WELDING *Journal*

NOVEMBER 2020

AWS

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The Business of Welding

Company Highlights

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

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November 2020 • Volume 99 • Number 11

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On the cover: A welder at Dixie Mechanical in Tuscaloosa, Ala., completes a pipe welding pass with the Miller® PipeWorx 400 multiprocess welding system. (Credit: Miller Electric Mfg. LLC.)

WELDING JOURNAL

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saleman@aws.org

aws.org
8669 NW 36 St., # 130, Miami, FL 33166-6672
(305) 443-9353 or (800) 443-9353

AWS Promotes Diversity

AWS values diversity, advocates equitable and inclusive practices, and engages its members and stakeholders in establishing a culture in the welding community that welcomes, learns from, and celebrates differences among people. AWS recognizes that a commitment to diversity, equity, and inclusion is essential to achieving excellence for the Association, its members, and employees.

Welding Journal (ISSN 0043-2296 Print) (ISSN 2689-0445 Online) is published monthly by the American Welding Society for $120.00 per year in the United States and possessions, $160 per year in foreign countries: $7.50 per single issue for domestic AWS members and $10.00 per single issue for non-members and $14.00 per single issue for international. Not available for resale in either print or electronic form. American Welding Society is located at 8669 NW 36 St., # 130, Miami, FL 33166-6672; telephone (305) 443-9353. Periodicals postage paid in Miami, Fla. and additional mailing offices. **POSTMASTER:** Send address changes to *Welding Journal*, 8669 NW 36 St., # 130, Miami, FL 33166-6672. **Canada Post:** Publications Mail Agreement #40612608 Canada Returns to be sent to Bleuchip International, P.O. Box 25542, London, ON N6C 6B2, Canada.

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AWS Forges on with the Welding Community Taking Center Stage

Gary Konarska II
AWS Executive Director and CEO

"Through a renewed focus on you, we will continue to build upon the great legacy from all the volunteers and staff who came before."

There is a word that I consistently use to describe these unprecedented times: crazy. Altering a career path and moving your family at the height of a pandemic? Crazier. I am the new executive director and CEO of the American Welding Society (AWS), and it is my humble honor and privilege to lead this organization into the future. Here is a brief background of how I was fortunate enough to join AWS.

Three days after graduating university with an industrial engineering degree, I started my career in the welding industry. Over the past 20 years, I built a portfolio of experiences that has uniquely prepared me to rekindle the growth that AWS has achieved over its 100-plus years. I spent my first seven years working as a technical sales representative in the United States prior to taking on a two-year assignment to work in Singapore. The two-year assignment turned into ten years of living and working in Singapore and Shanghai, China, where I learned that the international welding community has so many things in common with the American welding community. Upon my return to the United States, I shifted gears to focus first on robotic arc welding automation before expanding to be responsible for 13 automation integration companies servicing much more than just welding.

Throughout these experiences, I have seen how critical both vocational and higher education are, the important role that welding distributors play, the phenomenal innovation of the welding product manufacturers, the volunteers who give back, and the different needs and pain-points of the end-user segments that make up our great welding community.

If you are reading this, then you understand there is a tremendous welding ecosystem, and you are also undoubtably proud to be a part of it. So what does the future look like from an AWS standpoint to warrant your continued engagement? The short answer is **you**.

We will continue to emphasize an outward focus on the constituents of AWS. From our certifications to our education training offerings, we must ensure that we are addressing the current needs of the welding community. We will extend our stakeholder feedback to include individuals who are not currently engaged with AWS in order to learn how we can better serve a broader base. Finally, we must communicate in language that the different personas can identify with.

To guide our path forward, we are currently focused on four strategic objectives: digital transformation, product portfolio, shortage of welding personnel, and global presence.

- **Digital Transformation.** When you see the phrase "Digital Transformation," usually a website comes to mind. However, it is so much more than that. It is a marriage of technology and business processes that make interactions easier and more efficient. AWS's digital transformation falls into two primary categories: foundation building and customer experience. To provide a customer experience that exceeds your expectations, we must have the foundation to be able to deliver.
- **Product Portfolio.** Through in-depth stakeholder analysis, we need to continue to add new products that address the challenges people face today and improve awareness of the existing product offerings. Furthermore, we need to solve pain-points so that our constituents can focus on growing their businesses and remaining competitive in the global marketplace.
- **Shortage of Welding Personnel.** By now, we are all aware of the shortage of welding personnel that our industry is facing, but are we making progress? Over the last decade, Weld-Ed (*weld-ed.org*) has been tracking the welding student enrollment. Today, there are twice as many students completing some type of welding program or enrolled in a welding program. Through the continued grants and scholarships of the AWS Foundation (*aws.org/foundation*), along with engagement in your local community welding programs, AWS will continue this resurgence in welding education for this generation and the next.
- **Global Presence.** Supporting the overseas welding operations of U.S.-based companies will continue to be critically important. Therefore, we must continue to engage the global welding community in developing high-quality standards for national adoption.

As we look forward to a post-pandemic world, whenever that may be, the future is very bright for AWS. Through a renewed focus on you, we will continue to build upon the great legacy from all the volunteers and staff who came before. Stay safe. WJ

New AWS Websites Feature Education 2020 – Virtual Summit and Specbuilder FAQs; Society's CEO Participates in Podcast on Finding Labor

The American Welding Society (AWS), Miami, Fla., has launched websites for this month's Education 2020 – Virtual Summit and to answer Specbuilder frequently asked questions (FAQs). In addition, AWS Executive Director and CEO Gary Konarska II has taken part in a labor-related podcast.

• Visit *aws.org/virtual2020* to learn about the **AWS Education 2020 – Virtual Summit** set for November 18–20. While FABTECH isn't taking place, participating in AWS welding education programs is assured online. This virtual event will allow you to attend educational programming and workshops while earning professional development hours. There will also be award ceremonies and presentations.

• **AWS Specbuilder FAQs** are available at *aws.org/standards/page/aws-specbuilder-faqs*. This serves as the committee balloting software and file sharing system for AWS. It replaces the Online Committee System and the previous manual committee balloting process. The website includes general information, from accessibility to training, as well as details about login, committees, and voting on ballots.

• **"Doing the Dirty Work: How to Find Qualified, Consistent Labor w/ Gary Konarska"** can be streamed at *themanufacturingexecutive.libsyn.com/website*. Konarska participated in this episode of *The Manufacturing Executive* podcast to discuss how to attract and retain high-quality labor. Along with Host Joe Sullivan, they discussed the opportunity cost of college and the value of learning a skilled trade; how to address the shortage of welders; ways to attract fresh talent through creating great content; and how to upskill the current welding workforce. Included among the resources they talked about were Careers in Welding by AWS (*careersinwelding.com*).

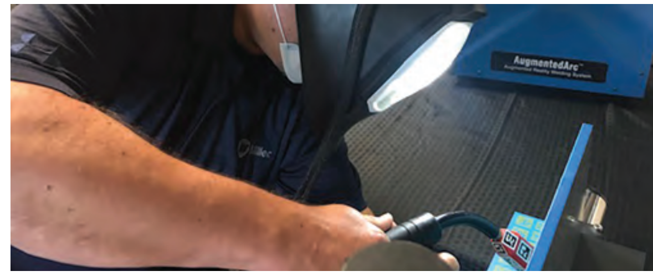
TC Energy and Natural Law Energy Sign Historic Memorandum of Understanding

TC Energy Corp. and Natural Law Energy (NLE), both based in Alberta, Canada, have signed a memorandum of understanding for NLE to pursue an equity interest in the Keystone XL Project and other potential related midstream and power projects. This understanding exemplifies the commitment the companies have made to create a meaningful, long-term partnership. A final agreement is expected to be completed in the fourth quarter of 2020.

"Today's announcement is a testament to what we can accomplish when industry and Indigenous groups work together," said Chief Alvin Francis, president of NLE. "This historic agreement is an important step for our Peoples and future generations to share in the energy wealth coming from our lands and traditional territories."

The Keystone XL Pipeline represents a 1210-mile pipeline capable of safely delivering 830,000 barrels per day of crude oil from Hardisty, Alberta, Canada, to Steele City, Neb. There it will connect with TC Energy's existing facilities to reach U.S. Gulf Coast refiners to meet critical needs for transportation fuel and useful manufactured products. Construction will create 13,200 jobs and local contracting opportunities for welders, surveyors, engineers, and more.

Career Academy of Pella Welding Program Receives Augmented Reality Welding System



The Career Academy of Pella was the recipient of an augmented reality welding system, donated by Miller Electric with participation from Vermeer Corp.

Miller Electric, in collaboration with Vermeer Corp., has donated an AugmentedArc® augmented reality welding system to the Career Academy of Pella, Pella, Iowa. This tool will enhance the school's welder training program and give students an industry-standard experience without leaving campus.

"Miller Electric is extremely excited about the donation of one of our AugmentedArc augmented reality welding training devices to the Career Academy," said Steve Hidden, national account manager of welding education and workforce development at Miller Electric. "Vermeer has been a strong partner with Miller for years, and we are happy to collaborate with them to train the next generation of welders in the Pella area."

He went on to note the training device will provide a realistic classroom welding experience, allowing students to learn proper welding techniques and develop muscle memory before moving from the classroom to the lab.

David Landon, manager of weld engineering at Vermeer and past AWS president, added the system is "one of the most impactful advances in welder training over the past ten years."

Students will begin using the welding simulator this semester, providing them the ability to quickly enhance their welding skills for future career opportunities.

Appalachian Regional Commission, U.S. Dept. of Energy Partnership Invites Proposals for Advanced Welding Training Programs

The Appalachian Regional Commission, Potter Township, Pa., and the U.S. Department of Energy's National Energy Technology Laboratory have issued a request for proposals for the Advanced Welding Workforce Initiative (AWWI). This is the result of a new partnership between the commission and the laboratory to invest in education and training for advanced technical workers in Appalachia.

As a joint effort, $1 million is available through the AWWI for training facilities and programs to develop and implement specialized curricula and learning modules in welding and other advanced manufacturing skills, such as robotics and process control. AWWI proposals are due by 5 p.m. (Eastern Time) on November 13. Application guidance and other information is at *arc.gov/AWWI*. WJ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Automakers Drive into Making a Difference: Ford Announces Goal to Donate 100 Million Masks, GM Earns N95 Certification, and More

Ford Motor Co., Dearborn, Mich., is targeting production of 100 million medical-grade masks through 2021. General Motors (GM), Detroit, Mich., has received N95 certification under the new National Institute for Occupational Safety and Health (NIOSH) public-health emergency process. And a partnership between Honda, Marysville, Ohio, and GM is producing hand sanitizer.

Charles Buchanan, a Ford Motor Co. employee, tests the 50,000th ventilator produced at Ford's Rawsonville plant in Ypsilanti, Mich. (Credit: Ford.)

• Following completion of its 50,000th ventilator to help clinicians treat COVID-19 patients, **Ford** is pivoting to target production of 100 million masks through 2021 for communities across the United States with limited access to personal protective equipment.

The company, currently manufacturing 2.5 million medical-grade masks a week for its employees and at-risk communities, grew the number of mask-making machines in October to increase production and deliver on its goal. The automaker is working with the Ford Motor Co. Fund to identify donation recipients across the United States through a network of nonprofit and state and local partners. It's focusing on military veterans, schools, food banks, and African American communities, among others.

"As the pandemic continues, so does the spirit, grit, and dedication of our Ford team and UAW [United Auto Workers] partners to step up and contribute to help our country," said Jim Hackett, former Ford president and CEO.

Also, a short documentary by award-winning director Peter Berg titled "On the Line" is at *youtube.com/watch?v=lYHgV2u1T2Y*. It focuses on Ford's Project Apollo, the internal code name for the company's effort to design and manufacture personal protective equipment, including powered air-purifying respirators, face shields, medical gowns for healthcare workers and first responders, and ventilators for COVID-19 patients.

GM has received N95 certification for the filtering facepiece respirators made at its Warren, Mich., facility. (Photo by John F. Martin for GM.)

• **GM** has received N95 certification for the filtering facepiece respirators made at its Warren, Mich., facility.

In response to the urgent need to increase the inventory of NIOSH-approved respirators during the COVID-19 pandemic, the staff at NIOSH's National Personal Protective Technology Laboratory has worked tirelessly to quickly evaluate domestic respirator applications for approval. These efforts are helping to increase the supply of available certified filtering facepiece respirators while ensuring new respirators meet the protective standards workers need and expect from NIOSH-approved respirators.

Achieving an N95 rating required an entirely new manufacturing process. At station 1, four layers of fabric are sandwiched together, tack welded in place, and cut into rectangular "blanks"; at station 2, blanks are loaded into a template that welds the outer perimeter as well as the pocket for the wire nose piece; at station 3, the wire nose piece is inserted, the blank is folded horizontally, and a sonic weld in the shape of a hockey stick is installed from the nose to the chin; and at station 4, the excess material is trimmed.

To expedite the launch of the N95 line, GM repurposed sonic welding units from the Brownstown Battery Assembly plant. For this line, the equipment was updated with templates to create the weld patterns needed for respirators.

GM will donate some of the N95 respirators to frontline workers. To date, the Warren facility has delivered more than 4 million face masks and 230,000 face shields to frontline workers.

• In addition, as part of an industry-wide effort to help alleviate the effects of the COVID-19 pandemic, **Honda** and **GM** are producing nearly 12,000 gal of hand sanitizer through their Fuel Cell System Manufacturing (FCSM) partnership. It will be used by both companies at their facilities throughout the region.

The hand sanitizer is being made at the Brownstown, Mich., facility where the FCSM team has been working on the development of fuel-cell stacks for the next generation of hydrogen-powered cars. Using an apparatus designed to manufacture the electrodes used in the fuel cells, the team developed a process to repurpose the equipment to produce a hand sanitizer.

Honda will also donate nearly 75% of its allocation of the hand sanitizer, packaging the product in 9-oz bottles for healthcare facilities.

Great Bay Community College — Rochester Creates Welding Lab to Meet Workforce Demand

Great Bay Community College (GBCC) — Rochester, N.H., has built a new welding lab to provide additional training opportunities and meet the hiring needs across the state.

A welding lab has been constructed by Great Bay Community College — Rochester to provide training opportunities and meet the hiring needs across New Hampshire. (Photo courtesy of Great Bay Community College.)

The lab houses 14 six-ft-wide, self-contained welding cells with ventilation geared to individual health and safety as well as the latest in welding technology. The facility enables the program to triple the number of students enrolled, which will prepare 42 welders to join the workforce annually.

"Great Bay Community College has partnered with Exeter and Portsmouth school districts to offer welding in their high school labs," said Paul Giuliano, head of the welding program at GBCC — Rochester. "This new welding lab will allow us to offer classes throughout the day and shrink the program's waiting list so that we can train more welders to meet the demand across the state."

In this program, students will learn cutting, brazing, and torching and joining metal, plus problem solving to discover the best materials to join together to maximize strength. After three semesters, students are ready to test for American Welding Society Certification, which prepares them for employment.

Two Companies Win 2020 National Metalworking Reshoring Award

Die-Tech & Engineering, Wyoming, Mich., and Trenton Forging Co. (TFC), Trenton, Mich., were awarded the National Metalworking Reshoring Award. The award honors companies that have effectively reshored products, parts, or tooling made primarily by metalforming, fabricating, casting, or machining, including additive manufacturing.

The virtual award ceremony was held on September 15

and presided over by Harry Moser, founder and president of the Reshoring Initiative. The Reshoring Initiative was founded in 2010 and helps manufacturers realize that local production can reduce their total cost of ownership of purchased parts and tooling.

Founded in 1967 with a facility originally built from recycled materials, TFC is a leader in the forging industry.

"Trenton Forging is a tried and true American family-owned business, and we take pride in providing the quality and integrity required to mark its products 'Made in USA'," said Dan Moxlow, director of market/process innovation at TFC. "This product line is a win for Trenton, and a win for American manufacturing."

Die-Tech & Engineering manufactures plastic injection molds and die cast dies known for speed and the appropriate use of advanced technology. They were selected for the award because molds and dies are complex, labor-intensive products that many assume are not produced in the United States.

"Our ability to collaborate with customers on quick-delivery complex tooling solutions was highlighted by our ability to supply tooling for the production of ventilator components in days, not the expected weeks or months at the beginning of the COVID-19 crisis," said Bill Berry, president and owner of Die-Tech & Engineering.

R&B Wagner Acquires ENPROCON Inc.

R&B Wagner, Milwaukee, Wis., an employee-owned company, has acquired ENPROCON Inc., Barron, Wis., a

ENPROCON Owner Boyd L. McEwen (left) and R&B Wagner CEO Bob Wagner pose for a photo.

manufacturer and sole supplier of ENDURALL™ stainless steel junction and device boxes. The company determined the purchase of ENPROCON's various assets would fit well with its manufacturing capabilities and drive further growth opportunities.

ENPROCON Owner Boyd L. McEwen has been in the stainless steel fabrication business for decades. He founded the business in 2007 and has run/operated it for the last 13 years alongside his wife and business partner, Ann.

R&B Wagner President Michael Dover added that the technology acquired includes a wire-fed, robotic gas tungsten arc welding unit.

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A Labor of Love for Lady Liberty

Artists Stephanie Hoffman and Barbie the Welder share their progress on the welder Statue of Liberty

If there's one lesson we can learn from the Statue of Liberty, it's that great endeavors don't come easy. Lady Liberty took ten years to assemble, built out piece by piece in France and then taken apart and shipped to the United States to be reassembled.

Although the 6-ft sculpture of Welder Liberty won't take that long to build, it is still a labor of love for metal artists Stephanie Hoffman and Barbie the Welder.

The statue is part of the American Welding Society's (AWS's) Arc 2 Art project (*aws.org/arc2art*), which promotes welding as a creative profession. Both artists are working on separate portions of the sculpture and will eventually come together to join their pieces. The final part of the statue will be a metal American flag draped across on the body, handcrafted in person by both artists.

In September, the women shared their progress on their respective components via two episodes, which were released on the AWS Instagram account *@americanweldingsociety* and YouTube channel at *youtube.com/user/videoaws*.

Fig. 1 — Stephanie Hoffman welds the beveled edges of the Statue of Liberty base. (Photo courtesy of Hoffman's Instagram @underground_metal_works.)

In the episodes, Hoffman gave details about the fabrication of the base, and Barbie explained her process of hand forming the body. Both artists shared their challenges and wins. One thing they both had in common: The project has taken longer than they expected.

The following is a rundown of each episode.

Episode 2 — A Solid Foundation

Hoffman had her work cut out for her building the base of the statue, which measures about 3 ft long and 3 ft wide.

She started the foundation by beveling the edges for complete joint penetration during welding, which was important to maintain the integrity of the piece once it came time to sand the edges — Fig. 1.

"If I would have just butted these corners all together and welded on it, I would have been worried about cracking from sanding it down," she said.

Ultimately, Hoffman completed 36.66 ft of gas tungsten arc welding (GTAW) on a ¼-in. aluminum at 225 A. She used a Thermal Arc® 250 GTSW unit from Thermal Dynamics, along with a water-cooled GTAW torch at Exit 74 Custom Fabrications, Whiting, N.J.

Fortunately, there was no cracking in the foundation, but trouble arose when Hoffman began sanding it down. She started with an 80-grit flap disc, then went to a 120-grit disc, and then back to an 80-grit orbital sander to clean up all the corners. She found the orbital sander didn't have enough power, so she put the sanding discs on a buffer, working up to 3000 grit — Fig. 2.

"It seemed like every grit I went up to, I had to go back

Fig. 2 — Hoffman buffing the base.

Fig. 3 — Barbie the Welder uses a ¼-in. round bar to build the frame of the statue's body.

down a couple of grits because I was finding scratches and things that I didn't like," Hoffman said.

In the episode, she displayed the foundation after one coat of polish. The base has an opaque sheen but will don a mirror finish at the final result.

"I wasn't happy with the RPM rate that I was polishing this at. So now the next coat of polish this thing is going to get is going to be low and slow," said Hoffman.

Next, Hoffman revealed the copper plate that will be attached to the foundation and hand engraved with the AWS logo and industry scenes such as a refinery, bridge, and airplane.

"I'm also going to do a really cool citycape across the front," Hoffman said. "I think it's important to highlight all the people in a lot of those trades unions who help build all of our cities across the country."

Hoffman plans to sand the copper down with 3-in. sanding discs, taking it to 3000 grit before polishing.

"There's no welds on this, so this copper will be quick, easy peasy," she said.

Although Hoffman said building out the base took longer than she imagined, she believes "in the end, it's going to be well worth all the extra effort I put into it."

You can see behind-the-scenes details on Hoffman's Instagram account *@underground_metal_works*.

Episode 3 — Body Works

The next episode of Arc 2 Art featured Barbie the Welder displaying the frame of the statue's body. She used a ¼-in.

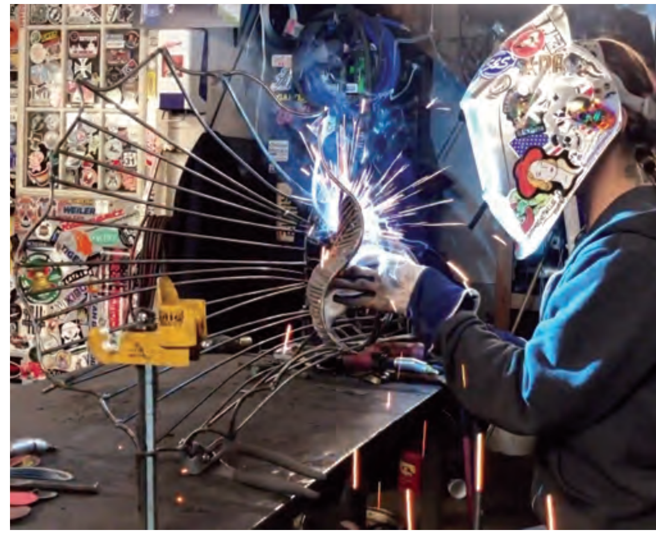

Fig. 4 — Barbie traded an 11-gauge steel for a ¼-in. round bar for the body's sheeting.

round bar running vertically and horizontally to create a cage-like shell for the plating — Fig. 3.

The first step of building the frame was calculating the size of the body and limbs. Barbie used the measurements of the original Statue of Liberty and scaled them to determine the proportions of the welder Lady Liberty.

"I know overall that from the top of her hand to the bottom of her dress is going to be 5 ft. So making sure everything is in proper proportion is key," Barbie said.

Building out the frame took multiple attempts as Barbie worked to get the look just right. Initially, she wasn't satisfied with the shape of the stomach or bottom of the dress, resulting in a redo of those areas.

"I did not keep in mind at first that as I'm plating this, it's going to have an extra ½ in. of thickness on it," Barbie explained. "So I had to go back and make it a little bit smaller so that once I get the sheeting done, it's going to proportionally look good."

For the sheeting of the sculpture, Barbie's first attempt was with an 11-gauge steel, which she uses for some of her other smaller sculptures that have a similar style. But the flat plating of the steel didn't give the dress the soft flow that fabric usually has.

Barbie decided to try another method: using the ¼-in. round bar that she had used for the frame — Fig. 4. Although time-consuming, it delivered the desired result.

"I'm putting [the round bar] side by side, and then I'm welding the seam between the two. It is giving me that soft look that I want," Barbie observed. "It's going to make the dress look flowy like an actual dress would."

The process has been laborious, but Barbie cut down the time it would take for her to remove spatter by spraying the piece with anti spatter. In the video, the beginning of the sheeting is covered in residue from the spray, but Barbie assured viewers that "in the end, the finish is going to be really beautiful and something that I'm deeply proud of."

