press Time News
- Society News
- Personnel
- Editorial
- Soldering Topics
- Stainless Steel Q&A
- Coming Events
- International Update
- Resistance Welding Q&A

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<td>• Torches and Welding Guns Update</td>
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<td>• Matching Filler Metals to the Base Metal</td>
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