To see more of her work on the piece, visit her Instagram account *@barbiethewelder*. WJ

ALEXANDRA QUIÑONES (aquinones@aws.org) *is associate editor of the* Welding Journal.

BY DAMIAN J. KOTECKI

Q: The American Society of Mechanical Engineers *Boiler and Pressure Vessel Code,* Section III, Division I, paragraph NB-2433.1 states the ferrite content of nominally austenitic stainless steel weld filler metals shall be done according to American Welding Society A4.2M, *Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic and Duplex Ferritic-Austenitic Stainless Steel Weld Metal.* Then it states, "Alternatively, the delta ferrite determinations for welding materials may be performed by the use of chemical analysis of NB-2432 in conjunction with Figure NB-2433.1-1." Beneath the figure are two notes, which are quoted as follows.

"(a) The actual nitrogen content is preferred. If this is not available, the following applicable nitrogen value shall be used:

(1) GMAW welds — 0.08%, except when self-shielding flux cored electrodes are used — 0.12%.

(2) Welds made using other processes — 0.06%.

(b) This diagram is identical to the WRC-1992 Diagram, except that the solidification mode lines have been removed for ease of use."

Are these nitrogen value instructions always appropriate?

A: Figure 1 presents the WRC-1992 diagram in the way it appears in the American Society of Mechanical Engineers (ASME) *Boiler and Pressure Vessel Code* (BPVC) without solidification mode boundaries. It is noteworthy that Note (a) above seems to lump flux cored arc welding (FCAW) together with gas metal arc welding (GMAW), which is not exactly correct. GMAW and FCAW are distinct welding processes.

Note (a) has accompanied Fig. NB-2433.1-1 since the WRC-1992 diagram replaced the DeLong diagram in Section III, Division I of the ASME BPVC in 1992. Prior to that, the DeLong diagram in Fig. NB-2433.1-1 carried a note with the same instructions, and that version of the figure dates from the 1970s. In the 1970s and early 1980s, nitrogen analysis of stainless steels was generally done by the wet Kjeldahl method (Ref. 1). I recall from my early years at Teledyne McKay, when the chemistry laboratory was headed by the late Chief Chemist George Fleming, that this method was laborious and generally required the laboratory to shut down other wet analysis work out of fear that ammonia in use elsewhere would contaminate the Kjeldahl procedure. Therefore, nitrogen analysis was avoided where possible, and Note (a) to Fig. NB-2433.1-1 was a way of avoiding the Kjeldahl method.

That situation changed with the first publication in 1984 of the American Society for Testing and Materials (ASTM) E1019, *Standard Test Methods for Determination of Carbon, Sulfur, Nitrogen, and Oxygen in Steel, Iron, Nickel, and Cobalt Alloys by Various Combustion and Inert Gas Fusion Techniques*, and the proliferation of instruments based on ASTM E1019. The analysis for nitrogen was quick and not laborious or

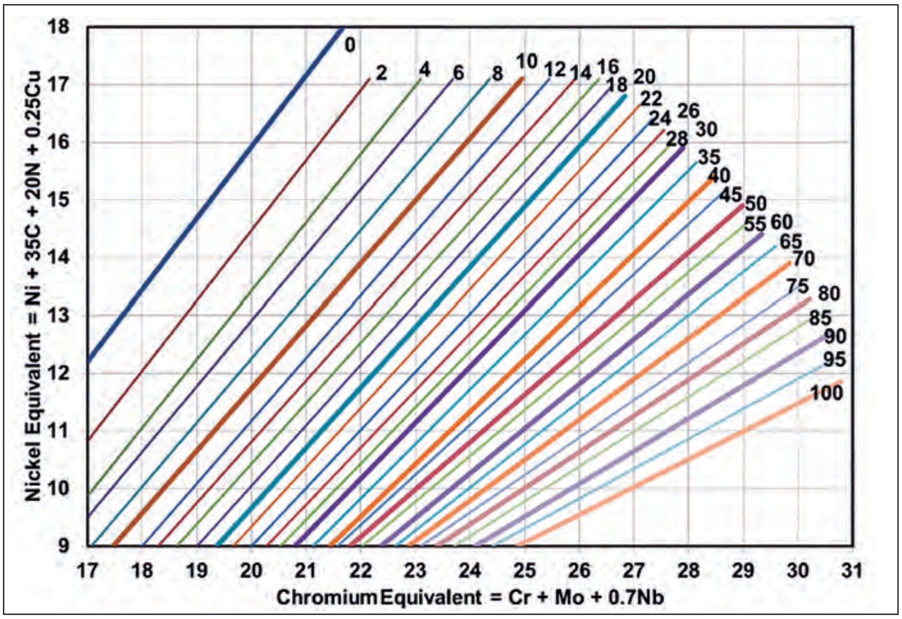

Fig. 1 — Pictured is a WRC-1992 diagram with a similar appearance to Fig. NB-2433.1-1 in the ASME BPVC.

susceptible to contamination from ammonia being used elsewhere in the laboratory. Note (a) could have gone away, but it did not.

Paragraph NB-2433.1 of the ASME BPVC, which directs the user to Fig. NB-2433.1-1, applies to A-Number 8 welding materials defined in the Code, Section IX, Table QW-442, containing less than 0.15% C, less than 2.5% Mn, less than 1.0% Si, 14.5–30.0% Cr, 7.50–15.0% Ni, and less than 4.00% Mo. Elements not mentioned in, but not excluded from, A-Number 8 include Nb (also known as Cb), Cu, and N. Accordingly, A-Number 8 includes the nominally austenitic stainless steel filler metals, which are those whose weld metal is expected to produce a small amount of ferrite in the otherwise austenitic weld metal, such as 308(L), 309(L), 316(L), 317(L), and 347. For these, the aforementioned nitrogen instruction in Note (a) seems to provide reasonable estimates, but significant variations in nitrogen content are possible. For example, a study of 3/32-in. (2.4-mm) self-shielding flux cored stainless steel weld metals documented nitrogen values in undiluted 308L weld metal, from a single lot of electrodes, as low as 0.046% (measured 20.8 Ferrite Number [FN]) and as high as 0.246% (measured 3.2 FN), depending upon the actual welding current, welding voltage, and electrode extension (Ref. 2). Another study included weld metal from a single heat of 0.045-in. (1.14-mm) ER308L GMAW electrode and found nitrogen as low as 0.057% (measured 9.1 FN) to as high as 0.319% (measured 0 FN) as a function of the integrity of the shielding gas

(Ref. 3). In both references, large variations in ferrite content resulted from the nitrogen variations. Similar effects can be found in shielded metal arc welding by varying arc length, with a long arc leading to nitrogen pickup and reduction of ferrite.

There are no specified limits for nitrogen content of the above-mentioned A-Number 8 filler metals. However, 2209 duplex stainless steel filler metal also fits in the A-Number 8 composition limits. The nitrogen ranges for E2209-XX covered electrodes, ER2209 bare solid electrodes and rods, and E2209TX-X flux cored electrodes are identical, 0.08–0.20%. Obviously, application of Fig. NB-2433.1-1 with Note (a) could lead to an erroneous estimate of the FN for these filler metals.

There are some key words that should be considered (or reconsidered) in using Fig. NB-2433.1-1. Paragraph NB-2433.1 in the BPVC uses "determination of delta ferrite" both for measurement utilizing a magnetic instrument calibrated according to American Welding Society (AWS) A4.2M, *Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic and Duplex Ferritic-Austenitic Stainless Steel Weld Metal* and for what I would term "estimation" according to Fig. NB-2433.1-1. That figure, while useful for anticipating results, does not measure or determine anything. The figure allows a prediction to be made that is helpful but not always right, like forecasting the weather. The uncertainty attached to the figure is about ± 4 FN when measured nitrogen is included in the composition data (Ref. 4).

The prediction gets even less certain when using Note (a) to Fig. NB-2433.1-1. That note makes a prediction about nitrogen content that is then used to make a prediction about ferrite content. Paragraph NB-2433.1 states, "Alternatively, the delta ferrite determinations for welding materials may be performed by the use of chemical analysis of NB-2432 in conjunction with Figure NB-2433.1-1." At this point, there is uncertainty in the diagram and uncertainty in the nitrogen estimation. I do not see how this could be considered a "delta ferrite determination."

In conclusion, measurement of weld metal ferrite using an instrument calibrated according to AWS A4.2M is a determination or measurement. Estimation (or prediction or forecast) of ferrite by using Fig. NB-2433.1-1 in conjunction with a complete chemical analysis of the weld metal including nitrogen has a degree of uncertainty. Estimation of weld metal ferrite using Fig. NB-2433.1-1 along with an estimation of nitrogen content according to Note (a) has at least two degrees of uncertainty. Where possible, measure, don't estimate. WJ

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DAMIAN J. KOTECKI is president of Damian Kotecki Welding Consultants Inc. He is a past treasurer of the IIW and a member of the AWS A5D Subcommittee on Stainless Steel Filler Metals, D1K Subcommittee on Stainless Steel, and WRC Subcommittee on Welding Stainless Steels and Nickel-Base Alloys. He is a past chair of the A5 Committee on Filler Metals and Allied Materials and served as AWS president (2005–2006). Questions may be sent to Damian J. Kotecki c/o Welding Journal, *8669 NW 36 St., # 130, Miami, FL 33166-6672, or via email at* damian@damiankotecki.com.

American Welding Society

Do You Have a Stainless Question?

Email your submission to Stainless Q&A author, Damian J. Kotecki, at *damian@damiankotecki.com* or send it to his attention at
Welding Journal Dept.
Damian J. Kotecki
8669 NW 36 St., #130
Miami, FL 33166

Your stainless question may be chosen for this bimonthly column and help other individuals better understand how to solve a particular problem.

BY RON FOREMAN

Q: How do I resistance weld projection-style weld fasteners? I purchased a resistance welding machine, got fixtures made for this new weld job, and realized I have no idea where to start with a weld schedule.

A: It's a different world trying to successfully resistance weld projection weld fasteners.

For more than 40 years, I have seen quite a change in resistance welding equipment. For many years, the old standard alternating current transformers ruled resistance welding. Add the tube-style timer control units and the job got done. How things change.

To respond to your question, let's talk about what you are trying to resistance weld. First, what type of material are you welding? Next, what is the thickness of this material? Is there any type of coating applied before welding? What type of resistance welding machine did you just purchase? If it's the alternating current type, what kVA size rating does it provide? Then finally, what made you decide on this type of

Fig. 1 — Samples of different styles of projections and their location on the weld fastener.

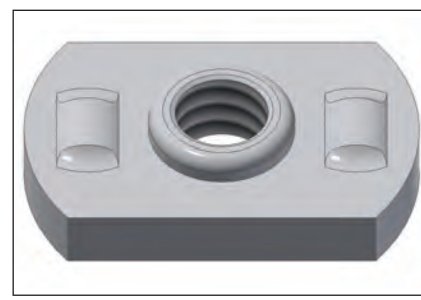

Fig. 2 — This is a rib-style projection. It's used to provide more projection mass with thicker material.

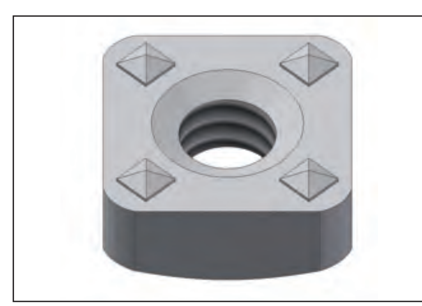

Fig. 3 — These are the pyramid-style projections carefully located for more bearing surface to achieve consistent weld results.

resistance weld fastener for your new weld application?

There are different types of weld fasteners with projections on them — Fig. 1. Therefore, I need to stress the importance of well-formed projections and what to look for when buying.

Good projections can make great welds consistently all day. Using projections that are not uniform is like trying to get good welds with misaligned electrode tips. Try placing a sheet of metal on a flat surface, then put the weld fastener on top of the metal sheet. Are all the projections touching the metal? If not, here is what will happen. The electrode tip pressure is applied, the weld current starts flowing, and guess where all that energy is going first? It's flowing to the projection touching the metal.

With short weld time cycles being used, by the time the heat forms a liquid, the weld time cycles stop and new hold time cycles start.

For consistent welds, the projections need to be unified both in height and mass. There is a close plus or minus tolerance accepted in manufacturing resistance weld fasteners. Drawings are included to show these tolerances.

Here's a second thought for you to ponder. What type of projection do I need for this new welding application? How many projections should I use for my customer's suggested assembly torque requirements?

Those type of questions are basically answered with material types and thicknesses being used. Here's a general rule of thumb: The projection height should be close to 40% of the material thickness being welded. Of course, this is never a standard practice because there are many different components added to materials requiring a different size projection for that application — Fig. 2.

Another factor is the material thickness. The better question to ask is where is the projection located on the fastener and why? Correct balance of heat leads to better welds. Having the proper location of the projections to provide more bearing surface helps contain the weld liquid as it forms the nuggets within the electrode tips — Fig. 3. Projections designed on the outer edge of the fastener can lead to liquid material escaping the electrode tips, which is known as weld spatter. Projection location is very important for consistent weld nuggets.

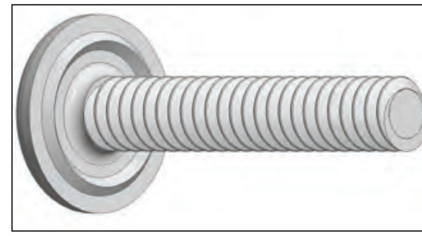

Fig. 4 — Pictured is a ring projection-style weld fastener.

Moving on with my discussion on welding projections, I usually ask if a ring-style projection is ever needed with weld jobs. When resistance welding for a hermetic or liquid seal, the ring projection is your only choice — Fig. 4. Once again, the location, and mass of the ring projection determines a full ring weld nugget or a weak weld. Electrode tip alignment is critical when welding ring-style projections.

Ring projections can be the ideal projection for cross wire welding or on the mesh-style material. Having the ring touch only at the needed points of contact speeds up production. Orientation of projections is not required. If you need a stronger-type weld but the ring projection requires more secondary amperage than your kVA welding machine can provide, consider using the three sausage-style projections when the hermetic or liquid seal is not required. This type of projection works for harder materials or extremely thick material.

If you need information on resistance weld fasteners or projection types, feel free to contact Buckeye Fasteners Co., Cleveland, Ohio, or myself at The Ohio Nut & Bolt Co., Berea, Ohio. We can help you with all your resistance welding questions. Buckeye Fasteners is an active member of the Resistance Welding Manufacturers Association (RWMA), and its website (*buckeyefasteners.com*) links you to

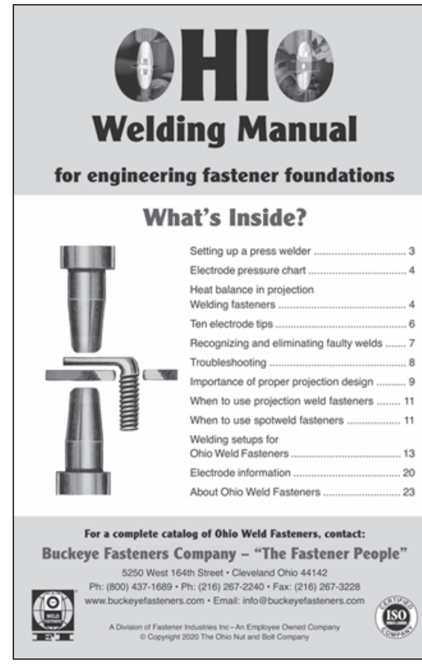

Fig. 5 — The weld data guide booklet is offered on buckeyefasteners.com *in PDF format, or the company can send customers hard copies.*

RWMA manufacturers. If we don't answer your questions, there is a world of help from experts in the RWMA.

Buckeye Fasteners also offers a weld data guide booklet upon request or via the website (Ref. 1). On the website, click on Resources, then scroll down to the weld data guide. Click on About Ohio Weld Fasteners. There is a PDF block (Weld Guide 2020), which will open the manual. This weld manual (Fig. 5) will help you understand resistance welding of fasteners, and how they can be successfully welded. There are generic weld schedules provided using the alternating-current-type welding machines along with kVA size requirements and electrode tip sizes for each fastener. The material covers the dos and don'ts of resistance welding of fasteners. WJ

Reference

1. *Ohio Welding Manual*. 2020. *buckeyefasteners.com/media/1205/weld-guide-2020.pdf*

RON FOREMAN is the weld department supervisor at The Ohio Nut & Bolt Co., Berea, Ohio. He is also a resistance weld technician. Send your comments and questions to Ron Foreman c/o Welding Journal, *8669 NW 36 St., #130, Miami, FL 33166-6672, or via email at* rforeman@on-b.com.

Welding Machine Suits Numerous Applications

The MIG Striker 200 multipurpose welding machine joins steel, stainless steel, and aluminum. Designed for gas metal arc welding (GMAW), gas tungsten arc welding (GTAW), and shielded metal arc welding, the dual-voltage (115 or 230 V) system provides digital readouts that automatically identify the power grid voltage and operates accordingly. The welding machine also features the power factor corrector, which increases power efficiency, reduces input power requirements, and stabilizes the welding current. As a safety precaution, it has a voltage reduction device that lowers the voltage across the outputs when idling. Its other features include a hot-start function for easy ignition of the weld arc; an arc force function to prevent the electrode from sticking to the workpiece; and a power-saving smart fan that reduces dust. The compact welding machine comes standard with a flow gauge regulator. It is also offered with optional equipment, such as a spool gun, 15-ft GMAW gun, and 12-ft GTAW torch (i.e., measured from the connection in the machine to the end of the GMAW gun/GTAW torch, including handle/cable, etc.).

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Free Poster Aims to Simplify Installation of Gas Regulators

The Helpful Hints: Connecting a Gas Regular poster displays tips for the safe, correct, and efficient setup of gas regulators. Designed for use in industrial, laboratory, or personal settings, the poster is organized into four sections: getting started, inspecting equipment, attaching equipment, and checking for leaks. It contains nine easy-to-follow recommendations accompanied by colorful photos. The free poster can be ordered on the following website: *bit.ly/RegulatorPoster.*

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Report Evaluates the 2020–2026 Arc Welding Equipment Market

Global Arc Welding Equipment Market predicts this segment will reach $19,170 million by 2026 at a compound annual growth rate of 5.5%, an increase from $13,890 million in 2020. The 128-page report provides a look into this market's current competitive landscape by covering topics such as market size, growth rate, and dynamics; recent developments; major drivers and restraints; and prominent players, along with their mergers and acquisitions, technological advancements, and R&D investments. The report also analyzes future opportunities, demands, and challenges. This includes strengths, weaknesses, threats, and opportunities as a result of the COVID-19 pandemic. For example, the report predicts COVID-19 will have a significant impact on the global arc welding equipment market by influencing production and demand; creating supply chain and market disruption; and financially affecting firms and financial markets.

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Updated Software Facilitates Pipe Welding

The updated software for the PIPEFAB™ welding system delivers process control options that improve simplicity and machine performance for operators and managers. It enables additional memory functions, such as the memory-only mode, to allow managers to limit the machine capabilities to only the processes and parameters they have saved. Users can further customize memory names that appear on the screen when the memory is loaded and active. Additionally, the software adds a weld mode update for the HyperFill® twin-wire gas metal arc

welding process. Suited for heavy-wall pipe and vessel applications, this process expands the system's welding capabilities to achieve deposition rates above 18 lb/h. Other enhancements include weld modes for stainless steel shielded metal arc welding as well as optimized Smart Pulse™ performance for stainless steel gas mixtures.

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Electric Material Removal Tool Accomplishes Diverse Tasks

The radially compliant RCE-710 electric material removal tool handles rust and weld spatter, blending, polishing, and light grinding. It showcases large bearings, a shaft designed for demanding robotic use, and a variable speed motor with a range of 0 to 13,000 rotations per min. The motor works by rotating clockwise and counterclockwise, producing continuous torque on the workpiece. The material removal tool also has built-in compliance to simplify the programming process and compensate for part and fixturing misalignments. Offered as a complete end-effector package, the material removal tool includes the deburring tool, power/signal cables and connectors, and an easy-to-use controller. It can also perform tasks with carbide burrs, brushes, flap wheels, unitized wheels, and a variety of other cutting, grinding, and polishing media.

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Line of GMAW Machines Saves on Electricity

The Taurus Steel gas metal arc welding (GMAW) machines meet the requirements of the new European Ecodesign Directive with their inverter technology, which achieves resource efficiency and cost savings. This technology also allows the welding machines to serve as an alternative to step switch-controlled machines. Designed for working with steel, the welding machines come in three models with 350, 400, and 500 A. The 350- and 500-A models feature a duty cycle of 60% at maximum current, while the 400-A model achieves a 100% duty cycle for easy welding with full penetration.

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Blog Helps Welders Calculate Heat Input for GMAW

The blog titled *Calculation of Heat Input in MIG/MAG Welding* provides guidance on how welders can figure out the heat input for gas metal arc welding (GMAW) according to the requirements in ISO 15614-1:2017, *Specification and qualification of welding procedures for metallic materials — Welding procedure test — Part 1: Arc and gas welding of steels and arc welding of nickel and nickel alloys*. Using tables, figures, equations, and photos, the blog covers the following topics: requirements set by standards, formulas for calculating arc energy, how the formulas are applied, the heat input calculation formula, voltage losses in welding cables, practical welding tests, and how new GMAW machines facilitate heat input calculations. Visit *weldingvalue.com* to read the free blog.

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Welding Fume Extractor Easily Mounts to Wall

The compact WallMaster fume extraction system saves space in production areas due to its ability to be mounted on a wall, pillar, or separately available stand. Little effort is required to integrate and mount the stationary unit behind extraction elements, such as extraction arms or fans, and it does not need its own power supply. This makes it suitable for simple retrofitting in existing collection devices. With a filter surface of about 452 ft^2, the stationary unit filters medium quantities of welding fumes and dust for up to two workplaces simultaneously. It separates ultra-fine particles with a size of less than 0.1 µm to a degree of more than 99.5%. To enable contamination-free filter change, the fume extractor comes with the SafeChangeFilter technology, which prevents welders from coming in contact with the hazardous substances in the welding fumes, even during disposal.

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Correction

On page 57 of the Product & Print Spotlight section in the September 2020 issue, the Cryo-Shield Ni9 alloy flux cored welding wire from ESAB Welding & Cutting Products was mistakenly said to come in packaging that provides moisture absorption. That is incorrect. It comes in a vacuum-seal foil packaging that *prevents* moisture absorption.

Fabricator Benefits from Switching to a Multiprocess Welding Solution

A change in welding processes and a new welding system helped Dixie Mechanical save time and money without compromising quality.

Dixie Mechanical eliminated back purging on stainless steel and doubled welds by making the equipment change

BY JEFF ROBEDEAUX

Increased quality, reduced costs, higher productivity, and a motivated workforce: How do you get one without sacrificing another? Pipe fabricator Dixie Mechanical found the answer with a change from traditional methods.

Pipe shops typically accept an argon back purge as part of the welding process — one that consumes time and drives up costs. But the company was able to eliminate this back purge practice and generate savings as a result.

With a recent switch in welding processes and adoption of a new welding system, the company doubled the number of welds completed every day without compromising quality, allowing them to finish more jobs and meet demanding timelines.

"We're looking for whatever it takes to make it faster, but we want quality," said Keith Henline, shop foreman. "At the end of the day, it's about how much time did you save that operator to make more welds?"

Based in Tuscaloosa, Ala., Dixie Mechanical fabricates pipe and completes field installation and construction for customers in power and energy, oil and gas, and chemical sectors nationally and internationally. In these critical environments, weld quality is paramount, but fast production and efficiency aren't far behind.

"Projects are just so much faster nowadays. Being able to meet the customer's schedule is important, and sometimes the schedules are really demanding," said President Greg Howell, who founded the company in 2002. "Technology is going to change every day, so you've got to keep up with it or you're going to be behind."

Welding Stainless and Carbon Steel Pipe

With about 75 employees in shop and field operations, the company typically has four to five projects in the works at any given time. A sizable project for the shop may involve fabricating 2000 spool pieces; they often produce 300 to 400 ft of pipe daily.

Capabilities include the fabrication of large- and small-bore piping, with outer diameters ranging up to 72 in. and wall thickness up to 2¼ in. Commonly welded materials include carbon steel, stainless steel, duplex stainless, and chromes. All of the company's weld procedures and operators are tested and certified to meet American Society of Manufacturing Engineers Section IX standards.

While weld quality has always been important, the company wanted to find ways to save time and produce quality welds more efficiently. Any technology they considered had to demonstrate a good return on investment. Howell emphasized the importance of looking at daily costs.

Fig. 1 — A switch to the Regulated Metal Deposition (RMD®) process eliminated back purge on stainless steel pipe welds, saving significant time and money.

Before: Back Purging Stainless Steel Pipe

For welding stainless steel pipe, the welder followed the traditional process of using a gas tungsten arc welding (GTAW) root pass with an argon back purge followed by flux cored arc welding (FCAW) fill and cap passes.

Back purging on stainless steel was an especially time-consuming process, typically requiring 20 to 30 min depending on the pipe size to set up the argon shielding gas and tape the pipe ends for purging. In addition, the argon gas used for back purging added to consumable costs.

Another productivity killer was swapping leads and polarities when they changed from GTAW for the root pass to FCAW for the remaining passes.

After: Eliminating Back Purging With a Multiprocess Solution

In looking for efficiency improvements, the company worked with their local welding supply distributor to test several welding power sources from different manufacturers. They knew it was important to get buy-in from the welders who would use the machines.

Their team chose the Miller® PipeWorx 400, a multiprocess system that offers capabilities for GTAW, FCAW, gas metal arc welding (GMAW), and shielded metal arc welding (SMAW), as well as the Regulated Metal Deposition (RMD®) process, a modified short-circuit GMAW process — Fig. 1.

With the system change, they switched from a GTAW root pass to a

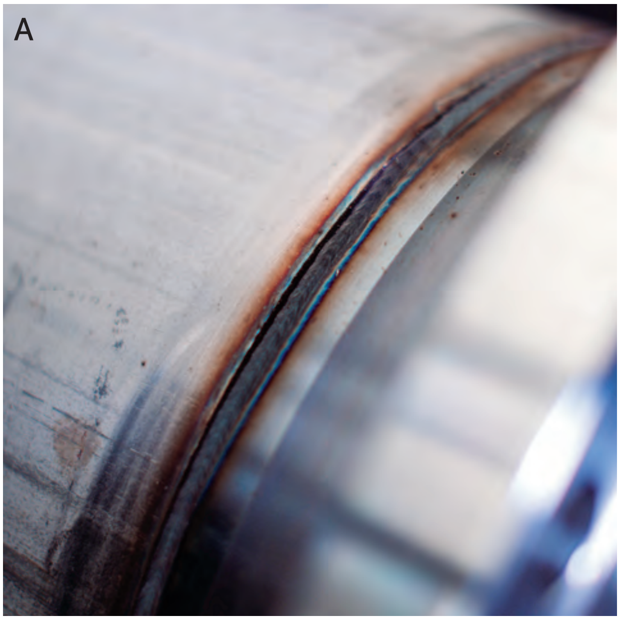


Fig. 2 — A — The outside of the pipe weld completed with a RMD root pass and flux cored fill and cap passes; B — the inside of a complete pipe weld, showing the backside of a completed weld. A switch from a GTAW to RMD root pass allowed welders to eliminate back purging.

RMD root pass with high-silicon wire, allowing the fabricator to eliminate the time-consuming and costly back purge on stainless steel pipe.

A modified short-circuit GMAW process uses precisely controlled metal transfer to provide uniform droplet deposition, which makes it easier for the welder to control the weld pool. Controlled metal transfer and faster pool freezing yield a less turbulent weld pool and ensure the shielding gas exits the GMAW gun relatively undisturbed. This allows the shielding gas to push through the open root, displacing the atmosphere and preventing oxidation on the back side of the weld — Fig. 2. Such gas coverage is only needed for a short time since the pool freezes quickly, eliminating the need for a back purge.

Some customers were initially wary of changing from the traditional GTAW process they were familiar with, but the productivity and quality results of the new process helped shift their mindset. The company sends customers coupon samples, and test results show welds just as high quality as what is produced with traditional methods.

"It pays dividends when the welder can stay under that hood longer. It allows us to do more work," Howell said.

Doubling Welding Productivity

Eliminating the back purge on stainless steel pipe proved a major time saver. Where the back purge used to take 20 to 30 min per pipe, welders could now be set up for the modified short-circuit GMAW root pass in about 5 min or less.

In addition, the wire-fed process is much more productive, allowing operators to complete more welds in the same amount of time. For an 18-in. pipe, the GTAW root pass and back purge followed by FCAW fill and cap passes often took a few hours. The modified short-circuit GMAW root pass with no back purge followed by a FCAW cap pass takes about 30 min.

"On average with GTAW, I was doing ten welds, and now I can get 20. It's definitely doubled," Welder Joey Sullivan said. "The quality is just as good, if not better, and the speed is a lot faster. Pretty impressive."

Those time and cost savings have added up and helped the company compete for jobs and complete work earlier than expected. The new equipment allows them to gain more arc time and produce more welds in a shift than before.

Producing Quality Welds

Welding stainless steel presents some unique challenges. The material is often thinner than carbon steel and can't take as much heat input during welding. The modified short-circuit GMAW process requires less heat input, helping welders avoid burnthrough on the material.

The company's welders also liked the consistent flow of the arc. It penetrates well and is more forgiving to changes in welder technique or an inconsistent gap between the parts.

"The gap doesn't have to be exactly the same all the way around, and it will make up for it," Welder Jeff Hannah said. "It's a lot quicker than the GTAW process we used in the past, with just as good welds."

Compared to the traditional short arc GMAW they had been using for carbon steel pipe, the modified short-circuit GMAW process doesn't blow out as much.

Since the process is more forgiving, it helps with training new welders and getting them on the floor producing quality welds quickly.

"We've always been proud of our quality," Howell shared. "Our reject rate on testing has always been very low. But I think this makes it easier on the younger guys coming in."

Ease of Setup and Use

Choosing a welding system with a user-friendly interface is another factor that makes training easier for all. Operators can just push a button to change welding processes.

"After we changed, we saw how easy it was to train everybody on this, even our apprentices," Henline recalled.

Having one multiprocess machine capable of every process that welders regularly use is a great benefit. The company outfitted ten welding cells in its shop with the system, eliminating the need to have two different machines for each of the various welding processes in which they work. A welder gets one unit with every

Fig. 3 — The new welding system lets welders change processes with the push of a button on one interface, offering simplified ease of use and reducing considerable time.

process at their fingertips, allowing them to switch from GTAW to SMAW to GMAW or RMD just at the push of a button.

Gaining a Competitive Edge

Making the switch in welding processes provided Dixie Mechanical with a competitive edge by helping them improve efficiency and reduce costs.

"I think we would be losing out on a lot more opportunities without it," Howell said. "It's a money saver, no doubt."

Their customers also noticed the efficiencies and faster turnaround times for projects. They are able to finish projects ahead of their due dates and have seen a growth in their business as a result of these changes in their practices. These results validate the company's decision to move into the new system and its shift in processes used. WJ

JEFF ROBEDEAUX (jeff.robedeaux@millerwelds.com), *CWI/CWE, is welding specialist, Miller Electric Mfg. LLC., Appleton, Wis.*

End-to-End Cloud-Based ERP is the New Now

Software solutions lead to greater efficiency for welders and fabricators

BY CHRISTINE HANSEN

On July 23, the New York Yankees took to the field at Nationals Park, and during the very first inning of the game, outfielder Giancarlo Stanton launched the first home run of the pandemic-delayed Major League Baseball season. Purposeful inspiration to go big was certainly on the mind of this ballplayer as he stepped up to the plate, picked the right pitch, and made a statement about the sport. Baseball was officially back. For many of us, like in baseball, getting back to what we do best has changed and looks a bit different from the way it did eight months ago. What has not changed is our drive to succeed and adapt. This is the new now, and we've got to get used to it if we want to flourish. What we've learned is that incremental changes and the adoption of key technologies, such as enterprise resource planning (ERP) software, can drive greater performance for greater success in the future.

Growing Customer Expectations Demand Innovative Technology

For welders and metal fabricators, much like many other industries today, the need to strengthen customer relationships and drive value in new, innovative ways continues. Expectations are evolving around responsiveness to change and accountability in areas like sourcing materials and ensuring employee health. As the workforce continues to look and feel different, investments in technology to support remote collaboration, mobile (and remote) workers, and business-to-business eCommerce portals that offer self-service oversight on job or shipment status both reduce costs and shorten time-to-market. Metal fabricator Dalsin Industries, Bloomington, Minn., understands this and the value that evolving technology delivers.

"Some of the most significant challenges we face are increasing customer demands from the standpoint of technical ability, documentation, and service lead time being reduced, but yet wanting it all for less," said Keith Diekmann, vice president of technical operations, Dalsin Industries. "It's very competitive out in the market today, so we must maintain our competitiveness through technology to reduce costs and time-to-market."

Communication across an extended remote workforce can be difficult but has proven necessary to continue to deliver a high level of experience to customers. Digital collaboration tools offer enhanced messaging capabilities for the business that allows employees

Fig. 1 — Give employees intuitive messaging with hashtags # and @ capabilities to improve communication.

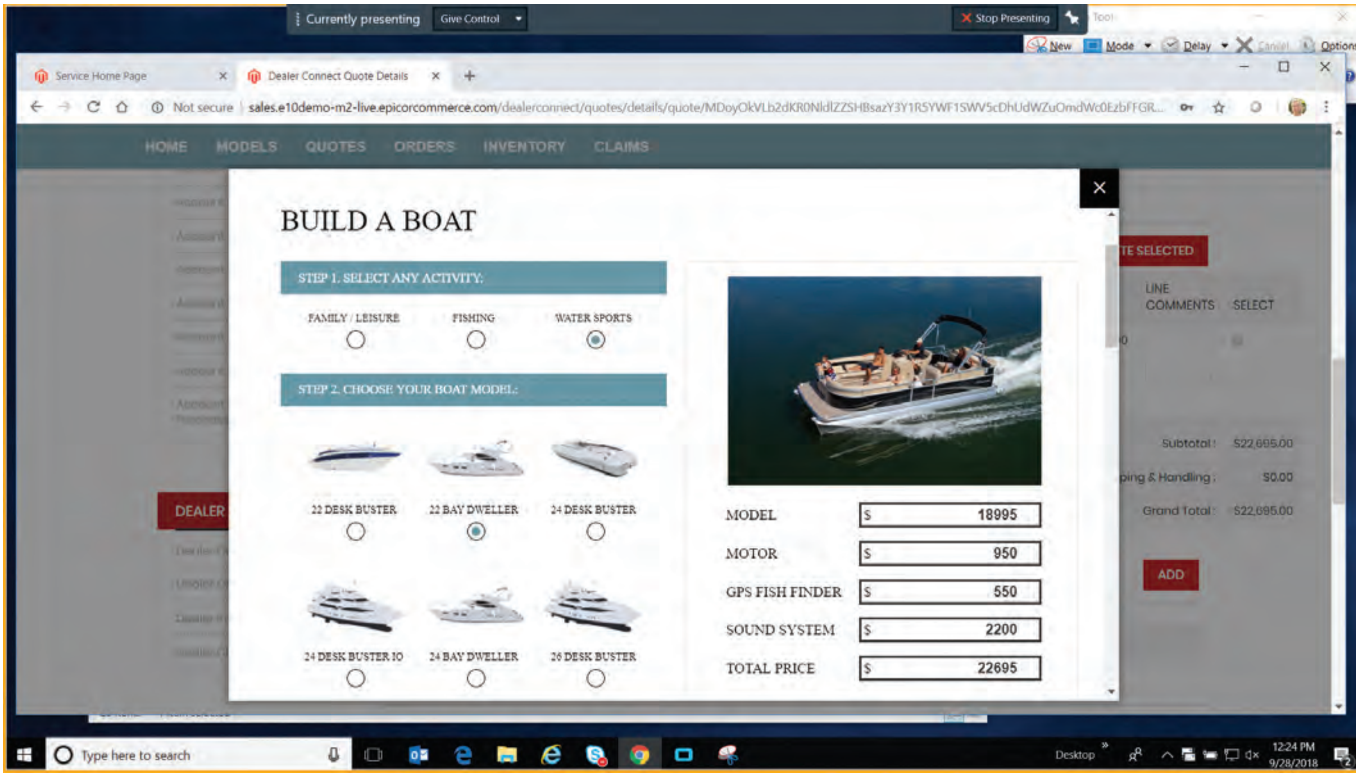


Fig. 2 — Target great experiences for customers with online commerce where they can configure and self-serve estimates.

to communicate with hashtags and @ symbols, two widely used social tools — Fig. 1. Additionally, businesses can integrate ERP events into message streams and build cross-functional teams that can solve problems quickly, reducing the clutter of emails, unnecessary notifications, and status update meetings. Everyone can easily be on the same page on a customer order, problem job, or ongoing project, even if the team is not physically together.

With businesses like Amazon seemingly competing against all industries, time-to-market from the point of order to shipment continues to be squeezed and shortened. In response, manufacturers are deploying online commerce solutions where customers can self-serve with quote requests, order repeat items, and even configure standard products for pricing right from a company's website — Fig. 2. Integrated to backend production systems, these configurations and orders are automatically transferred, validated, and sent to procurement or directly to production based on available schedules. Customers prefer the simplicity of electronic commerce solutions that allow them to quickly check on the status or review their account, especially during a time of such unease.

Reducing risk in the supply chain is also a high priority for customers who are now asking for greater insight into sourcing and alternative sourcing where available. The ability to deliver is now top of mind, especially when sourcing materials from certain regions of the world where delays in product or shipping may have occurred in the past. Also, closely managing suppliers from a quality and delivery perspective with scorecards and systems that support supplier audits and supplier corrective action requests not only offers benefits to the business, but it also demonstrates the rigor customers are looking for in trusted suppliers. Deploying quality management systems (QMSs) can help achieve these goals alongside the reduced cost of quality.

A QMS reduces the cost of quality across the enterprise by introducing standardized workflow for manufacturers that meets industry standards for compliance. This is critical in many industries for entry, but for others, the rigor of quality systems can provide a strong basis for reduced waste. Secondly, as many manufacturers look to deploy quality, a natural benefit is in the management of documentation that may be scattered. Understanding standard processes with strong documentation offers a critical tool when nonstandard events such as a returned item happen and the employee who handles that is on vacation or moved to another department to fill in for someone else. It drives a level of operational flexibility that is needed by businesses today to stay afloat against competitors. Quality systems also deliver a level of traceability that reduces time spent looking for or into what transpired. The audit trail is available for easy access. Lastly, customer interactions take a new tone as your customer service team is armed with accurate data when responding to reports of quality problems.

Greater Operational Performance with Complete ERP

Operationally, businesses continue to focus on doing more with less, improving operational productivity across the value chain while reducing overall costs. Traditional strategies of going paperless, continuous improvement programs, and digital transformation are initiatives that once offered incremental advantages. Now, however, as the majority of manufacturers are well on their journeys and competing at new levels, digital transformation is deepening across more processes. For many businesses, deployment of electronic content management, manufacturing execution systems (MESs), and Industry

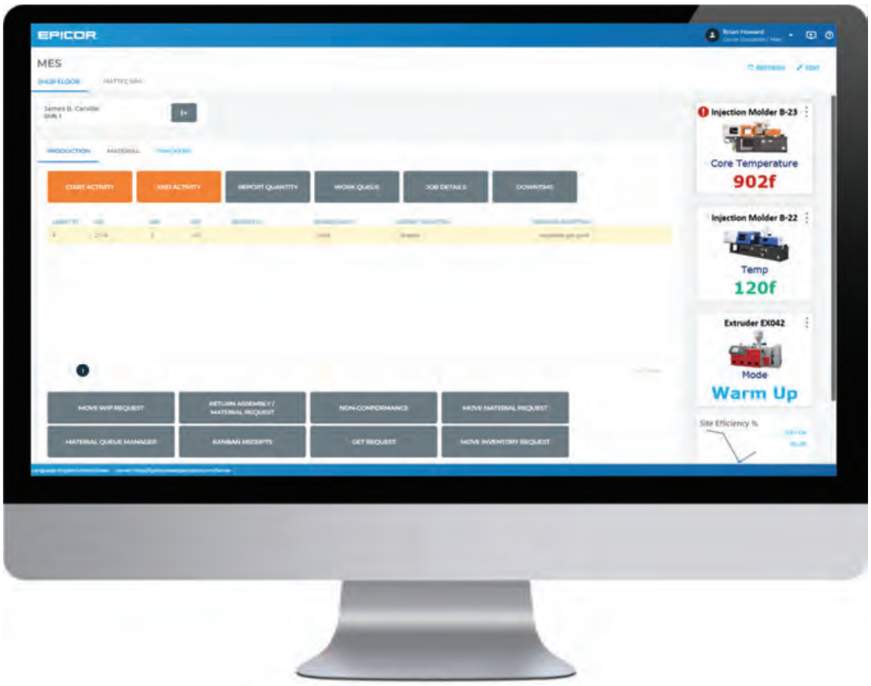


Fig. 3 — Leverage Industry 4.0, IoT technologies to drive new efficiencies for shop workers and greater equipment effectiveness.

4.0 technologies that drive new efficiencies for shop workers and offer greater equipment effectiveness translate to reduced costs and provide a path to offering greater value-added services for greater profits.

Outside the clutter that paper introduces, the "point-in-time" nature of paper-based processes means when things change, which is more likely than not to happen, the paper will need to be replaced with a new one. Going paperless, deploying electronic records instead of job packets with paper drawings and manually signed work orders, declutters operations. There are also many benefits to these digital processes that go beyond just going paperless on the plant floor. Alongside the environmental benefits of going electronic, operators can more easily receive queues of work from their MES and always know what is coming next in production. This wasn't as seamless before paperless options were available. Nowadays, workers aren't walking around looking for something to do or someone to ask what to do. Work is accurately logged with the time it took and the quantity completed, which helps to drive more informed estimates the next time around and delivers greater accountability regarding the cost of production.

Beyond a worker-driven MES, Industry 4.0 or the internet of things (IoT) technologies connect equipment notifications directly to ERP systems where the notifications can be filtered to what the business cares about — Fig. 3. For example, the business employees may not care about every weld joint being completed, but they may be concerned about the weld joint that failed. They would likely care more about the pieces of equipment that aren't running or that will soon need to be repaired. Keeping capital investments running optimally helps drive new levels of efficiency and productivity and reduces the cost of production, which are crucial during a time like this.

Serving customers at new levels, reducing costs to maximize margins, and delivering on expectations consistently will yield results. This is the new now — and this is the time to consider your technology journey.

Getting Current and Staying Current is Easy in the Cloud

Manufacturers on older ERP technology are quickly seeing they are at a disadvantage to compete. The path of least resistance and minimal cost for many businesses is to upgrade their technology and take advantage of what their vendor has to offer in the latest releases. For some that are many releases behind, the cloud offers a clear solution and is an opportunity to forge a new path forward. This is especially true when considering the cost of software updates, new hardware servers, and vendor contracts for installation and management of systems. The cloud continues to perform for businesses with limited IT budgets to ensure the security and sustainability of current systems. One of the values of the cloud that manufacturers who leverage the technology speak to consistently is that staying current delivers value in taking advantage of the latest innovative technology as it becomes available, without the disruption of a costly upgrade.

Conclusion

Much like after Major League Baseball's first home run of 2020, there is uncertainty around the challenges to overcome. Many businesses have spent the last several months pulling together resources to take on the unknown. What we do know, however, is that resilient businesses with agile technology will continue to compete strongly and win business. Serving customers at new levels, reducing costs to maximize margins, and delivering on expectations consistently will yield results. This is the new now, and this is the time to consider your technology journey. What will your business look like in 6–12 months? What part does technology play in your success? These are questions top of mind for many welders and fabricated metals manufacturers, and they will ultimately determine who is successful in the long-run. WJ

CHRISTINE HANSEN (chansen@epicor.com) *is principal product marketing manager, Epicor Software, Minneapolis, Minn.*

GMAW in the Internet of Production

Learn about the demands and challenges of this welding process in connected production systems

BY UWE REISGEN, SAMUEL MANN, AND RAHUL SHARMA

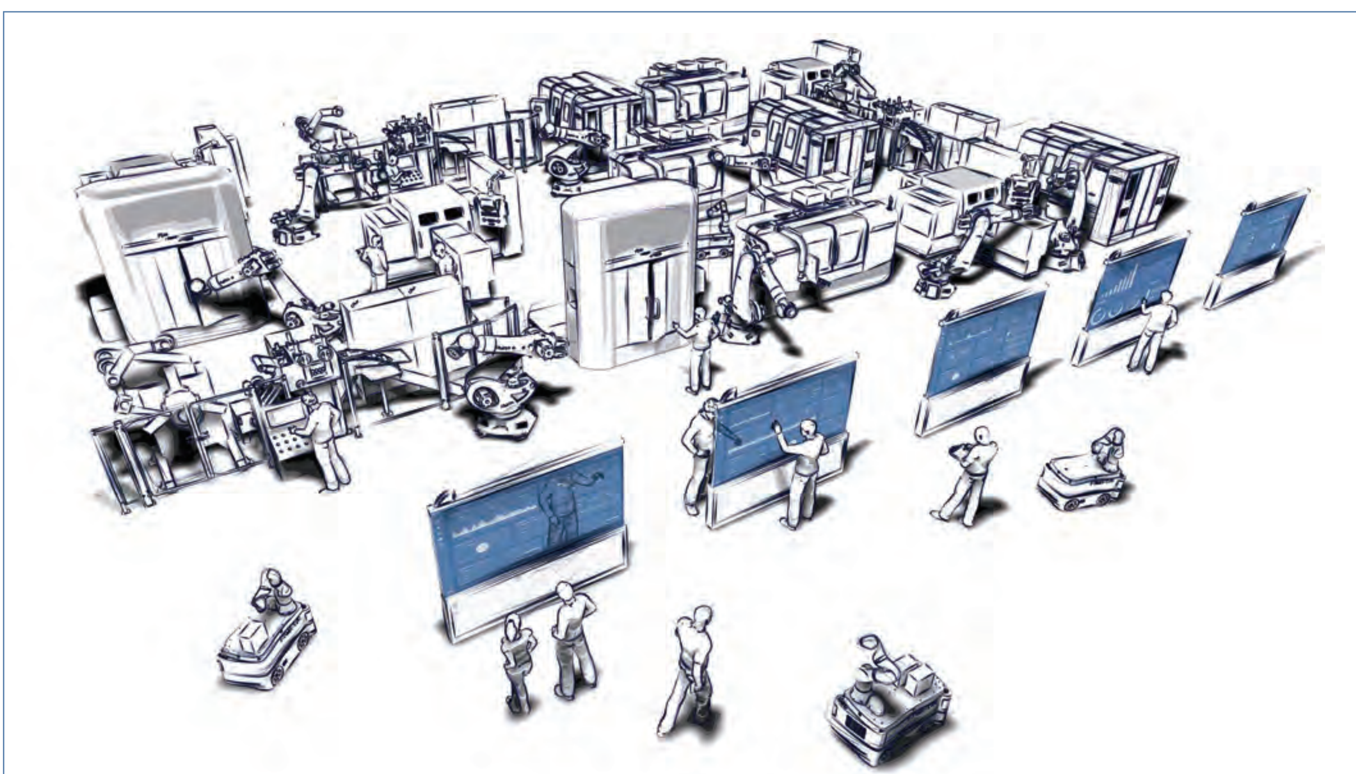
The Internet of Production (IoP) is a counterpart to the Internet of Things, but with production-specific data and applications. The IoP builds new data infrastructures for greater cross-domain collaboration by connecting all systems throughout the product's life cycle.

The utilization of connected information sources has led to a paradigm shift in value chains and society, but it remains largely unexplored within an industrial context. Initiatives such as Made in China 2025, Industrie 4.0 in Germany, and Industrial Internet Consortium in the United States are recent efforts to deliberately access and utilize information sources in industrial environments. But how do we utilize these developments for welding? And is this really necessary?

This article answers those questions by focusing on the gas metal arc welding (GMAW) process within a connected production environment, its closely related components, and how together they can lead to a better weld.

A Historical Look at GMAW Process Development

Historically, welding process development, especially for arc welding, is closely connected to the development



The utilization of data in a networked production environment is key to improving welding technology.

of power electronics and the signal processing electrical circuitry of the welding power source. Puschner established fundamental principles for the modern, pulsed-GMAW (GMAW-P) process in the mid-1970s with the development of the transistorized welding power source (Ref. 1). Due to a possible modulation of the welding current, droplet detachment was controlled without being bound to power supply alternating current frequencies, thus enabling a new degree of stabilization in the welding process.

In the early 1980s, patented concepts for arc-length control in the pulsed arc welding process described the superposition of several power sources with constant-current and -voltage characteristics using analog signal processing. Additional patent specifications appearing by the end of the 1980s detailed concepts for arc-length control that were based on the power electronics topology of the power source as well as its signal processing circuitry.

In the late 1990s, Merfert investigated the use of auxiliary power sources to improve the dynamics of inverter power sources and increase the potential in current climb rates from 1000 A/ms up to 4000 A/ms (Ref. 2). However, the increase in the current decay, and thus the possibility of withdrawing the stored energy at high speeds from the welding process, led to the development of advanced short-circuiting processes.

An important common feature of these GMAW process variants is the rapid decrease of the welding current shortly before the short circuit breaks. This counteracted the undesired, eruptive short-circuit release and minimized heat input by controlled current profiles. The well-known representatives of these process variants include Surface Tension Transfer from The Lincoln Electric Co., Regulated Metal Deposition from Miller Electric Mfg. LLC, and coldArc from EWM AG (Ref. 3).

Greater freedom in welding process development was introduced by the end of the 1990s with the dynamic change of the wire feed direction (Ref. 4). With this technology, the short-circuiting bridge could be released without relying solely on gravity, surface tension, or the so-called "pinch force" that appears in regular short-circuiting processes. With a correspondingly dynamic reversible wire feed, the jumper could be separated merely by retracting the wire electrode. The importance of high current density for a stable short-circuit release diminished, which decreased the high power requirements and spatter tendency. With reversible wire feed, the application range of the GMAW process has been extended, particularly in energy-sensitive areas such as welding of thin sheet metal or mixed metal joints. Although several welding power source manufacturers offer processes with reversible wire feed to this day, Fronius International GmbH was instrumental in developing this technology and bringing it to market maturity.

Even though the latter technology involved the mechanical feed of the wire, the advancement of the GMAW process was mainly linked to the development of power and signal processing electronics. However, due to increased digitalization in recent years, a new trend has emerged, especially in regards to inverter power sources. As a result, the power electronics of modern inverter power sources have sufficient dynamic potential (Ref. 2) for the material transition requirements of the GMAW process. They are also digitally controlled and have almost no effect on the welding behavior due to their constructional design (Ref. 5).

However, to meet the requirements that come with modern accelerated development speeds, the welding process control has to be considered part of a connected system, which provides greater comprehensive control. Only an open, flat, and hierarchical system topology enables the integration of external sensory, actuator systems, and data-driven models that improve the weld joint. Initiatives like Germany's Industrie 4.0 laid the infrastructural foundation for, and enabled the collection of, vast amounts of data that are necessary for current machine-learning approaches.

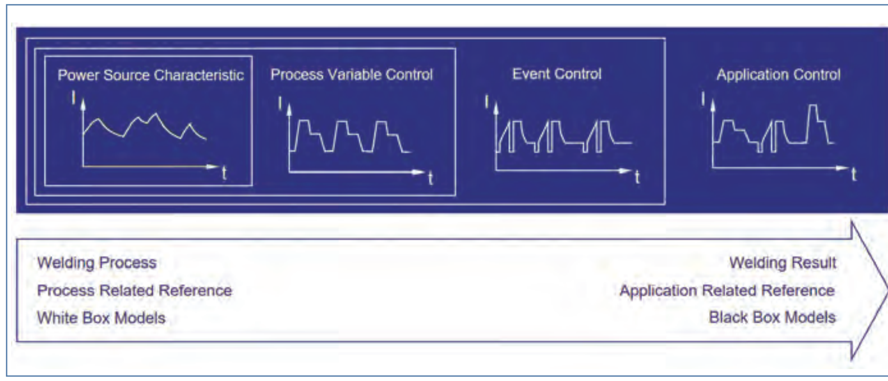


Fig. 1 — Categories for controlling the GMAW process (top) and process tendencies (bottom).

Stabilization and Control of the GMAW Process

The GMAW process requires a certain kind of stabilization due to its complex influences and variables. This section provides an overview on the categories of GMAW control and underlines the challenges faced by modern process development.

The categories, introduced on the top of Fig. 1, can be seen as control steps in modern GMAW processes, but they might not exclude each other. Additionally, the overall GMAW process follows certain tendencies that are shown in the bottom, blue arrow in Fig. 1. The requirements of the process control change; this stems from the welding process itself (the stability of material transfer) to the actual welding result (the weld joint and its properties).

Power Source Characteristic

The most basic kind of GMAW stabilization was introduced with the design of power sources that have a constant-voltage characteristic. In accordance with its power limits, the power source characteristic is capable of compensating arc-length disturbances, a critical process stability criterion. A shortened arc length decreases the overall resistance of the free-wire arc system, consequently increasing the welding current and therefore the wire melting rate until the initial arc length is reached.

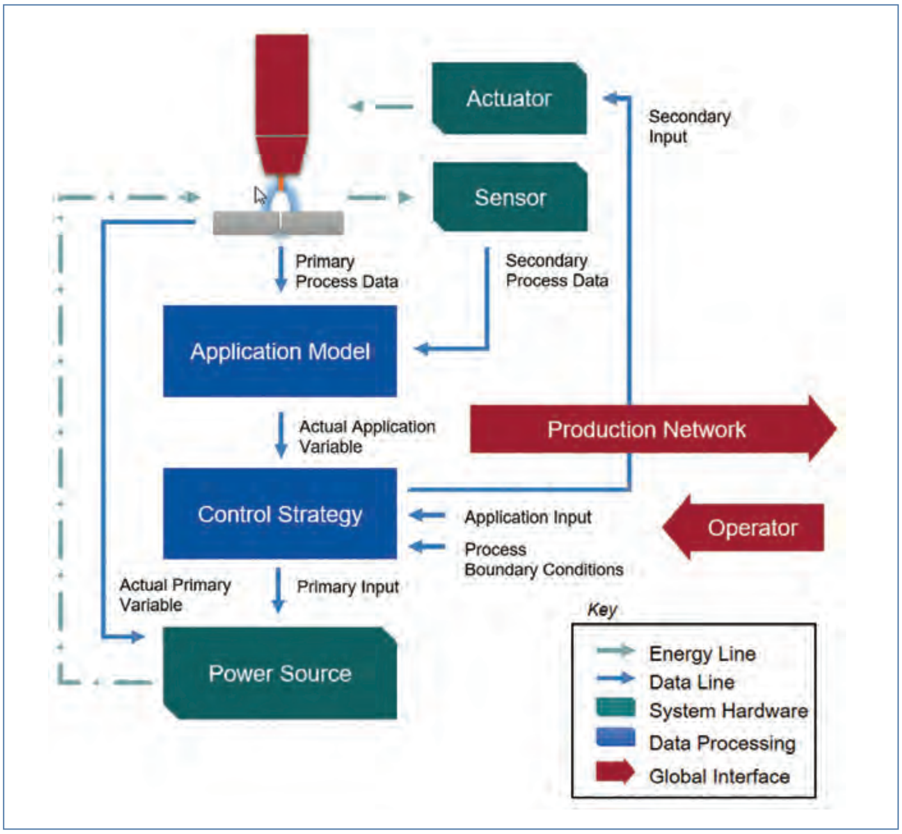


Fig. 2 — The function of an application model and a control strategy is shown within a GMAW setup.

Process Variable Control

With the introduction of transistorized welding power sources, the available electrical energy for GMAW has become transiently adjustable. The process working point no longer follows one characteristic power source curve but can be defined on a characteristic field, restricted only by the power limits of the welding machine and its dynamic behavior (Ref. 4).

The possibility to use variant voltage and the current reference input were the prerequisites for modern, GMAW-P developments that were no longer bound to supply frequencies. Process variable control is capable of forcing, e.g., a defined material transfer characteristic that occurs by periodically pulsing the welding current. But this control category is not capable of controlling droplet detachment itself because its sensory and data processing capabilities are not able to close the control loop.

Event Control

The GMAW process in general is characterized by discontinuity and certain, oftentimes stochastically occurring, events. Detecting subsequent events by means of welding process data becomes important in the context of unwanted, and especially poorly treated, short circuiting that may cause spatter, unreliable welding processes, or even termination of the entire welding process.

The event control category relies on advanced data processing (compared to simple process variable control) and knowledge on how to adjust the process parameters accordingly. For example, in 1989, The Lincoln Electric Co. patented a setup that detected the undershooting of the measured process voltage to initiate certain welding current profiles and actively resolved the detected short circuit. This measure was capable of reducing spatter and stabilizing the short-circuiting periodicity. However, closed-loop controls for application critical values, such as heat input per unit length or weld joint geometry, are impossible to attain under the event control category because they cannot be directly detected.

Application Control

The category of application control closes the loop between adjustable process parameters and application-relevant variables like weld joint geometry or the allowable heat input. The main differences between application control and the formerly discussed categories are the extent of model-based system mapping as well as the acquisition and processing of sensory information, which easily surpass the capabilities of current welding machines.

However, the formerly introduced categories of GMAW-process control are not substituted by application control. Instead, they remain necessary for their relevant tasks and are superimposed by application control strategies. For example, SKS Welding Systems introduced the Synchroweld process, which is capable of controlling heat input per unit length by accessing the robot welding speed. Changes in welding speed can be compensated by the welding process to maintain a constant heat input per unit length.

But why wasn't application control put into practice long ago? Regulating the weld joint quality can hardly be called a flash of inspiration. Welding — especially arc welding with all its aggregate states, varying boundary conditions, and materials — is still a scientific challenge and is not fully understood. The data-driven approaches in the field of machine learning that have appeared in recent years show great potential to map the complexity of arc welding.

However, it is important to note that well-trained welders with empirical knowledge will remain necessary and valuable despite all efforts to translate some of their knowledge into a production system.

GMAW Process Demands

GMAW production currently faces the following demands:

1) Temperature-sensitive, high-tech materials; high-tensile steel; nickel-based alloys; or complex surface coatings require not only the abidance of defined process windows but also the control of critical application parameters (e.g., amount of heat introduced into the workpiece). Other demands include ecological aspects like fume emission rates. However, the currently

available system solutions are not capable of performing sensorial mapping for these requirements. They are also unable to model the welding process variables to produce a closed-loop control for critical application parameters.

2) Setup and running time become even more critical, especially with today's aspiration of small batch sizes and individualized production. This trend requires even faster product and application changes that challenge the operability of modern GMAW processes.

Individualized production and small batch approaches require the transfer of application knowledge into the welding system, particularly within the context of limited process knowledge at the production site. For this purpose, corresponding application models are necessary to map the welding process parameters to the corresponding application target variables.

3) Within the context of production, the welding process itself can no longer be considered on its own. A welding system that may exist in a digitalized production network has to supply appropriate interfaces and the capability to extract pre-analyzed process information and parameters. Vast amounts of raw process data cause logistical storage and transfer problems; they are also barely digestible within the production network because they require interpretation.

In contrast to these demands, the welding process competence of the end user in association with process application is declining. Highly qualified welding personnel have become a rarity even in high-wage countries. Therefore, the lack of welding process knowledge has to be compensated by the welding production system.

Concept of Applied Application Control

The GMAW process provides a continuous fusion of the workpiece and melting of the wire electrode by means of the arc plasma by introducing electric energy. It relies on variables involving energy and material flow, along with their specific interactions, because the GMAW process does not describe an energetically stable state. The task of the welding system consists not only of providing the energy and material flow variables but also of their control and regulation in a continuous welding process.

In regards to application control, two methodological key principles come to the forefront as the complexity of the management variable increases. The first principle is the model representation of the application variable. The second principle is a corresponding control strategy that is capable of mediating between sufficient process stability and targeted quality. The function of both key aspects within a GMAW system are shown in Fig. 2.

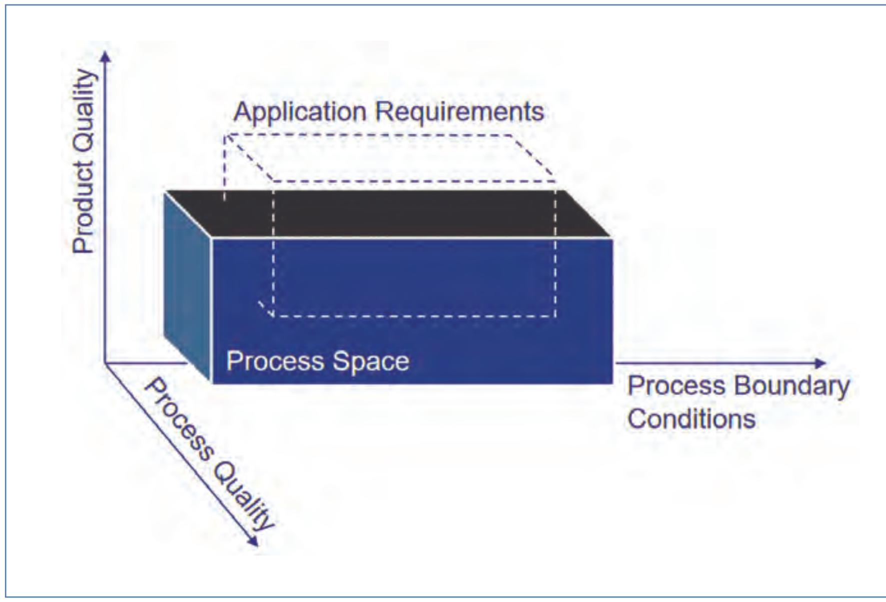


Fig. 3 — Requirements for a new welding system can be determined over a space spanning the dimensions of product and process quality at appropriate process boundary conditions.

Application Model

The input variables of the application model are the primary process data from welding current, voltage drop, and wire feed speed. In addition, depending on the application requirement, secondary process data must be acquired, which may be necessary for a sufficient description of the application.

Using energy per unit length control as an example, the welding speed has to be sensed as a secondary process variable because it is not directly involved in the electrical mechanism of the welding process. As a result, the output variable of the application model (actual application variable) provides a quantifying description of the application.

The application variable is particularly important when viewed in the global context of the entire production and the quality assurance process. Only the application variable allows a globally interpretable welding process description, thus providing an interface for networked production concepts. Machine vision systems are already capable of navigating cars through traffic by means of neural networks. It is not far-fetched that similar approaches will navigate the welding torch through the welding joint in the near future. A connected welding system lays the foundation for collecting crucial data. It also acts with all its components according to the specific application.

Control Strategy

The requirements for a new welding system can be determined over a space spanning the dimensions of product and process quality at appropriate process boundary conditions, as seen in Fig. 3. Process quality mainly describes the volatile properties and, for example, can be defined by spatter tendency or fume emission. Product quality can be defined by the mechanical/technological and nonvolatile properties of the welded workpiece.

The GMAW process, however, cannot be arbitrarily altered due to its physical process mechanisms without violating fundamental stability criteria, which are indispensable for a continuous welding process. Due to the dynamic and susceptible behavior of the GMAW process, the agreement between the application requirements and the actual process space is a continuous adaptation process. The GMAW system shown in Fig. 2 requires a management strategy based on the application requirement. This is decided only after clarification as to whether the executing components, in this case the power source and possibly external actuators or other system operators, can be controlled via suitable primary and secondary outputs.

Conclusion

Advanced material development, individualized production, and the demand for production system networking form the very core of modern GMAW process requirements, especially while the available human competence for process application declines. However, the development of GMAW processes has come to a turning point where the power source circuitry itself no longer restricts advancements in the GMAW process, its interfaces, and the implemented model-based application knowledge. Applied application control is capable of supplying necessary approaches for a local system network consisting of a welding power source, actuators, and sensors for short-time scale control tasks. Viable application knowledge can therefore be transferred into the welding system without relying on rare human process knowledge. In addition, this approach is capable of scaling into a larger production network by supplying aggregated process information via the application variable to generate benefits, e.g., for quality control or general production management. WJ

Acknowledgment

Funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under Germany's Excellence Strategy – EXC-2023 Internet of Production – 390621612.

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UWE REISGEN, SAMUEL MANN (mann@isf.rwth-aachen.de), *and RAHUL SHARMA are with RWTH Aachen University, Welding and Joining Institute, Aachen, Germany.*

Leveraging New Technology Can Add to Your Bottom Line

Using the value chain approach to enhance and improve operations

BY RICKY LUDEMAN AND JUSTIN MORSE

The manufacturing industry has shown productivity increases through the value chain analysis. For example, alloy pipe welding with GMAW-S and FCAW is outperforming traditional manual processes.

In an evolving world fueled by high-speed needs for products and information, the growth of technology has been at the forefront of making these demands a reality. Whether it's having a package delivered to your door in a day or large amounts of data shot across the globe in fractions of a second, we can all thank the myriad of technological steps that make this all possible. In parallel with these advancements, and fueled by technology, the productivity of the global economy continues to grow and expand. However, the construction sector is one industry that has not shared the same productivity increases as the global economy — Fig. 1. Instead, construction is lagging the overall global economy by a $1.63-trillion gap in productivity.

While the construction industry has been slow in efficiency gains, another similar industry had been experiencing steady growth year-over-year. The manufacturing industry has been leveraging ever-evolving technology, nearly doubling its dollar of productivity per worker compared to the construction industry, which has remained relatively stagnant over the course of 10–15 years — Fig. 2.

Evolution in Manufacturing Technology

Manufacturing has continuously pushed the boundaries of technology over the decades to make productivity increases. These advances are readily apparent. For example, compare the Ford assembly line in the early 1900s, which was sweeping technology for that era, to the modern automotive assembly line, which is nearly fully automated by comparison. This evolution in technology is the catalyst for greater production and higher output of products, which, in turn, generates greater revenue and higher profits. Even though on the outside manufacturing and construction may not seem like a fair comparison, both industries see many of the same constraints, such as shortage of skilled labor, fierce competition leading to tighter margins, similar economic environments, sudden increases in regulatory oversight, and increasing complexity of the products they produce.

With the obvious successes of technology implementation in manufacturing, figuring out ways to have similar achievements in the construction industry should be at the forefront for anyone trying to improve their own business practices. The key to making the leap is being able to identify what technologies will create a positive return on investment (ROI) and which ones are smoke and mirrors.

How did the manufacturing industry determine the need for technology and the type that was appropriate? One way was by utilizing the value chain analysis and lean metrics approach to determine the appropriate technology that would complement the products to be produced in conjunction with reducing the overall cost of production. This is by no means a new theory — first gaining prevalence in the late 1970s to early 1980s partially due to a large automotive manufacturer's strict adoption of these tools — but it is widely misused, most often over forecasting benefits while not fully understanding the potential pitfalls. These factors may be some of the reasons why these tools have been underutilized in the construction industry.

The Value Chain Approach

The steps to implementing the value chain approach are simple, but the key is fully understanding the available options and all the associated implications at each step.

The three key tenants to utilizing this technique (as modified to be more applicable to industrial operations) are improve quality, eliminate waste, and reduce time. Any operation can be measured utilizing these three points to gain an accurate image of where the greatest efficiency gains can be had. These are the tools that allow us to take a page from manufacturing's book and place a critical lens on construction operations.

Field welding operations have lagged many other operations within the construction industry. Gas tungsten arc welding (GTAW) and shielded metal arc welding (SMAW) are the predominant processes widely used throughout the welding industry and have been for decades. Technology advancements for welding are available to the industry, just underutilized. A lean business analysis can sort through which available tools are appropriate for your welding needs.

Fig. 1 — Economic value loss of the global economy vs. the global construction sector.

Contractor Looking for a Competitive Edge

Field construction operations are prone to being mired in the old way of doing things. The adage "don't fix what isn't broken" is a common phrase heard when trying to implement new means and methods in an industry rooted in legacy. However, the way

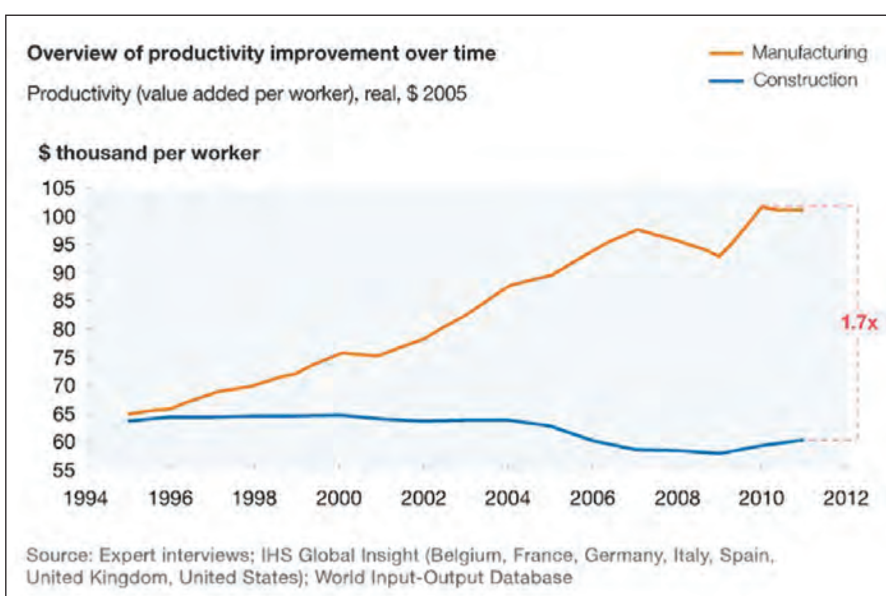

Fig. 2 — Manufacturing vs. construction worker productivity.

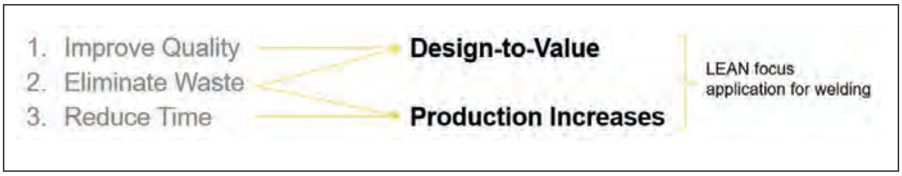

Fig. 3 — Value chain analysis breakdown for welding operations.

work is currently being done is "broken" if looked at from a value-added perspective.

For example, at Kiewit, Omaha, Neb., the welding team could see there was room to generate more value within the field welding operations. GTAW and SMAW were the default choices for field pipe welding for most contractors and, at the time, were viewed as the only choices because that was the industry norm. It was assumed that doing anything different would either cause a detriment to quality or would be more costly. However, to convince projects to abandon the old way of doing things for new technology, the team had to justify that leap to get buy-in from management. The initiative to standardize gas metal arc welding (GMAW)/flux cored arc welding (FCAW) for the company was based on the same approach manufacturing uses — value chain analysis.

Value Chain Analysis to Field Welding

As previously mentioned, the value chain analysis can generally be broken down into the following three steps: 1) improve quality, 2) eliminate waste, and 3) reduce time — Fig. 3. To suit these steps to field welding operations more easily, the three steps were further combined into two because waste, in this sense, is not referred to as material waste but rather as wasted company resources. Also, an important facet is that labor cost is such a large part of any welding operation, so the reduce time step was rebranded as production increase in our scenario.

Design to Value

The design-to-value approach focuses on providing a product that meets the minimum requirements by contract or code of construction. Minimum is often seen as having a negative connotation, but in this instance, it is positive. Most contractors would agree that giving away product or time is not a sound business practice. To analyze the design-to-value metric, one must first understand what is being built. In the world of construction, a universal ask of any client is to deliver the project they want on budget and on schedule. Overbuilding is a quick way to undermine all of those desires and ultimately create an unhappy client. If a client asks for piping to be built to the American Society of Mechanical Engineers B31.3, *Process Piping*, they are not going to be upset if you understand and use the weld acceptance criteria contained within. Additionally, as a contractor, wouldn't you rather fully understand those costs when bidding to be competitive?

One example of doing a design-to-value analysis switch from GTAW for open-root welding to an advanced-waveform, short-circuit GMAW (GMAW-S) process is the removal of the need for internal purges. Most codes do not require a purge for materials such as stainless steels, but a purge is a necessary evil baked in if open-root GTAW is the process selected because GTAW does not physically work without it in this case. Switching to advanced-waveform GMAW-S allowed for the development of procedures. It also alleviated the need for purges while still maintaining the end quality required by the client for the intended service but at a vastly reduced cost.

Production Increases

When discussing welding production, there are two metrics that are important. First is deposition rate, or how many pounds of filler metal can be distributed in a fixed amount of time (typically pounds per hour in the United States). Second is operating factor, or what percentage of time (in any time frame) a welder spends depositing metal vs. other things, typically measured as a percent. Exploring these two metrics is the key to unlocking greater welding production.

Deposition rate is probably one of the easiest ways to increase production. For example, just by trading SMAW for FCAW, one can achieve at least a doubling in deposition if not more. The same type of production increase was also seen going from GTAW to GMAW for root welding. Simply by switching a process, we can drastically increase our production. These types of process changes are also within a company's control.

Increasing operating factors can present challenges and often requires looking at the project in its entirety, not just at any particular weld. Again, the goal of the operating factor is how we keep a welder's hood down. As a company, Kiewit deconstructed its internal welding operations and observed that welders were not welding nearly as much as one would think, but it wasn't necessarily his or her fault. There are so many steps, some necessary and some not so necessary, that make up a typical shift that it is hard to get a high percentage of true welding time. Here, a value analysis is helpful in discovering tweaks that can be made to facilitate increases in operating factor.

One classic example here is the SMAW to FCAW comparison again. With SMAW, the welder is forced to stop after every electrode, discard the stub, and grab a new one. Also, good practice here is to clean any slag from the area being welded to avoid defects down the road. However, all these baked-in steps don't generate any additional value, i.e., the time the welder is forced to spend not welding doesn't make a better final product. Thus, any way to eliminate that step should be explored. Through swapping to FCAW, that welder can now weld for drastically longer periods of time, only stopping to reposition (and this repositioning step can also be seen as non-value adding and explored, etc.). Both processes create the same code-compliant final product, but one of them does it in drastically less time.

Another operating factor-related area to analyze is what does access look like for the welders? This doesn't just encompass having good access to the weld itself, but what does access look like to the rod room, break shack, or bathrooms? If the filler metal management program requires welders to pull new consumables every morning and at the start of any new weld, that could be an extra 15–30 min a day spent walking to a rod room that was not conveniently located. If there are 20 welders over the course of a year doing this, how does that math add up in your operation?

Vetting Potential Options

The goal to the vetting process is to minimize risk when making drastic changes to the way welding was previously done. During this step, there will most likely be multiple options for process improvement. For each option, the theory of increasing output needs to be proven, the upfront costs and ROI need to be understood, and any downside risk needs to be explored. Most importantly, there must be no detriment to the final product quality. Diminished quality is the greatest risk assumed and outweighs a failed ROI. By the end of the vetting process, the best option should rise to the top and will be the one the team needs to champion.

During Kiewit's analysis, the team determined the best fit for the types of welding applications the company had was advanced-waveform GMAW-S coupled with FCAW. The selected product met all the company's needs and had a quick payoff period. Additional testing was also performed at this juncture to alleviate quality concerns and begin to develop new operating procedures.

The key to making this analysis work is knowledge of your current costs, understanding of your contract and code requirements, and honesty regarding what type of investment and changes it will take to get there.

Developing Buy-In

Creating buy-in can be a challenge across any company adopting innovation. A large percentage of technology-based initiatives fail in all industries due to lack of stakeholder buy-in, innovation fatigue, and failure to support the transition. There is not an executive or project manager who doesn't want a project to be more profitable, but there is always a risk of a negative outcome that needs to be weighed. Changing culture and legacy (or old ways of welding) is difficult but can be overcome with a pragmatic approach. When developing stakeholder buy-in, we need to understand all the parties affected by the adaptation of changes, which for Kiewit, and not unlike most industries, were the contractor (the company), the owner (or client), and the craft workers.

The company is going to have concerns of what the return on the investment looks like, warranty risk, and finding a pool of qualified welders to perform the work. By providing factual data upfront to management teams, along with additional research and development, a comfort level can be had when it comes to ROI and warranty issues. To address training welders, plans were put in place with the local unions to train welders, and internal welding training programs were developed to standardize getting welders to the level of competency needed to not diminish quality.

Owners and end users are going to have concerns on warranty and performance risks. Often, changes toward increased construction efficiency are viewed as "corner cutting" or somehow a lower-quality product. Along with that, many owners have specified that GMAW-S is not permitted on projects due to long-held truisms. Strong companies pushing new technology will provide good explanations and benefits of the processes. Small investments on additional testing also provide great comfort levels for owners. Over the years, as advanced-waveform welding has seen greater adaptation on projects, there is a greater comfort level with clients and their corresponding specifications. As an industry, we need to keep this trend going.

Lastly, we look at developing buy-in from the skilled men and women performing the work. If we are going to ask a workforce to completely change the way pipe welding has been done for decades, we have to be cognizant that we are also affecting their job security in an industry where welders are always one failed joint away from losing their job. As a company, showing empathy for this change is key. We are pushing the change and need to support whatever is required to ensure all parties are successful. For example, teaming up with local unions to provide a greater level of training and staffing projects with welding support personnel has helped Kiewit gain the buy-in from craft to make it successful.

Out with the Old, in with the New

Change is no easy task, especially in an industry that has highly ingrained ways of operating. Asking the question "why?" about any of the facets of your operations is a good place to start, and analyzing the value generated at each step is really the crux of the issue. If an operation seems superfluous and is done "just because we always have," it is probably a good candidate to analyze. If a task appears lacking in value, then ask what changes can be implemented to make it more valuable or maybe eliminate it altogether.

Also be aware of trying to force fit technology into old ways. Any technology adopted this way is doomed to fail. For example, if a certain technology allows for faster welding, a crew makeup may need to change to feed that new demand. If this is not taken into account, then the new technology will be underutilized, and the goal of increased production will not be realized.

Ultimately, there is not a one-size-fits-all approach for any company or project. What worked for Kiewit may not work for its competitors. The key to making this analysis work is knowledge of your current costs, understanding of your contract and code requirements, and honesty considering what type of investment and changes it will take to get there. WJ

RICKY LUDEMAN (ricky.ludeman@kiewit.com) *is welding technical services manager and JUSTIN MORSE is welding director at Kiewit, Omaha, Neb.*

Harris Salutes Workshops for Warriors' Veteran Programs

Workshops for Warriors has trained more than 700 veterans who have earned thousands of nationally recognized portable, stackable certifications and are working in every state.

November has been declared National Veterans and Military Families Month in honor of the service members who have answered the call of duty for the United States. This appreciation is further emphasized by companies and organizations who offer special programs for veterans.

Just as they've helped our country, sometimes our comrades in arms need assistance when transitioning to civilian life.

The Harris Products Group, Mason, Ohio, and its parent company, Lincoln Electric, Cleveland, Ohio, have long supported veterans with established programs and also back several outside organizations that play significant roles in helping veterans.

One organization that is making a difference in service members' lives is Workshops for Warriors® (WFW), San Diego, Calif., a nonprofit organization that trains and certifies veterans and transitioning service members in welding and computer numerical control machining for careers in advanced manufacturing — Fig. 1. The organization's motto is "Rebuilding American Manufacturing, One Veteran at a Time®."

Since its inception, WFW has trained 700-plus veterans who have earned more than 6000 nationally recognized portable, stackable certifications and are working in every state of our nation.

Meet a Graduate Who Welds

Gabriel Lara is one example of the hundreds of veterans who found a purpose with the help of WFW — Fig. 2.

Lara, 22, grew up near Los Angeles, often in the same room as his two siblings and mother. Because they didn't have much, they moved around a lot, often renting one room of an apartment where they would all live together.

At 17, after a recruiter from the

Fig. 1 — Workshops for Warriors provides veterans and transitioning services members with advanced manufacturing training and industry-recognized certification for careers in welding, machining, and fabrication at no cost to the veteran.

Fig. 2 — After serving in the Marine Corps, Gabriel Lara found a purpose with the help of WFW. He graduated from its program and earned ten nationally recognized welding certifications.

Marine Corps visited his high school, Lara enlisted. Eight days after receiving his diploma, he was in boot camp.

"It was a shock, a really big shock," he said. "But I knew I wanted to do something I could be proud of and my family would be proud of too."

Lara served in logistics and maintenance management, where he was responsible for inventorying and instituting preventive maintenance for his entire unit's gear. In 2017, he was chosen for a Special Purpose Marine Air-Ground Task Force, which put him in Kuwait and Afghanistan.

Near the end of his service, Lara began tossing around the idea of returning home to Los Angeles and maybe using his G.I. Bill to enroll in college. Almost immediately after transitioning out, however, his girlfriend found out she was pregnant and suddenly, his timeline for finding a job got much tighter.

"Everything changed all of a sudden. With a pregnant girlfriend and a baby on the way, I knew I had to find a way to support them," Lara said. "I needed something I knew would give me financial security quickly. I needed my daughter to have more than I did growing up."

After attempting community college for a couple of months, Lara found out about WFW.

"Before Workshops for Warriors, I felt lonely, like I didn't really have a purpose," he said. "Here, everyone is a veteran. I feel like I got some of that brotherhood back, and we are all learning a trade that will give us financial security and a future as America's manufacturing workforce."

Though faced with unforeseen challenges and adjusting to remote learning due to COVID-19, Lara graduated from the welding program on April 23, earning ten nationally recognized welding certifications. Now married with a daughter, Lara plans to move with his family to Nevada, where he hopes they can buy their first home.

Sales from Metalworking Outfit to Make a Difference

A military history buff with several veterans in his family, Harris's industrial sales manager for North America Patrick Fagerquist learned about WFW several years ago. After spending time at its school in San Diego and seeing the significant contributions made by the organization, he suggested that Harris create a promotional program to draw attention to WFW and raise funds for its operations.

Fagerquist took his idea to Greg Barnes, a graphic designer at Harris and a fellow veteran. Having served four years in the U.S. Navy before going to work at the company, Barnes recognized firsthand that military training does not always translate to a civilian job.

"I was a damage control petty officer in the Navy and was responsible for maintaining firefighting equipment on the ship," Barnes said. "That doesn't translate well into a civilian job, so I decided to go to art school. I am like most veterans — good with my hands. What Workshops for Warriors is doing is amazing because affording a veteran the opportunity to have a career in welding can be a perfect fit. That is why I was excited to be a part of this project. I wanted to develop a product that would pay homage to our military personnel and what they mean to this country."

Harris rolled out its new limited-edition Ironworker outfit in June and, for every outfit sold, will donate $5 to WFW, with a goal of raising $25,000. The company is also encouraging its distributors to donate $5 per outfit sold.

The Ironworker outfit is packaged in a U.S. government-issued, 40-mm metal ammunition can with side-carry

Fig. 3 — Harris Products Group is selling limited-edition Ironworker outfits to benefit the organization. They come in a U.S. government-issued, 40-mm metal ammunition can and feature Model 25GX gas regulators with a special digital-camo pattern.

handles and a removable lid — Fig. 3. It features Model 25GX regulators with a special digital-camo pattern. The regulators come with a seven-year warranty. The outfits are available in Harris Series and V-Series with either 300 or 510 CGA fittings. They also come with a cutting tip, shade 5 safety glasses, ignitor, and a 3/16-in. × 20-ft twin grade "R" hose.

Parting Words

"We are extremely proud to support the efforts of Workshops for Warriors," Fagerquist concluded. "This organization is providing a valuable service to our industry, as well as helping those who have served our nation and are looking for new ways to help it succeed." WJ

Information provided by The Harris Products Group (harrisproductsgroup.com), *Mason, Ohio.*

As a special addition to this *Welding Journal,* enjoy these Company Highlights from advertisers and exhibitors that would have participated in FABTECH. These pieces detail the resilience shown by the industry this year as well as spotlights on product offerings.

Abicor Binzel USA Inc.

2020 has proven to be a challenging year for everyone, but ABICOR BINZEL USA has stayed committed to providing high-quality welding solutions and top-notch customer service through it all. In September, the company officially launched the xFume™ Advanced and xFume™ Robo as additions to their ever-growing xFume product line. The Advanced is a portable fume extraction system that, when paired with the xFume MIG torch, provides optimum fume extraction at the arc to keep welders healthy and facilities free of toxic weld fumes. The Robo uses these same principles and applies them to robotic welding. Its patent-pending design fits onto all of their existing robotic torches. The flexible suction boot, and hose management provide at-the-source fume extraction without interfering with your established welding process.

(301) 846-4196
binzel-abicor.com

Aimtek Inc.

Aimtek offers turnkey solutions for the automation of specialized joining and coating processes used in the Aerospace industry, such as gas tungsten arc welding, brazing paste application, resistance tack welding, and thermal spraying (plasma, twin wire arc, and HVOF). The company designs, builds, installs, trains, and offers after sales support on each customer-centric solution. Offerings range from traditional and collaborative multiaxis robots to end of arm tooling, as well as the consumables needed to keep automation rolling. Though they face challenging times due to the pandemic and its impact on all aspects of life, the company has invested in itself, purchasing a new hydraulic press and CNC milling machine. The engineering department has grown, and the company has maintained the entirety of its full-time workforce, operating at full capacity and ready to assist customers as they come back online.

(508) 832-5035
aimtek.com

Airgas® an Air Liquide company

As everyone continues to cope with the effects of COVID-19, Airgas is showing their customers how to achieve sustainable cost reductions and become more competitive. The Unlocking the Hidden Cost of Welding™ program creates value for companies by helping them benchmark their performance, create and implement an improvement plan and track progress. Their ARCAL™ shielding gas line covers any welding application and exceeds AWS A5.32/ISO 14175 standards. Simplify arc welding with a concise Reference line of five ready-to-weld pure argon and argon/CO_2 mixes. Their Technical line offers customized mixes for special applications with tight specifications. It is available in a range of innovative supply modes adapted to meet customers' needs, including cylinders equipped with SMARTOP™ and EXELTOP™ valves designed for safety and consistency.

(800) 909-8058
airgas.com/unlocking

AGT Robotics

AGT Robotics is a Canadian robotic integrator whose team has delivered hundreds of automated systems across North America and beyond over the last 25 years. The BeamMaster WELD is an award-winning robotic welding system specifically engineered to answer the welding needs of structural steel fabricators. This system helps to fill the gap left by the skilled labor shortage by tackling the bulk of welding jobs, allowing fabricators to apply their skilled labor to more challenging tasks. Business owners love the system for its affordability and its impressive return on investment. Users love it for its ease-of-use (absolutely no robot programming) coupled with the productivity and predictability it brings to production schedules.

(819) 693-9682
agtrobotics.com

Air Purification Inc.

Air Purification is an exclusive distributor for indoor industrial air pollution equipment as well as replacement filters. The company is offering COVID-19 Virus Eliminating Ambient Air Cleaners for industrial applications. The company has proven solutions to help collect the smoke and fumes from welding cells. Premium welding ventilation hoods collect welding smoke and fumes, even oily welding smoke, right at the cell with no ducting needed. We have perfected school welding station units. Ours are easy to use and maintain while providing a safe workspace, adjustable table surface, acoustical liner for noise control and good energy efficiency. We've been serving our customers for over 35 years and 2020 has been no different.

(800) 829-0225
airpurificationinc.com

ALM Positioners Inc.

ALM Positioners is a manufacturer of 1-, 2-, and 3-axis positioners. Established in 1982 in Streator, Ill., the company began building positioners in 2002. In 2015, they relocated to Rock Island, Ill., to a state-of-the-art, 24,000-sq-ft facility. With over 30 employees, they provide positioning solutions to customers across 13 industries, ranging from custom manufacturing shops to Fortune 100 companies. During this time, ALM has focused on developing Heavy Duty (HD) line of positioners and PROBOX® lifts. Currently, the HD line consists of a 12K lb Skyhook, 75-125K lb Headstock & Tailstock, and now a 20K lb single column. The PROBOX® lift is geared towards the agriculture industry to nest and de-nest seedboxes. As the leader of intelligent positioning equipment, customers rely on their innovation, experience, and product quality to help them succeed.

(309) 787-6200
almmh.com

Ambrell® Corp.

Founded in 1986, Ambrell, an inTEST company, is a global leader in the induction heating market renowned for its application and engineering expertise, including its complimentary applications testing from THE LAB at Ambrell. THE LAB has extensive experience with applications like brazing, soldering, and pre- and post-heating for welding. Exceptional product quality and outstanding service and support are at the core of their commitment for customer experience. Headquartered in the United States with operations in Europe, including the United Kingdom and The Netherlands, all products are engineered and made at their ISO 9001-certified manufacturing facility in the United States. Over the last three decades they have expanded their global reach through an extensive OEM and distribution network. Today they have more than 15,000 systems installed in over 50 countries.

(585) 889-0286
ambrell.com

ATI Industrial Automation

ATI Industrial Automation's AOV-10 axially-compliant orbital sander is the ideal robotic solution for surface preparation and finishing. A pneumatically-actuated compliance mechanism allows for dynamic control of contact forces and ensures an ideal result every time. Users can mount the sander directly to their robot or to a fixture, in any orientation, including upside down. The design is compact and lightweight, which suits a range of robot sizes and types, from cobots to industrial models. The company has designed and manufactured robotic end effectors for over 30 years. Since 2017, they have been devoted to providing solutions for automated material removal that make customers' lives easier. With a dedicated robotic material removal lab and an expertly curated team of engineers, thediverse Material Removal Tool product family is rapidly expanding.

(919) 772-0115
www.ati-ia.com

Automatic Welding Wire Co.

AWW is part of Plasticos y Alambres SA (PYASA) group. The company manufactures wires for gas metal arc welding (GMAW), and wires and fluxes for submerged arc welding (SAW), as well as wire forms. They pioneered the manufacture of welding wire in their own drums, achieving one of their main goals to improve productivity by having the fastest, most productive and reliable welding wire in the market. The company offers wire in 990, 550, 500, and 220 lb drums. We also carry 2, 10, 33, and 44 lb spools. Earlier this year, they launched a 2000 lb wood reel for the U.S. and Canada. Their drums have a patented system, which guarantees no tangles, greater arc stability with less spatter, assures 100% wire consumption and wire will always unwind in the same direction as the contact tip. They are suppliers for several industries including automotive.

(210) 277-9451
pyasa.mx

Aquasol Corp.

Since its inception in 2003, Aquasol has dedicated its resources to developing patented products that enhance welding efficiency including water soluble paper and tape; EZ Purge® pre-formed water soluble purge dams; I-Purge® and I-Purge X® advanced mechanical purging devices; EZ Zone™ purge gas retaining tape; EZ Wipes® multipurpose 55% alcohol wipes; Fiback® fiberglass backing tape; PRO OX-100/Bluetooth-enabled 100 PPM oxygen monitors; water soluble and stainless steel socket weld spacer rings and SoluShim® alignment sticks. As an internationally recognized leader in the manufacturing of advanced purging technology, the company remains optimistic despite COVID-19. They continue to offer same-day order fulfillment and shipping. They also offer support to their distributors and encourage them to contact them to obtain product samples and brochures; flash drives with product presentations and videos free of charge.

(716) 564-8888
aquasolcorporation.com

Auburn Mfg. Inc.

AMI is the largest producer of FM-approved hot work fabrics in the U.S. The company was the first to have all of their fabrics approved to ANSI/FM 4950, the performance test that revolutionized hot work safety. They have developed over 20 different curtains, blankets, and pads for every job from combat ship repair to auto body repair. A U.S. manufacturer with decades of development and production experience with fire-resistant textiles, their more recent AMI-GUARD™ line of quilted or cut and sewn covers are used for hot work and specialty insulating covers of all kinds. Its newest innovation is Fire Quilt™, a modular cover that can stand up to any hot work job. Not only can it stand on its own, it can be easily stored and re-used again and again, thanks to a 3-layer construction finished with a tough carbon-infused outer coating.

(800) 264-6689
auburnmfg.com

AXXAIR USA Inc.

AXXAIR USA is the U.S. subsidiary of the French group AXXAIR, manufacturer of high precision orbital tube and pipe cutting, beveling, squaring, and orbital welding systems for industries such as pharmaceutical, food processing, semiconductor, aerospace, oil and gas, automotive, and solar, with 20 years of experience in orbital technology.
Driven by their business of manufacturing innovative equipment for orbital tube work, the company constantly increases exposure and improves services for their customers and distributors. Given their high percentage of export sales (over 70% turnover), the company has subsidiaries and distributors located around the world, strengthening the global presence for innovative industrial processes.

(281) 968-7138
www.axxair.com/en-us/en-us/

Bahco® and Sioux® Tools

Bahco Bandsaw Blades and Sioux Tools are two trusted brands within the metal fabricating and welding industries. Together they offer a complete line of professional cutting and finishing tools to help metalworkers get the job done right. TOP Fabricator 3853 Bandsaw Blade aids metalworkers by cutting faster, longer, and straighter. It is engineered with a powdered metal M42 high-speed steel tooth edge for higher hardness and added toughness, providing fast, precise cuts when cutting bundles of square and round tubes and profiles, as well as I-beams, H-beams, angle iron, and structural steel. When cutting is completed, finish the job with Sioux Tools, a legendary American brand for more than 100 years with their line of grinders, cutoff tools, and sanders with precision-machined components and powerful, efficient motors designed specifically for welding and metal working professionals.

(800) 446-7404
snaponindustrialbrands.com/30/home.htm

Bessey® Tools North America

Bessey is one of the world's leading manufacturers of professional hand tools in the fields of clamping and cutting technologies since 1889. The company is one of the only sliding arm clamp manufacturers who produces and processes high quality steel in its own mills. Steel forms the cornerstone of their legendary line of clamps. With expertise in engineering, research and development, they are working on new and innovative ideas for continuous product improvement. As the company invents and perfects the patented brands in Germany, they often become models for an entire generation of clamping and cutting tools. Their clamps deliver superior results in less time and with less effort, and are often copied but never duplicated.

(800) 828-1004
besseytools.com

Bug-O Systems

For 72 years, Bug-O Systems has been a leading manufacturer for welding and cutting mechanization equipment in the U.S. Our dedication to the industry has been helping customers achieve greater productivity and efficiency in their welding/cutting applications. During this challenging year for everyone, Bug-O has stepped up their game by offering live support webinars to help both distributors and end users. Serving as both a support and a training tool, the custom webinars have taken mechanization training, learning, and support to a whole new level. Driven by customer demand, the company continues product development designed to give excellent return on investment. They continue to offer their six benefits of mechanization: 1) increased production, 2) improved quality, 3) improved workers' environment, 4) reduced distortion, 5) reduced material handling, and 6) adaptability of our equipment to fit your application.

(412) 331-1776
bugo.com

Bernard®

Throughout 2020, Bernard continued its commitment to developing semi-automatic welding products to address its customers' challenges. The company has expanded its AccuLock™ S consumables offering to include Lincoln®, Tweco® #4 and Tweco #5 power pins (in addition to Miller® power pins) that are available as part of the online BTB semiautomatic gas metal arc welding (GMAW) gun configurator. Users can select these power pin options while customizing their entire gun, including handle, trigger, consumables, and more. The consumables system provides error-proof liner replacement without measuring. Users simply load the liner through the neck and trim it flush with the power pin. The liner locks and concentrically aligns to the contact tip and power pin to provide a flawless wire-feed path that minimizes feeding errors and helps the contact tips last two to three times longer.

(855) 644-9353
bernardwelds.com

Bluco Corp.

Bluco's goal for 30 years has been to serve the industry by creating modular fixturing solutions backed by outstanding service and support. Despite the challenging year, the company stayed laser-focused on that goal. They remained open to provide service for customers classified as essential businesses, and ramped up research and development (R&D) efforts. That R&D yielded product enhancements, new designs, and redesigns of classic solutions like their latest generation of manual positioners. The positioners offer new features like a customizable frame that can be expanded to fit any project, or mounted to be mobile or stationary. Powered rollover options and manual or hydraulic adjustable height options are also available. New safety locks reduce the risk of injury, and an easy center of gravity adjustment eliminates the need for counterweights. Their new positioner is already available to help manufacturers make it better.

(800) 535-0135
bluco.com

Carr Lane Mfg.

Carr Lane Mfg. is recognized as a world leader for standard tooling components and industrial parts used by virtually every industry around the globe. Known primarily for jig and fixture tooling components, they offer more than 100,000 industrial parts products including quick change tooling plates and accessories, hoist rings, toggle clamps, handles, knobs, ball and spring plungers, threaded inserts, clamp straps, drill bushings, alignment pins, fixture bases, and power workholding devices. Proud to sell American-made products, the majority of their fixture manufacturing is done at two plants located in St. Louis, Mo., and Austin, Tex.

(314) 647-6200
carrlane.com

Cavitar

Cavitar is introducing its welding camera for acquiring high-quality images of welding processes. The camera is small, robust, and especially suitable for a variety of arc welding processes as well as plasma welding. It was developed and designed to address the needs in the industry and for welder education. The cameras provide a detailed view of the welding process, which brings several benefits. Welders can follow the welding from a safe distance and correct the process in real time. This leads to increased quality and reduction of scrap and repair work, while ensuring the safety of the welders. Customers that aim for process control benefit from the clear images that enable the use of various image processing methods. The cameras are also valuable tools for production engineers to improve their welding processes.

358 3 447 9330
cavitar.com

Chart® Industries Inc.

Despite difficult months from the COVID-19 pandemic, Chart continued global operations to serve our customers with a strong emphasis on increasing medical and critical care equipment. Our focus, internally and externally, on safety and protecting health while ensuring production remained robust. The company utilized webinars, online meetings, social media posts, and direct email and phone communications to connect with customers. They remain resilient to building innovative cryogenic products for the laser and welding industry and announced the new Perma-Cyl® 7000 VHP MicroBulk Storage System. The high capacity storage system is configured for any liquid nitrogen (LIN), liquid argon (LAR), and liquid oxygen (LOX) gas or liquid application with very high operating pressures. When filled with the Orca™ MicroBulk Delivery System, the tank provides a safe, automatic shut-off with no filling losses under normal operating conditions.

(800) 400-4683
chartindustries.com

Coxreels®

Proud to manufacture the industry's highest quality and widest variety of hose, cord, and cable reels, the company remains aware that their products are called on to be reliable and built to perform in various settings and applications. Their team takes great pride in their growth and innovation as a U.S. manufacturer. They recognize that U.S. made, U.S. quality, and U.S. support are critical components to delivering incomparable product value. These founding principles are displayed and reflected in each model and every part of the Coxreels product line. Over 90 years as an industry leader proves that constant learning and communication with the industries served, innovative engineering, and the highest standards in quality and service ensure they will continue to innovate with new proprietary technologies, superior special features, and superior products that set the bar in the reel industry.

(480) 820-6396
coxreels.com

Cerbaco Ltd.

Cerbaco specializes in the design and manufacturing of nonmetallic weld backings that permit finished quality, full penetration welds from one side. Technical assistance and service is what makes them a leader in this field. Quite simply, they will ask the customer about their procedure and advise on what will work, and will also make suggestions about the procedure if necessary. In the past, full penetration welding involved costly backgouging, grinding, and rewelding. With their nonmetallic weld backings, customers achieve x-ray quality, full penetration welds from one side and in a single pass. The result is a finished high-quality weld and savings in labor, materials, and time. The weld backings are manufactured in many different configurations and in formulas for the diverse conditions encountered when welding anything from light gauge sheet metal to heavy metal fabrication. They can be used to compensate for poor fit-ups and valuable when welding conditions are not ideal or where the back side of a weld joint is inaccessable.

(908) 996-1333
cerbaco.com

CK Worldwide

Since 1967, CK Worldwide has brought innovations to gas tungsten arc welding (GTAW) equipment manufacturing. With a worldwide network of distributors, and products that fit every niche in the market, the company is committed to bringing premium quality GTAW torches and accessories wherever their customers are located. Flex-loc™ torches, Super-Flex™ cables, Gas Saver™ Kits, Micro Torch, Wedge Collets, and Steady-Grip™ amperage controls are a few of their industry known products with a vast array of other GTAW parts and consumables available to fit your specific welding needs or situation. With many patents on product design and improvements, and a robust focus on helping push the welding community forward through educational support, CK sets "The Standard in TIG Welding."

(800) 426-0877
ckworldwide.com

Dewalt®

Dewalt is obsessed with how users work in the real world and is relentlessly pursuing total jobsite solutions. By incorporating its latest technology and industry innovations, the company is leading the charge for the jobsite of the future. To help contribute during the height of the pandemic, they partnered with Ford and 3M in April to supply a portable battery solution for their new powered air-purifying respirators (PAPR), which are used to help protect healthcare professionals on the front line as they treat patients of the COVID-19 health crisis.

(800) 433-9258
dewalt.com

D/F Machine Specialties® Inc

D/F Machine Specialties, manufacturers of American made heavy-duty semiautomatic, automatic, and robotic welding guns and consumables, rising to the many challenges of 2020, has introduced a new semi-automatic curved water-cooled GMA gun built for welding ³⁄₆₄- and ¹⁄₁₆-in. aluminum wire. The curved gun was designed for trailer manufacturing but is suitable for a number of industry segments, including heavy fabrication, structural, and automotive/transport manufacturing. The NCC P-38 features a 50-deg gooseneck, 100% duty cycle rated at 500 A, slip-in contact tips for quick tip changing, and multipositionable trigger switch, flexible, lightweight, and features the company's gun build. The gun will connect to any Lincoln, Miller, ESAB, or Euro wire feeder and power source with provisions for water cooling.

(507) 625-6200
dfmachinespecialties.com

Electron Beam Technologies

Electron Beam Technologies has been servicing the welding industry for more than 50 years. Located 50 miles south of Chicago, Ill., the company is ideally located to service not only the entire United States, but the world. It specializes in the design and manufacture of customized GMA cable, for applications from small hobby units up to high volume robotic welding systems. It designs and builds to original equipment manufacturer requirements using its custom blend of polyethylene, which is cross linked by one of its electron beams to be resistant to weld spatter. The company's proprietary POLY-XL® jacketing compound has cut resistance and tear strength. It also manufactures plasma cable, wire rope, custom tubing, standard welding cable, and electrode conduit/accessories.

(815) 935-2211
electronbeam.com

EWI

EWI empowers industry leaders to overcome complex manufacturing challenges and integrate new processes to bring products to market more quickly and efficiently. It provides comprehensive engineering services to help companies identify, develop, and implement the best options for their specific applications. Also, it has remained open for business throughout the coronavirus pandemic. It has been able to respond to client inquiries, start and finish projects, maintain applied research programs, and recruit new talent to meet the shifting industry needs. It has been busy, extremely busy, in the last few months working with clients; enhancing technical resources; mobilizing associates to get the most of its collective, internal expertise; and responding to the urgent needs presented by the coronavirus crisis. What is your biggest manufacturing challenge? Let us hear from you.

(614) 688-5000
ewi.org

Diamond Ground Products

"The Tungsten Electrode Experts" are a top supplier of tungsten and tungsten preparation products in the world. It carries a large and diverse supply of tungsten electrodes. The company manufactures pre-ground tungsten welding electrodes to the strictest tolerances in the welding industry. It offers the tungsten electrode grinders with an option for every application and budget. The company is dedicated to the improvement of weld quality and welder productivity, maintaining a reputation as an industry leader in tungsten and tungsten preparation. Their management philosophy is to provide quality product and receptive service that exceeds even the most stringent expectations.

(805) 498-3837
diamondground.com

ESCO Tool Co.

Once it became apparent that the COVID-19 was taking the world on an unpredictable ride, ESCO focused on ensuring health and safety for their employees at the same time as financial survival for the company. The company was fortunate to be an essential business and have employees that showed their resilience and adaptability to the changing times and safety precautions. Their standard operating procedure is to be financially conservative, which prepared them to handle the unexpected "what-if scenario."

(508) 429-4441
escotool.com

FANUC America Corp.

As we make our way through the pandemic, the workplace is evolving, and robotic automation is helping companies adapt. FANUC and its team of Authorized System Integrators and automation equipment suppliers are working tirelessly with companies that manufacture lifesaving products, including personal protective equipment, disinfectants, medical diagnostic equipment, ventilators, and many other items used in the fight against the coronavirus. New and innovative automated systems are also helping companies minimize product handling to create more space on the production floor and meet social distancing requirements. The latest trends include collaborative robots to work with people. The company offers a full line of cobots, including those that perform welding. All of its cobots are easy to setup and use, and operate with the same reliability as the rest of its industrial robots.

(888) 326-8227
fanucamerica.com/welding

Forney Industries

Forney Industries continues to innovate products designed for durability and performance. This year, it introduced three welding machines and a plasma cutting device that offer ideal welding and cutting performance at an enticing price. The company has taken assembly back to its roots with these new machines. Technicians assemble the machine with sheet metal, aluminum die cast parts, aluminum extrusion handles, and knobs — all of which are made in America and locally manufactured in Fort Collins, Colo. "I am proud that my family started this company almost a century ago and high-quality has always been, and remains, paramount to all of us and our employees," said Steve Anderson, president and CEO. "It's the Forney promise that the products we offer to our users are of the highest quality, and we offer our customers the products they need to remain successful."

(800) 521-6038
forneyind.com

FumeVac

FumeVac is the future of clean, air-quality-compliant facilities. Its line of weld fume extraction equipment is a solution for arc welding applications. Whether a manual, semiautomatic, fixed automation, or robotic weld process, the company can tailor a solution to meet your application. Its high-pressure/high-capacity systems are an effective way to protect welders from the serious threats caused by hexavalent chromium, manganese, and other contaminants present during the welding process. Regardless of company size or the materials you are welding, air quality is of utmost importance, so compliance-conscious employers are choosing the company to protect their employees and maintain a safe and contaminate-free environment. Have a question or problem? Reach out and we can work together to design a solution.

(800) 236-8450
fumevac.com

G.A.L. Gage Co.

A call to action in an unprecedented time: In March of 2020, when COVID-19 became a reality, Michigan closed all businesses except for those labeled essential. The G.A.L. Gage Co. was deemed essential. The value of its products to our consumers coupled with the safety of our employees was a balancing act that required rethinking, retooling and designing a new normal. The company's doors have never closed. It remains resilient with the desire to meet customers' needs and innovative in this ability to do so safely. The strength of our company, and our country, is defined by all of its employees/citizens' willingness to listen to the experts, follow health guidelines, and value the safety of others with actions. The adversity of these times will make us stronger, more resilient, and will demonstrate our compassion for other's needs.

(269) 465-5750
galgage.com

Fronius USA LLC

Although FABTECH was canceled, Fronius is still pushing forward to bring customers welding solutions they require. For example, its newest product, the new multiprocess TransSteel Pulse, is one device for all manual welding applications. This pulsed arc machine allows faster welding speeds on thicker materials, while rework is reduced as the pulsed arc causes less welding spatter, saving you time and money. The company is also celebrating its 75th anniversary. Come test its welding machines and show off your welding skills for a chance to win a limited vintage edition TransPocket 180 (*fronius.com/en-us/75yearsweldingcontest*). There are solutions for every application, whether manual, robotic, or automation. It knows every customer is different, so it doesn't just sell equipment, it sells solutions specific to you. The company is here to be your partner, especially in these challenging times.

(877) 376-6487
fronius.us

Fusion Inc.

For 50 years, Fusion has been providing automation solutions for manufacturers engaged in production brazing and soldering. The company takes a process approach to automating your application. This process consists of three key ingredients: paste alloys, applicator equipment, and automatic machines. Your operation will be transformed with the overall goal of reducing metal joining costs through increased productivity. With its process, joint quality is virtually guaranteed, due to the elimination of human error. Material costs are controlled, since filler metal and flux are applied in a single step, in just the right amount. Labor costs become insignificant, as one operator turns out hundreds of brazed or soldered assemblies per hour.

(800) 626-9501
fusion-inc.com

Gentex Corp.

PureFlo™ industrial respiratory protection systems, used in heavy industry, welding, pharmaceutical, and healthcare environments, are part of Gentex's innovative industrial safety solutions portfolio. Its head-mounted technology and design protect workers from immediate and long-term health and safety hazards presented in industrial environments, as well as enhancing performance and productivity. Without hoses and belts, snag hazards are reduced. Users have less interference with their tools, machinery, and other personal protective equipment, as well as less exposed equipment in hazardous environments. Easy and quick donning and doffing, with fewer parts than waist-mounted powered air-purifying respirators (PAPRs), requires less maintenance and support, and increases work efficiency, while decreasing the cost of ownership. The family of products includes the PureFlo ESM+, 1000, and 3000 PAPRs, along with an extensive catalog of accessories to meet specific user needs.

(888) 894-1755
gentexcorp.com

Harbach Marketing Inc.

Harbach Marketing continuously evolves its products to incorporate new technologies and make offerings stronger through customer feedback and industry needs. From the new Mag-Saw for cleanly removing welded components to improvements to its switchable magnets, nothing has stopped the company from moving forward. The latest achievements in hardfacing equipment, robotics, and consumables from its Fusion Technologies brand include laser cladding and new powder formulations for spray, cladding, and weld overlay. The Padeye.com brand is also available. Fit Up Gear is its extensive line of fitting tools. Harbach Positioning continues breaking new ground in positioning and welding automation equipment, providing systems incorporating the Pathfinder seam tracking solutions, positioners, turning rolls, manipulators, and mounting components.

(281) 440-1725
har-bach.com

IMPACT

IMPACT is an ironworker-contractor partnership that provides a forum for the ironworkers and their signatory contractors to address mutual concerns and encourages reasonable, balanced solutions. The mission is to expand job opportunities for its ironworkers and contractors through progressive and innovative ironworker-contractor cooperative programs, while providing specialized training, assistance in obtaining construction certifications, safety training, marketing and public relations services, and construction project tracking. A board of trustees comprised of an equal number of ironworker and contractor representatives oversee the partnership. It is funded by its ironworker and contractor participants who are committed to increasing the competitiveness and market share.

(800) 545-4921
impact-net.org

InterTest Inc.

InterTest provides the welding and fabrication industry with camera systems to help view and perfect the weld. Its team is proud to help with the challenging process of moving welding instruction to virtual by supplying welding schools with the WeldWatch® EDU System, which uses filters and visual technology to see through the weld arc. The company continues to innovate by bringing HD imaging to all its advanced visual tools. From the iShot® Weld-i® camera system designed for remote monitoring of welding processes to the many HD borescopes engineered for detailed orbital weld inspection, the company has the tools you need.

(800) 535-3626
intertest.com

Hypertherm Inc.

Hypertherm engineers and manufactures a broad range of industrial cutting products used by companies around the world to build ships, airplanes and railcars, construct steel buildings, manufacture heavy equipment, and more. Its products include cutting systems, CNCs, and software trusted for performance and reliability that result in increased productivity and profitability for hundreds of thousands of businesses. Its Powermax® air plasma systems ensure you get more for your money. In addition to regular cutting, you get gouging, extended reach cutting and gouging, flush cutting, fine feature cutting, and marking. Founded in 1968 and based in New Hampshire, it is a 100% associate-owned company, employing more than 1800 associates, with operations and partner representation worldwide.

(800) 643-3441
hypertherm.com

Imperial Systems Inc.

The Air-Port fume exhaust hood brings its own unique set of patent pending benefits. For standard and robotic welding, the product offers the first true new innovations in welding hood design. Features include an optional integrated spark trap, pre-installed duct work with easy install in under an hour, compact footprint with two legs instead of the standard four, arched hood shape captures more smoke and fumes, dampers for easy air flow adjustment, optional crane slot, weld curtain, and internal lighting to best fit your needs. It's available in a variety of sizes.

(800) 918-3013
imperialsystemsinc.com

IRCO Automation Inc.

Since 1963, IRCO Automation has been designing, engineering, and manufacturing integrated welding automation solutions and weld positioning products. Its standard products and custom-designed solutions have built-in, reliable features that deliver measurable return on investment improvements in work throughput, on-arc time, weld quality, reduced rework, and operator ergonomics and safety. With a focus on building lasting relationships and ability to evolve with the industries it serves, the company continues to offer welding automation solutions. Its in-house expertise enables providing a range of options, including robotics, allowing clients to take advantage of the latest developments and weld process enhancements. IRCOpulse™, the latest offering, is designed to address emerging demands of Industry 4.0 and offers clients complete weld and production monitoring systems, a soon-to-be necessity for manufacturing companies.

(905) 336-2862
ircoautomation.com

IVEC Systems

Changes to the way we do business means remote monitoring and access to your system's data is more critical than ever. IVEC Systems' controls, implemented as either a brand-new system or as a retrofit, are energy-efficient dust collection systems. The company's on-demand solutions provide up to 85% lower energy costs and up to 400% longer filter life. With employee well-being at the forefront, it modified existing units to meet CDC guidelines for infectious diseases and released the GVAP-HG to reduce the spread of COVID-19; this unit incorporates energy-saving controls along with hospital-grade, HEPA-quality filters and multistage filtration. Have a question or problem? Reach out and we can work together to design a solution.

(866) 670-4832
ivecsystems.com

Koike Aronson Ransome

Koike has been an industry leader in the cutting machine, welding and positioning equipment, and portable and gas apparatus markets for more than 100 years. It offers a wide variety of machines across multiple price ranges to provide a solution that fits your application and budget. The Cricket-I is the company's newest welding manipulator line. It was developed to meet customers' demand for fixed automation equipment serving the small- to mid-size pipe fabrication market. This machine is a smaller sized welding manipulator that utilizes vertical lift, manual reach, and a manual travel car. The product provides stable gas metal arc welding from end to end. Users can combine its range of positioning products like the MD tilt/turn welding positioner or MD turning rolls to complete a full welding system.

(585) 492-2400
koike.com

Laserline Inc.

Laserline is one of the pioneers in diode laser technology and played a role in achieving a breakthrough with this laser type. Founded in 1997, the company grew within a few years to becoming an international leading developer and manufacturer of diode lasers for industrial applications. Its diode lasers can be found in a variety of different sectors and application areas. Typical application areas are classical forms of metal processing, as welding, brazing, hardening or softening, as well as realization or repair of coatings. Furthermore, the company's diode lasers have been established for plastic welding and additive manufacturing (metal 3D print) or welding of fiber composites. With the blue continuous wave high-power diode laser (450 nm), the company now also enables controlled heat conduction welding of copper and other highly reflective materials.

(408) 834-4660
laserline.com/en-int/

Kalas Wire Inc.

Manufacturing quality copper wire and cable along with value-added solutions for more than 60 years, Kalas Wire offers bulk welding and battery cable, welding assemblies, and numerous customization options. All offerings are created in-house. The company is fully integrated for material control and constantly evolving to deliver increased value to customers, collaborative partnerships, and technical expertise. In addition, it manufactures a vast portfolio of bulk wire and cable as well as custom-built terminated battery cables.

(717) 336-5575
kalaswire.com

KUKA

KUKA is a global automation corporation with around 14,000 employees. A global supplier of intelligent automation solutions, the company offers its customers robots and cells to fully automated systems and their networking in markets such as automotive, electronics, general industry, consumer goods, e-commerce/retail, and healthcare. Started in 1898, the company is one of the world's automation specialists and has played a central role in the implementation of intelligent automation like Industry 4.0, bringing the digital connectivity of production, flexible manufacturing concepts, and new business models to the forefront. Through decades of experience in automation, deep process expertise, and digital services, KUKA gives its customers a head start and supports them with optimizing value creation. Earlier this year, the company unveiled its KR IONTEC, delivering versatility and performance to the medium payload category.

(800) 459-6691
kuka.com

Lenco

Lenco has been in business since 1948 (under present ownership since 1989). The company is a U.S.A. manufacturer of manual products that include electrode holders, cable connectors, ground clamps, rotary ground clamps, cable lugs, Dinse-style connectors, chipping hammers, and automotive resistance spot welding units. The Isolator electrode holder prevents shock from open-current voltage when used as recommended. Electrode-stabilizing rod ovens from 10 to 450 lb are also available. The manufacturing facility is vertically integrated. The company has a more than 100,000-sq-ft manufacturing facility located in Jackson, Mo. It's is a family-owned company.

(573) 243-3141
profax-lenco.com

Liburdi Dimetrics

COVID-19 forced most companies into survival mode, and in difficult times, businesses tend to focus on the present, not the future. Liburdi Dimetrics adapted to the changing circumstances; however, forward-looking decisions were a big part of the strategy. Serving critical power generation and infrastructure projects, business interruption was not an option, but neither was a "business as usual" attitude. In March, the company took decisive measures to ensure a safe work environment. The plan included increased production space, flexible hours, and remote work. Working remotely enabled focus on product development, resulting in introduction of the Gold Track™ VII. The next-generation system is full of new technologies, including multiprocess capability, auto head recognition, and a graphical user experience. With the launch of the product in early 2021, the company will be ready to answer the industry's new challenges.

(800) 991-2100
liburdi.com

MCR Safety

MCR Safety has 45 years of experience in the field of personal protective equipment (PPE). Its assortment of offerings includes gloves, glasses, and garments that are made from the highest quality materials available to ensure maximum safety, comfort, and style. The companydistinguishes itself as a manufacturer of its core product groups. Its knowledge as a manufacturer helps evaluate other sources of supply to assure reliable quality. Additionally, the company prides itself in providing distributors with technical expertise and customer service. Today, it is recognized as a global PPE leader and employs more than 1600 internationally with approximately 300 locally. It has been recognized multiple times for new product of the year innovations and awards in manufacturing operations.

(901) 795-5810
mcrsafety.com

Michigan Pneumatic Tool Inc.

Michigan Pneumatic Tool is a full-service air tool company celebrating 75 years of service in the design, manufacturing, distribution, repair, and rebuilding of industrial air tools. With a focus on the metalworking industry and increasing productivity, the company continually adds new industrial, heavy-duty material removal tools to its offering of more than 250 models. To help facilities minimize costly downtime, the company not only stocks more than 400,000 spare parts for virtually any model of tool, but it also offers quick-turn repair services on all leading industrial brands. In addition, engineering services and production capabilities allow the company to modify, design, and manufacture tooling for special applications or to suit a facility's needs. The company proudly manufactures and assembles more than 550 models of pneumatic tools in Romulus, Mich., and offers a range of finishing, fastening, percussive, drilling, riveting, and specialty tools.

(800) 521-8104
michiganpneumatic.com

Luvata

Luvata offers products for the resistance welding and gas metal arc welding industries, including contact tips, nozzles, braze wire, welding accessories, and consumables. The company is a world leader in the manufacture of resistance welding electrodes. Its products are available in a variety of alloys and designs, and manufactured to exact specifications. Using its combination of metallurgical, welding, and manufacturing expertise, it helps customers overcome the challenges they face in welding different materials, including aluminum, heavy-coated, or ultra-high strength steel. In addition, the company's welding expertise is used to determine the exact welding cap electrode that avoids unnecessary costs and risks associated with welding spatter. Its technical support helps end-users maximize their production efficiencies while ensuring an optimal weld.

(740) 957-4110
luvata.com/ohio

Metabo

Metabo's line of power tools is designed for professional users and provides the highest level of safety, reliability, and performance. The company manufactures both corded and cordless power tools and a full line of abrasives and accessories for metalworking, concrete, and many other industrial and construction applications. 2020 brought unprecedented challenges for the industry. The company rose to the challenge by implementing recommended protocols to ensure the safety of employees, customers, and suppliers while minimizing disruption to business. It continued with planned, new product introductions, including an expanded range of PowerUp angle grinders with more available power and increased overload protection, a line of 12-V/18-V brushless reciprocating saws, and a 10-Ah battery platform offering the longest run time in its class. The company also added an 18-V shear and nibbler to the growing line of metal-working tools with its second-generation brushless motor and the multitool with StarlockPlus® blades for metal and wood.

(800) 638-2264
metabo.com

Micro Air

Micro Air provides multiple options for providing "breathe easy" clean, safe air in welding processes. Ambient capture is a good way to capture pollutants and keep plant air below OSHA and NIOSH permissible exposure limits. In basic terms, the company filters plant air in problem areas to achieve desired air changes per hour based on application and pollutant levels. Its recent launch of the MXT series T-style ambient air cleaners provides another option for collecting particulate generated in industrial processes such as welding, grinding, sanding, metalworking, and composites. These powerful collectors draw contaminated air in from the inlets at each end of the collector. The particulate then passes through up to three levels of filtration and exhausts clean, safe air into the facility, all while eliminating the need to exhaust conditioned air outdoors.

(866) 566-4276
microaironline.com

Miller Electric Mfg. LLC

A worldwide manufacturer of Miller® brand arc welding equipment, the company provides solutions and technologies to help improve productivity and efficiency in today's challenging environment. With added economic pressures, it's critical to utilize labor and equipment solutions that maximize value-added activities and minimize nonvalue-added activities (like setup) and quality problems, such as scrap, rework, and grinding. The Deltaweld® 500 welding power source paired with the Intellx™ Pro wire feeder offers Accu-Pulse™ pulsed gas metal arc welding, designed with a 28% wider operating window, so the process is more forgiving to variations in welder technique. In addition, EZ-Set technology automatically sets parameters based on material thickness, helping welders of all skill levels produce quality results.

(920) 734-9821
millerwelds.com

Nasarc Technologies

Nasarc Technologies, based in Waterloo, Ontario, Canada, recently announced the launch of its new, robotic gas metal arc welding tip change system, comprised of the Revolution360® torch, AUTOCLEAN torch maintenance center, and AUTOTIP tip changer. The need for a tip change system took on more significance due to challenges related to the COVID-19 virus and its impact on the manufacturing segment. With laser-like focus, the company's engineering and manufacturing teams, while operating remotely and with limited production staff due to the coronavirus, coordinated their activities to finalize the design, implement preproduction activities, and prepare for the rollout of the system with live, production-ready end-user trials. To date, results have demonstrated double-digit impact on overall equipment effectiveness.

(519) 747-0336
nasarc.com

NUBURU®

NUBURU is helping to lead the transformation to a world of high-speed, high-quality metal machining and processing. Its blue laser technology has defined a new class of high-power, high-brightness blue lasers, which each enable gains in speed and quality for metal processing, starting with the standard AO laser and the high-brightness AI laser. The company's lasers unlock a path to new designs for both conventional laser-metal machining and additive manufacturing (3D printing). Followed by aluminum and steel, copper welding was the first application to benefit from the capabilities of the blue laser, with rapid processing and spatter-free welding that enables many new applications with all metals not possible with infrared lasers. Its technologies and products open similar possibilities beyond metal and material processing.

(720) 767-1400
nuburu.net

MSC Software Corp.

MSC Software, part of Hexagon's Manufacturing Intelligence division, is a global leader in computer-aided engineers' software. Simufact Engineering is the metal manufacturing business unit of the company. It specializes in software to enable the "virtual tryout" of the manufacturing process to include metal forming, joining, welding, and additive manufacturing. Also, it enables users to evaluate the manufacturing process virtually in an effort to improve quality, reduce cost, reduce time to market, and a host of other benefits. What would have been in focus at FABTECH is Simufact Welding. This software is a welding process simulation that leverages a simple, process-oriented user interface and advanced coupled multiphysics to simulate the arc, laser, and spot-welding process. Through its use, users are able to predict distortion, residual stress/strain, thermal effects, microstructure, and even cracking. This analysis can drive improvement and optimization of weld sequence, clamping/fixturing, weld parameters, and component/joint design.

(714) 549-8900
mscsoftware.com

Ningbo Boway Alloy Material Co. Ltd.

Ningbo Boway Alloy Material Co. was founded in 1993 and listed on the main board of the Shanghai Stock Exchange in January 2011. After nearly 30 years of development, it has built nine manufacturing bases and a capital cooperation platform in the world. The company has become a scientific and international company integrating new materials, new energy, and other industries. High-strength, high-conductivity alloy bars from the company apply large tonnage vacuum casting and strict quality-control management process, with the diameter and distribution of precipitated phase strictly controlled to ensure uniform and stable composition and structure. The high-conductivity, free-cutting alloy bars from the company apply the large tonnage hot extrusion process to ensure denser structure, stable performance, and better uniformity.

+86-574-83004683
boway.cn

Olympus America Inc.

Olympus provides a portfolio of innovative test, measurement, and imaging instruments. Its technologies include remote visual inspection, industrial microscopy, ultrasound, phased array, eddy current array, and optical metrology. Its products include ultrasonic flaw detectors and thickness gauges, videoscopes, borescopes, microscopes, advanced nondestructive testing systems, and a large selection of industrial scanners, probes, software programs, and instrument accessories. Olympus has dedicated time to support customers by providing helpful resources, like virtual demos/trainings and webinars, on its website (*olympus-ims.com/resources*). In addition to online resources, the company is taking health and safety seriously by ensuring its sales reps adhere to all safety procedures in place at your facility. Tell us how we can safely visit when requesting a demo or planning a visit.

(800) 225-8330
olympus-ims.com

Optrel Inc.

Optrel, a manufacturer of personal protective equipment (PPE), produces eye, respiratory, and head protection products for professional industrial applications. The COVID-19 pandemic has led to a world-wide shortage of PPE. The company has provided emergency aid by shifting production focus toward the manufacturing of respiratory protection products and N95 masks. The clearmaxx e3000x powered air-purifying respirator is certified to TH3 (EN 12941) and corresponds to the highest respiratory protection class. It filters air and removes 99.8% of harmful solid and fluid particles to provide clean and purified inhalation (NIOSH approved). The P.AIR N95 respirator is NIOSH approved and Swiss-made with high-quality materials for comfort and protection against solid and liquid aerosols, dust, mist, and smoke.

(401) 398-7240
optrel.com

Pador Marketing Group

Unfortunately, we could not see you in Las Vegas, Nev., for the FABTECH 2020 due to the ongoing COVID-19 pandemic, but be assured we will be at FABTECH 2021 in Chicago, Ill. Serving the industry since 1990, Pador Marketing Group is the exclusive distributor of the Rotoweld 3.0 automated pipe welding workstation. The workstation is an automated pipe spool welding solution to increase productivity and help companies stay competitive in today's fabrication industry. The result of 30 years of experience and evolution, the workstation sets new standards for quality and consistency and offers a solution for the labor shortage.

(514) 634-0861
pador.com
rotoweld.com

Pearl Abrasive Co.

Pearl Abrasive has been supplying tools to welding, construction, tile, and flooring professionals since 1968. It offers full lines of diamonds and abrasives for cutting metal, grinding metal, cutting concrete, and coring concrete, as well as durable concrete saws, tile saws, and floor preparation equipment. It also offers tile solutions, including tile spacers and tile levelers that save time and money. The company's R&D team is proud to present the following products, having spent months designing and testing each one to ensure they meet quality and safety requirements: the 9-in. P2 Pro-V™ general purpose blades designed for battery-powered cut off saws, the green concrete/early entry blades, and the P5™ thin turbo mesh blades with ridged core.

(800) 969-5561
pearlabrasive.com

ORS Nasco

ORS Nasco is a North America-based wholesaler of welding and industrial supplies focused on meeting the needs of distributors. The company provides access to more than 200,000 products from 600 brands used in the welding; industrial; energy; safety; electrical; construction; maintenance, repair, and overhaul; janitorial; and rental equipment markets. Its partnership model aids distributor customers by offering shorter lead times on in-stock items, a portfolio of customized marketing solutions, rich content, no order minimums, and lower costs for transactions, shipping, and transportation, among other services. Focused on creating additional value for distributors in a challenging 2020 environment, ORS Nasco is continually sourcing new and alternative products to an already broad assortment across a nationwide distribution network. Its newly launched suite of value-added services maximize the company's dedicated support teams — a critical component for distributors navigating the pandemic.

(800) 678-6577
orsnasco.com

Pandjiris Inc.

For more than 75 years, Pandjiris has manufactured safe and reliable automated welding and positioning solutions. During this challenging year, the company remained open to serve it's customers and focus its efforts on continuous improvements of standard product offerings. The company offers a range of standard positioning equipment combined with engineering expertise to design and manufacture custom fixed welding systems for numerous applications across several industries: aerospace; aviation; shipbuilding; HVAC, transportation; truck and trailer body building; pressure vessels, and pipe fabrication. Pandjiris application engineers take the time to get to know a customer's unique requirements and work closely with them to develop a system that meets their specific needs.

(314) 776-6893
pandjiris.com

Praxair

Praxair, a welding, industrial, medical, and specialty gases company, is a provider of industrial gases, applications, products, and services that support welding, cutting and other processes. The company lives its mission of making our planet more productive every day by providing solutions, technologies, and services that make customers more successful and help sustain and protect the planet. The Lancer™ computer numerical control (CNC) plasma pipe cutting system, introduced in 2020, is an example of the company's commitment to develop new technologies that help customers improve productivity and reduce costs. The CNC plasma pipe cutting system enables users to cut up to 8-in. diameter pipe and 4-in. tubing up to 25 ft lengths. It also offers full support for Hypertherm® plasma systems and features a FlashCut® controller with a 3D pipe interface.

(877) 772-9247
praxairusa.com

Profax

Profax has been in business since 1969 (under present ownership since 1981) and manufactures a diversified line of welding, including the platinum HD gas metal arc welding (GMAW) gun, gas tungsten arc welding (GTAW) torches, self-shielded flux cored guns, spool guns, and arc gouging torches. The company offers positioners up to 10,000 lb., turning rolls up to 240,000 lb., and manipulators up to 10 × 10. It also offers oscillators, chucks, and grippers. The company recently added 2- and 4-roll wire feeders along with a 300-A constant voltage power supply and a 400-A power supply. It also manufactures consumables for GMAW, GTAW, plasma, arc gouging, and repair parts. Profax has a 146,000 sq-ft manufacturing facility located in Pearland, Tex.

(281) 485-6258
profax-lenco.com

PTR-Precision Technologies Inc.

PTR is an electron beam welding systems manufacturer and contract welding service provider. In addition to making welding equipment, the company assists customers with weld process development and provides maintenance and spares support for electron beam welding systems, including those manufactured by its predecessors: Hamilton Standard & Leybold. For those outsourcing electron beam welding, PTR's Nadcap-approved and FAA-certified electron beam welding job shop offers contract welding services. The job shop has a variety of modern, 5-axis computer numerical control electron beam welding machines with either 60- or 150-kV beam generation systems capable of welding parts as small as a few grams up to ones weighing several tons.

(860) 741-2281
ptreb.com

Pyramex Safety Products LLC

Founded in 1991, Pyramex Safety Products delivers innovative and stylish products, pays attention to customer service, and cultivates the mindset that it succeeds when the customer succeeds. The company has maintained a growing consumer base of hardworking people looking for products they can trust. Termed as an"essential business" during COVID-19, personal protective equipment companies are at the forefront of providing necessary products for healthcare workers, law enforcement, and emergency personnel. This has brought expansion opportunities for products such as cloth face coverings, face shields, and antifog eyewear. It has also brought a shortage of inventory due to increased demand. Pyramex continues to work hard to replenish stock levels for new business, while also maintaining the stock needed for its business prior to COVID-19.

(800) 736-8673
pyramexsafety.com

Protective Industrial Products (PIP®) Inc.

PIP, a provider of hand protection and personal protective equipment (PPE), has proudly served the safety industry for more than 35 years by providing safety solutions that are tailored to the specific needs of a variety of end-user markets, including welding safety. Its line of Ironcat® welding PPE includes a broad offering of welding gloves and protective apparel designed to safeguard professional welders using multiple welding technologies. The company's line of cut-resistant welding gloves feature four new styles. PIP selected its top-selling welding gloves (9051, 945, and 6140) and added an ANSI A4 para-aramid liner to help protect welders from sharp edges and burrs as well as provide an additional layer of heat protection.

(800) 262-5755
us.pipglobal.com

Pulsa

Pulsa manufactures cloud-based wireless telemetry sensors for gases (bulk, cylinder, and other cryogenic) and hard goods (welding wire, fasteners, and dry ice). Its affordable products are simple to use and set up. The company works with hundreds of industrial distributors, with thousands of sensors actively monitoring critical inventory today. Each sensor sends 500 readings a day. Through the third quarter of 2020, the company has increased sales by more than ten times compared to 2019. It has also introduced a differential pressure sensor, a wireless solar gateway, intrinsically safe hardware, and more than ten major software updates. Pulsa's solution is cellular and works with all mobile carriers.

(888) 259-1163
pulsasensors.com

Resistance Welding Machine & Accessory LLC

Since 1987, Resistance Welding Machine & Accessory has provided the manufacturing industry with high-quality parts and service. The year 2020 has changed a lot of things, but the company's philosophy remains the same. Throughout the COVID-19 pandemic, the company has continued to supply customers and stands ready to fulfill their needs. 2020 has given Resistance Welding Machine & Accessory an opportunity to make some improvements to the Genius nut weld sensor, which is now even easier to use. The company still offers a full line of resistance welding products, including tips, shanks, caps, nut weld electrodes, holders copper alloy bar stock, tooling, fixtures, and weld controls. Visit us at FABTECH 2021.

(269) 428-4770
resweld.com

Rex-Cut Abrasives

2020 has been a year of R&D at Rex-Cut Abrasives. Improving existing, and creating new, abrasive products that make the grinding process easier and faster has been its focus. Aluminum grinding had room for improvement, so the company examined the Aluminator grinding wheel and re-engineered it. The new Aluminator grinds 2.2 times more aluminum weld per minute compared to the original version. This revised formula outlasts the original by 46%. The company also created a fast grinding wheel that delivers quiet, chatter-free grinding for carbon steel, stainless steel, and all alloys. By modifying the Sigma Green wheel and only using alumina zirconia 24-grit grain, the company was able to accomplish this goal. The Sigma Z outperforms most ceramic and engineered grains and will be available early 2021.

(800) 225-8182
rexcut.com

Rite-Hite

Rite-Hite is a manufacturer of loading dock and in-plant equipment, all designed to improve safety, security, productivity, energy consumption, and environmental control in an industrial or commercial setting. For the welding and fabricating industry, the company's machine-guarding products, such as the Defender™, Cell, RollTop™, FlashFold™, and VertiGuard™, coupled with safety interlocks, offer an increased level of protection for point-of-operation guarding. Because these products provide safeguarding that can be seen, the opportunity for accidental work stoppage is reduced. The physical separation they provide is a clear visual indicator that the machine operator needs to be on task. The ongoing evolution of the company's machine-guarding products is fueled by its commitment to innovation and passion to provide effective solutions for customers.

(800) 456-0600
ritehite.com

Sawyer Mfg. Co.

Sawyer Mfg. Co., headquartered in Tulsa, Okla., is a global provider of pipeline and welding equipment. It was established in 1948 and has 72 years of manufacturing experience and expertise. The company's product line is primarily focused on midstream transportation, storage, and general movement of pipeline materials from upstream production to downstream distribution. Its products are designed and developed primarily for the energy industry. They are also used in the construction and maintenance of wastewater, sewer, nuclear, and offshore applications, as well as gathering and distribution systems. Sawyer Fabrication, a division of Sawyer Mfg. Co., is a full-service ASME facility focusing on heavy structure, vessels, tanks, piping, and other custom fabricated equipment that is exported worldwide for use in the energy industry.

(918) 834-2550
sawyermfg.com

Ridgid®

Ridgid is a manufacturer of more than 300 dependable and innovative tools, trusted by the professional trades in more than 100 countries. Despite the current pandemic, production has continued on purpose-built tools to help professionals in the demanding commercial, industrial, and energy markets. Examples of key products include the RP 350 press tool, which eliminates scheduled service intervals for less downtime and features a brushless motor, a 360-deg swivel head, and an advanced LED interface and lighting; the B-500 transportable pipe beveller for high-quality bevels in 45 s without flames or sparks; and the Press Booster that attaches to the tool to press steel pipe between 2½ and 4 in. in less than 25 s. Ridgid is headquartered in Elyria, Ohio, and is a business unit of Emerson™, a global innovator in technology and engineering.

(800) 474-3443
ridgid.com

RPB Safety

RPB Safety is a respiratory protection specialist dedicated to protecting people for life's best moments. The company's team of engineers and designers work directly with end users and universities to gain insight into the industries it serves and shape products to their needs. The company continually develops new technology by pushing the creative boundaries of respiratory protection to produce products that make a real difference in the lives of its customers. This year has tested everyone, and the team at RPB rose to the challenge by reacting to customers' needs and accelerating projects to get respiratory protection into the hands of the people who need it most. The company has recently launched the radiant heat shield for foundries. It is designed to revolutionize the user's experience of protection, providing uncompromised vision while prioritizing comfort by reducing heat stress and fatigue.

(248) 591-4000
rpbsafety.com

Schneider Electric

Schneider Electric offers automation solutions to help design cost-effective, energy-efficient, and high-performance material-working machines. Its material-working systems for all industries include glass-working, ceramic-working, marble- and stone-working, metalworking, and woodworking machines. The company knows that to increase customer satisfaction, it must supply safe machines that are reliable. With the EcoStruxure ™ machine, Schneider Electric makes it easier for customers to offer smarter machines that are better connected, more efficient, and safer throughout the machine lifecycle.

(877) 342-5173
se.com

Servo-Robot Inc.

Giving 3D vision and sensing capabilities to industrial welding robots has been Servo-Robot's focus over the last 37 years. To respond to the increased demand in robotic welding automation, it has recently introduced a number of new products. The QUICK-SPOT™ is a compact laser-range measurement system designed for easy robot integration and the ability to work on any surface. For robotic welding quality control, the company introduced the i-FACT 2.0™ that automatically digitizes parts, joints, and welds to verify their quality compliance. The NANO-TRAC™ for high-precision seam tracking applications in robotic arc and laser welding using the company's most compact control unit with Industry 4.0 networking capability. Servo-Robot's high-quality products are rugged, compact, and ready to immediately operate on the factory floor. The company simplifies the task of system integrators by providing complete process software packages and first-class service globally.

(450) 653-7868
servo-robot.com

Sideros® America

2020 has been a great year of innovation and development for Sideros. Many products have been added to its product portfolio, including welding positioners, material vertical storage, and automation products for laser cutting machines. The company has added to its Syncrolift head and tailstock positioner series a WiFi connection between the two columns to avoid obstacles on the floor during welding. The company furher added a teaching system to memorize and program sequences of movements automatically. Additionally, the following automated products were launched: the Spaziomatic sheet metal and tube vertical storage and the Loadmaster sheet metal load/unload systems for integration with laser cutting machines. Our working range includes the following sheet sizes: 5 × 10, 6 × 12, 6 × 20 ft, or customized sizes. For the tube vertical storage, the maximum length it can handle is 30 ft. At FABTECH 2021, the company will present the following products: a 3-axis welding positioner, a head and tailstock positioner, a sheet metal vertical storage, and an ambient dust collector.

(630) 208-1839
siderosengineering.com/index/en

SP Air® by Vessel Tools USA Inc.

SP Air is a Japanese manufacturer of pneumatic tools with more than 40 years of experience. Its main focus is the automotive aftermarket, but it also sells a number of precision products in the woodworking/craftsman and light industrial markets. The company's distribution extends to more than 40 countries worldwide. Its pneumatic beveling machine is suitable for fabrication, marine, automotive, and industrial applications. The product features a three-blade cutting head with changeable blades and a depth flange scale for setting cutting depth. This palm-sized tool cuts radius chamfers, straight chamfers, and circles with a minimum of 0.27 in. and a material thickness of 0.1 in. With a speed of 23,000 revolutions per min, it has a length of 4.375 in., a weight of 0.9 lb, and an air consumption of 2.5 ft^3/min.

(614) 529-6600
vesseltoolsusa.com

Shaver Industries Inc.

Supporting the health of communities has never been more important. Shaver Industries recognized the needs of clients and reinvigorated its production lines to adjust to the demand of personal protective equipment in the global community. During the pandemic, the company manufactured protective face shields, sneeze guards, and school desk barriers. Established in 1986, the company has evolved to become a trusted name in manufacturing, providing reliable products and services. It has developed supply and strategic partners in North America and Europe to offer technologically advanced products at competitive prices. Customers can count on the company's fully trained and knowledgeable staff to give their business undivided professional attention. The company also has the ability to offer turnkey solutions for customers' environmental and machine protection needs.

(888) 766-8328
shaverinc.com

SMC Corp. of America

SMC Corp. of America promotes advanced automation through automated control technology. It offers technology in pneumatic components such as actuators; cylinders; directional control valves; airline preparation equipment; chillers and dryers; vacuum components; static-elimination products; fittings and tubing; electric actuators; grippers; pressure switches; high-purity chemical valves and fittings; and process gas equipment. The company's presence with manufacturing, sales, and technical support in more than 81 countries assures that continuity of products and services are maintained to support global manufacturing requirements. The company has maintained its mandate of manufacturing and delivery of products as requested. New products continue to be introduced yearly to enhance and improve customer requirements.

(800) 762-7621
smcusa.com

Steiner® Industries

COVID-19 has had a profound impact on the economy. For Steiner Industries, the reduced need for welding safety products as manufacturers weathered the storm of industry shutdowns was challenging. The company was able to take traditional welding screen assemblies and promote them to businesses looking to reopen their facilities. These screens are ideal for maintaining a safe work environment by separating employees with a transparent barrier to help prevent the spread of COVID-19. The company's screens and curtains come in a variety of tinted-transparent colors, traditionally used to shield casual onlookers from the hazards of ultraviolet light exposure. With a crystal-clear transparent vinyl, these screens and curtains are a cost-effective physical barrier to exposure from COVID-19.

(800) 621-4515
steinerindustries.com

Strong Hand Tools®

At FABTECH 2020, Strong Hand Tools planned on debuting the new PRO28 28-mm modular fixturing system to answer requests for an affordable, heavy-duty metric welding table. The PRO28 five-face table for precision vertical and horizontal welding is the newest addition to the BuildPro® modular fixturing line of welding tables and fixturing kits. The key to the BuildPro system is the complete modularity of the individual, positionable, reversible, self-locating table plates. Patented locating bushings make it easy to position and reposition the table plates as needed for unlimited possibilities in heavy-duty modular fixturing. If FABTECH wasn't cancelled, what questions would you have asked at the company's booth? Their team is eager to respond to your questions and have the discussions they would have had at the show.

(800) 989-5244
StrongHandTools.com

SuperFlash Compressed Gas Equipment

For 60 years, SuperFlash and IBEDA brand flashback arrestors, gas mixers, quick connectors, manifolds, heating solutions, and other compressed gas equipment have protected and served millions of compressed gas users and welders in more than 100 countries. Grow your compressed gas business with SuperFlash's free 30-min product mini-seminars. Help your sales and tech teams gain new and retain existing gas customers by learning about the latest products and services before the competition. Visit the company's website for a complete list of products, connections, and approvals such as U/L, EN (BAM), other standards, regulatory requirements, and videos. You can also find information on how to easily and quickly submit special designs and requests.

(888) 327-7306
oxyfuelsafety.com

Team Industries Inc.

Team Industries, a manufacturer of welding positioners and grippers, understands the need to keep manufacturers up and running at all times, especially during the coronavirus pandemic. At the company, safety is a number one priority. Upon the onset of COVID-19, we immediately implemented an innovative COVID-19 response plan to keep employees safe and healthy while continuing to fabricate the company's line of positioners and grippers. Additionally, the company introduced the newly designed 8000-lb Generation V XS positioner keeping safety and efficiencies in mind. The positioner offers a drive system with two gearboxes controlling the load, therefore, enhancing the safety of the positioner by reducing the load on any single drive component as well as allowing for a secondary means of controlling the load should damage occur to one of the gearboxes or other drive components.

(920) 766-7977
weldpositioner.com

Sunstone Welders

Sunstone Welders provides microwelding and engraving solutions for many different industries. Its product line includes laser, pulse arc, capacitive discharge, alternating current, linear direct current, high-frequency inverter, and hot bar reflow welding systems used by many companies in different industries worldwide. Despite the difficulties of 2020, the company has introduced three welding machines to meet the needs of customers. These include a high-powered capacitive discharge welding machine, a copper-battery tab welding system engineered for production, and a portable, battery-powered fine spot welding machine for those remote or hard-to-reach places. With plans to release a new micro weld head and high-frequency inverter in the coming months, Sunstone is providing innovative and professional microwelding equipment for any industry.

(801) 658-0015
sunstonewelders.com

Surface Flow Technologies Inc.

Surface Flow Technologies offers high-alloy nickel, cobalt, and iron-based atomized powders used for surface engineering, additive manufacturing, and high-temperature brazing applications. These products are applied in various industries such as power generation, oil and gas production, plastics manufacture, holloware glass, exhaust gas recyclers and catalytic converters, industrial heat exchangers, and abrasive tools. The company also manufactures and sells a line of braze pastes and specialized binders and flow-control agents for use in high-temperature brazing. It offers customers technical expertise in applications involving these high-alloy powders. Surface Flow Technologies has a North American distributorship and partnership with LSN Diffusion Ltd. in the UK, which manufactures the high-alloy powders in a modern, high-capacity facility.

(313) 948-3600
surfaceflowtech.com

T. J. Snow Co.

Utilizing over 55 years of experience, T. J. Snow Co. is recognized as a provider in the resistance welding industry. The company specializes in the design and manufacture of standard and custom resistance welding machines and offers a diversified stock of used machines available for quick delivery. Additionally, the company maintains one of the largest inventory of resistance welding machine parts and consumables. In addition, the service department is available on short notice to visit your plant for troubleshooting, repairs, support, and training. The company now offers online resistance welding training in the form of live, virtual seminars that can be customized to fit the applications of your company. All seminars are led by an American Welding Society Certified Resistance Welding Technician and include interactive lessons, video content, and quizzes.

(423) 894-6234
tjsnow.com

Tregaskiss

While 2020 has been a challenging year, Tregaskiss continues to innovate automated welding solutions for its customers, with a renewed focus on its fixed automatic series gas metal arc welding (GMAW) guns. The guns are now available with AccuLock™ R consumables, which are designed for increased contact tip life and virtually eliminate contact tip cross threading to reduce planned and unplanned downtime. The gun's offering includes the MA1 fixed automatic air-cooled GMAW gun, the MW1 fixed automatic water-cooled GMAW gun, and the AW2 fixed automatic water-cooled GMAW gun. The company has also developed new online configurators for the fixed automatic series GMAW guns that allow users to configure their guns for their exact specifications. The configurators include a reverse part number lookup that helps users find replacement parts lists for currently owned guns.

(855) 644-9353
Tregaskiss.com

United Abrasives/SAIT

Since 1970, United Abrasives/SAIT has been synonymous with quality, reliability, innovation, and value. The company has navigated the uncertainty of 2020 by continuing to develop products, penetrating the field, and maintaining stock levels of American-made products. The company is proud of its commitment to manufacturing in America. Several new products have been added in 2020. The Ultimate Grind™ ceramic, a premium grinding wheel, provides maximum stock removal with a high ratio of ceramic grain. The company also offers 9-in. portable saw blades to use on 9-in. cordless cut-off saws; they are available in two formulas (A60S General Purpose and Ultimate Ceramic Cut-Off™ Premium Performance) for a wide variety of applications. The company's focus, in 2020 and beyond, remains on producing high-quality and safe abrasives.

(800) 428-5927
UnitedAbrasives.com

Up in Smoke Welding Apparel

Up in Smoke Welding Apparel was launched to provide welders with safety apparel that meets their needs, looks good, and outperforms anything else. The company's products are made with materials from the United States and manufactured in Canada, making it a North American company. Every product has been field-tested, industry vetted, and worn by welders across the globe. Products are used for jobs in oil and gas, mining, power and utilities, art, military, farming, construction, and much more. Its product line includes the following: welding hoodies, welding jackets, welding shirts, work pants, with flame resistant and non-flame resistant and left- and right-hand options where appropriate. New for 2020 is the lightweight Zestos flame-resistant. The company believes in providing high-quality products that look good and keep welders safe, so they can get home to what matters most. Watch their latest video, We are Welders, youtu.be/McjDREK7rsc.

(403) 923-6225
upinsmokewelding.com

U-Mark, Inc.

U-Mark makes markers for important jobs. The company strives to incorporate helpful innovations, which will benefit those who use its products. This is why the company is glad to introduce Label Guard™ Antimicrobial Label Coating. The coating uses copper and silver nanoparticle technology, which inhibits the growth of harmful bacteria by releasing copper and silver ions, stopping the bacteria from multiplying. Copper and silver are durable, long lasting, and highly active. In situations where markers are shared, Label Guard™ can help reduce the spread of harmful bacteria between users. This is a very beneficial feature in times when precaution is essential. Look for the Label Guard™ logo on the following products: A10, A20, M5, Dr. Paint reversible tip, and many others.

(618) 235-7500
umarkers.com

Universal Robots

Universal Robots (UR), a manufacturer of collaborative robots, has grown its UR+ ecosystem of certified kits and components in 2020. Certified application kits help companies automate faster with peripheral products, including welding/brazing kits from Vectis Automation, Computech Mfg., Melton Machine and Control Company, and Ultraflex Power Technologies. In late 2019, UR introduced a heavier payload robot, expanding the family to four robots, which now span from 3 to 16 kg payload. The company shifted its collaborative robots marketing from industry trade shows to its first fully online trade show in July, The Cobot Expo. After this first show, The Cobot Expo 2.0 is being planned for November 16, 17. See online demos, keynote sessions and chat live with the company and its partners in real time.

(844) GO-COBOT
universal-robots.com

Urrea Professional Tools

Urrea is a tools brand with a selection of products for heavy-duty, industrial, and everyday use. The company offers tools that provide high performance and exceed industry standards by using quality U.S. steel stock. The company uses the latest technology, innovation, and design processes that ensure the best tool for industrial use. It offers more than 7000 products in its portfolio, catalogued by the following types of use required in the industrial sectors: automotive, metalworking, building, manufacturing, energy, oil and gas, mining, aeronautics, medical, government, and transportation. The company holds a presence in more than 20 countries with 1200 points of sale in the United States and Canada and more than 3000 points of sale and 350 exclusive stores in Mexico and Latin America.

(210) 734-8703
urreaprofessionaltools.com

Vanterm Makina

Vanterm presents dust collectors for welding workshops and for the metalworking industry. The FABTECH shows provide a platform for the company to share its experience with its North American customers. Since 1971, Vanterm has been providing optimum solutions to its worldwide customers in the field of industrial dust and fume extraction. A high level of engineering is a feature of all of its filtration and dust collector solutions. The company will continue to present its dust collectors for laser/plasma-cutting systems and for welding workshops at future FABTECH shows. The new generation, high-efficiency extraction arms for welding fume and smoke provide an excellent solution, where dust extraction is necessary. The company's dust collectors are tested and certified according to ISO15012 or EN1822 standards.

+90 (262) 751 0594 (pbx)
vanterm.com

Vectis Automation

Vectis Automation's mission is to help manufacturers boost productivity amid the shortage of skilled labor by reducing the learning curve, set-up time, risk, and cost of robotic welding. Powered by a Universal Robots UR10e collaborative robot, the Vectis Cobot Welding Tool is portable, safe, versatile, and easy-to-use. Most users are set-up and welding within a few hours of arrival, with no prior programming experience. Many users are seeing 2–3× boosts in productivity, all while increasing quality and softening the blow of the skilled welder shortage. With more than 100 years of combined experience in robotic welding, customers can trust the Vectis team to deliver substance and results.

(970) 852-5200
vectisautomation.com

Weld Engineering Co. Inc.

Weld Engineering was founded in 1979 by Thomas M. Less, president and CEO. Before founding the company, Less was a technical engineer for the Lincoln Electric Co. Lincoln trained him extensively in all aspects of the welding products they manufactured and procedures they used, including being a welding expert. This led to working with many large steel fabricators in the Northeast where submerged arc welding is a major process. Flux handling was mostly overlooked and millions of dollars in flux were thrown away. Less transformed flux handling systems, concentrating on flux recovery, pressure feeding systems, re-baking, and storage ovens. These became essential equipment for most of the heavy steel fabricators, pipe mills, and shipyards worldwide. During these hard times with COVID-19, the company supports critical infrastructure, military, energy, and heavy steel fabricating industries.

(508) 842-2234
weldengineering.com

VDM Metals USA

VDM Metals is a manufacturer of high-performance metallic materials for the most demanding applications. The company's comprehensive product portfolio includes nickel, cobalt, and zirconium alloys, as well as welding consumables, such as filler metal, welding strip, and core wire. These are used in all joint welding methods, including weld cladding and wire arc additive manufacturing. The team at the Welding Technology Centre accompanies complex projects, from planning to commissioning of plants and installations, and instructs and trains VDM's customers in all related welding issues. The center is equipped with state-of-the-art machinery and tests and improves materials for new applications. Many of the welding materials are certified for special applications.

(973) 437-1664
vdm-metals.com

Weiler Abrasives

As a global manufacturer of surface conditioning solutions, Weiler Abrasives is dedicated to forging collaborative relationships with metal fabrication customers to help them tackle their toughest challenges. The company develops the productivity enhancing solutions for cutting, grinding, cleaning, deburring, and finishing because we understand the job at hand. Its products help customer's work better, faster, and safer. In 2020, the company developed several new products with that in mind. Tiger Aluminum flap discs feature an innovative paired flap design that eliminates loading when grinding aluminum. Additionally, the company has expanded its offerings of Tiger and Wolverine large diameter cutting wheels for chop saws and stationary saws, and introduced a new line of high-speed cutting wheels for gas and electric saws. The new products provide customers with more options for cutting in the metal fabrication, construction, and rail industries.

(800) 835-9999
weilerabrasives.com

WeldComputer Corp.

WeldComputer supplies high-performance controls and monitors to manufacturers for the detection and prevention of problem welds when failure is not an option. Products work with spot, projection, seam, flash, butt joint, stud, and capacitive discharge welding equipment to improve weld quality, increase weld consistency and throughput, reduce scrap, and improve operator safety. Expert support services provide practical solutions to improve welding performance and reduce losses from machine inconsistencies and weld variability. The company's core focus in 2020 has been to work with forward thinking companies to put in place the quality and throughput improvements they have been wanting to perform but simply lacked the time due to production commitments. The actions they have taken now have them well positioned to maintain a leadership position in their respective industries as world production starts to ramp back up.

(800) 553-9353
weldcomputer.com

Weld Pride USA

Weld Pride would like to thank their customers who forged on during this pandemic, saving jobs, and keeping this very necessary industry at the forefront. The WELD-Brush weld cleaning system, a proven performer when it comes to stainless steel weld cleaning, is robust, portable, reliable, and economical. Offering three machines, (WB450, WB500, WB700) with three levels of power, the WB700 is the star of the show. The key is the current that can be delivered for the electrochemistry, resulting in no fuss, no mess weld cleaning. Additional benefits include no overheating, no excessive current that's hard to control, and a long lasting carbon fiber brush.

(630) 656-2716
weldpride.com

Wendt USA

Dipl.-Ing Günter Wendt GmbH is a family-held, privately owned, manufacturer specializing in the production of grinding, finishing, and polishing products. The company was founded by Günter Wendt outside of Köln, Germany in 1971. In 2001, a full stocking warehouse, located in Buffalo, N.Y., was opened. In 2005, operations expanded to include domestic manufacturing. This increased the company's presence in the United States and North America. Wendt USA prides itself in developing longer term relationships with its distributor partners. The company listens to its customers and develop unique grinding and finishing solutions for specific applications. The team offers distributor training, distributor joint calls, and cost analysis. Günter's vision was to lead the industry by providing unique and innovative abrasive solutions for the most demanding applications. This philosophy is championed by today's management, engineering, and customer service teams at Wendt USA and all branch operations worldwide.

(866) 335-3527
wendtusa.com/en-US

Xiris Automation Inc.

Xiris Automation specializes in solutions for weld inspection and monitoring across a number of specialty industries for process and quality control. With an extensive product line, the company provides some of the world's dynamic manufacturers with the ability to detect and interpret quality defects in their manufactured goods. During the shift to online learning, Xiris weld camera kits have provided a solution for welding educators to record and playback instructional weld video demonstrations. Most recently, the company has developed a new solution for welding automation that involves the use of a tablet computer. The Xiris Tablet HMI allows welding operators to stay removed from the immediate hazardous area while still maintaining a clear view from anywhere they need. This new addition is another way the company assists operators in remaining safe while monitoring for good quality welds.

(905) 331-6660
xiris.com

Welding Material Sales

Welding Material Sales is in its 42nd year in the filler metal business. The company specializes in private label and packaging, currently supporting more than 125 different brands. At FABTECH the company typically promotes its house brands, Blue Demon® and Weldporn®. These two brands are extremely well recognized on social media as we promote from within the online welding community. Blue Demon has earned the reputation of having "The World's Best Filler Metals™." 2020 has been an exceptional year as the company has developed several new items that it planned to showcase. A lot of its product ideas originate from the online welding community, such as the True Flex bendable tungsten, kid-size welding gloves, Weld Zombie mismatched gas metal arc welding gloves, and the Dab Pen.

(630) 232-6421
weldingmaterialsales.com

Wire Wizard® Welding Products

Wire Wizard Welding Products features one of the largest line of wire delivery products for gas metal arc and submerged arc welding applications, along with high performance PowerBall® torch products, Blue Magic® anti-spatter, welding peripherals, and welding optimization technology. This year, the family-owned company celebrates 35 years manufacturing American-made welding products. New products released in 2020 include the updated Weld Central® welding optimization and DAQ system, Gas Tracker™ digital gas flow monitor, and Wire Tracker™ digital wire monitor. A new catalog highlighting the company's products and solutions for submerged arc welding was released this fall. This includes products designed for large wire, such as the Wire Pilot® feed assist, large wire guide modules, and conduit for large wire.

(517) 782-8040
wire-wizard.com

Yaskawa America Inc. Motoman Robotics Division

A manufacturer of robotic automation, Yaskawa Motoman's history of innovation propels the delivery of production-ready systems for virtually every industry and application, including arc welding, machine tending, material cutting/removal, assembly, coating, and more. To help businesses bolster production in unprecedented times, the company's flexible solutions, such as the HC10 and HC20 collaborative robots, are adding capacity to current production operations. Easily repurposed for the supplementation of manual welding or for rolling up to large workpieces, the IP67-rated HC10XP offers precision hand-guiding for quick implementation of a robot system. Robust solutions, like the pre-engineered ArcWorld® 6200 welding workcell, are optimizing medium- to large-sized part production. These products, and all of the company's highly reliable robots and technologies, including the high-speed SP-series spot welding robots and MPX-series paint robots, facilitate fast, accurate performance for greater productivity and better return on investment.

(937) 847-6200
motoman.com

Zehnder Clean Air Solutions

With skilled laborers in demand, employee health and retention are critical to a company's bottom line. Noncompliance with OSHA regulations can result in large fines and the potential closure of businesses. When metals are heated above their melting point during welding and cutting processes, they vaporize, and condense into welding fumes containing airborne gases and very fine particles. Most of the particles in welding fumes are ultrafine, which means they are less than 0.1 micrometers in size, which the human body can absorb in the lungs to the bloodstream. Standard dust collection and extraction systems do not address these particles. Zehnder Clean Air Solutions' patented filters target these small particles, removing the smoky haze from customer's facility and delivering clean air to its employees. The company is one of the largest air cleaning companies in the world with decades of experience and expertise.

(908) 200-9486
zehnder-cleanairsolutions.com/us-en/guide-to-combatting-welding-fume/

Genstar Technologies (GENTEC) Co.

Genstar Technologies (GENTEC) provides high-quality pressure regulators, fittings, valves, gas welding and cutting apparatus, welding and cutting automation equipment, manifold systems, and various gas control and handling devices. With custom product configurations, total system integration, and reliable engineering and support, the company is a global total solution provider for the most demanding customers. Founded in 1969, GENTEC has emerged as a global business. UL-approved products, competitive pricing, and continual technological innovation have fueled its steady growth. The company strives to continuously improve its product lines while developing innovative products for diverse markets. All of its products are manufactured under stringent quality control and manufactured in facilities that are ISO 9001, ISO13485, and API certified. Its products also meet CE, SEMI, and various international standards and certifications.

(909) 606-2726
gentec.com

Hobart Institute of Welding Technology

This year's pandemic has provided a challenge for everyone, including Hobart Institute of Technology (HIWT). From temperature checks and COVID-19 questionnaires to reducing class sizes and adjusting schedules, HIWT has made the necessary changes to offer a safe place for students to get the welding education they need. This process has expanded the welding school's professional network and now includes local and state health officials, infectious disease experts, sanitation engineers, and medical professionals. Going forward, we have a better understanding of how "essential" welding is to our great country. Despite the challenges, 2020 was still a great year to celebrate the school's 90 years of welding education. HIWT continues to enroll students into its skill training, corporate services programs as well as provide a welding curriculum the Institute is known for.

(937) 332-9500
welding.org

American Welding Society

Can We Talk?

The *Welding Journal* staff encourages an exchange of ideas with you, our readers. If you'd like to ask a question, share an idea, or voice an opinion, you can call, write, email, or fax. Staff email addresses are listed below, along with a guide to help you interact with the right person.

Publisher/Editor
Annette Alonso, *aalonso@aws.org, ext. 299*
General Management, Reprint Permission, Copyright Issues, Editorial Content

Managing Editor
Kristin Campbell, *kcampbell@aws.org, ext. 257*
Feature Articles, Industry News

Sr. Editor
Cindy Weihl, *cweihl@aws.org, ext. 256*
Section News, *SPRAYTIME®*

Associate Editors
Katie Pacheco, *kpacheco@aws.org, ext. 275*
Society News, New Products

Alexandra Quiñones, *aquinones@aws.org, ext. 465*
Arc-Tist Corner

Education Editor
Roline Pascal, *rpascal@aws.org, ext. 303*
Coming Events, Personnel

Production Manager
Zaida Chavez, *zaida@aws.org, ext. 265*
Design and Production

Managing Editor, Digital and Design; Editor of *Inspection Trends* and *Welding Journal en Español*
Carlos Guzman, *cguzman@aws.org, ext. 348*
Inspection and Spanish-Language Content, Design and Production

Advertising
Sandra Jorgensen, *sjorgensen@aws.org, ext. 254*
Lea Owen, *lea@aws.org, ext. 220*

Subscriptions
Sonia Aleman, *saleman@aws.org, ext. 329*
Subscriptions Representative

Welding Journal Dept.
8669 NW 36 St., #130
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Note: The 2020 and 2021 schedules for all certifications are posted online at *awo.aws.org/instructor-led-seminars/seminar-exam-schedule.*

Certified Welding Inspector (CWI)

Seminar covers Parts A, B, and C of the CWI exam. Only Part B of the exam is taken following the conclusion of the seminar. Parts A and C are given at Prometric testing centers.

Location	Seminar Dates	Part B Exam Date
San Diego, CA	Dec. 6–11	Dec. 12
Miami, FL	Dec. 6–11	Dec. 12
St. Louis, MO	Dec. 6–11	Dec. 12
Dallas, TX	Jan. 10–15	Jan. 16
Charlotte, NC	Jan. 10–15	Jan. 16
Long Beach, CA	Jan. 17–22	Jan. 23
Denver, CO	Jan. 17–22	Jan. 23
Milwaukee, WI	Jan. 24–29	Jan. 30
Houston, TX	Jan. 24–29	Jan. 30
Pittsburgh, PA	Feb. 7–12	Feb. 13
Los Angeles, CA	Feb. 7–12	Feb. 13
Seattle, WA	Feb. 14–19	Feb. 20
Orlando, FL	Feb. 14–19	Feb. 20
Indianapolis, IN	Feb. 21–26	Feb. 27
San Diego, CA	Feb. 21–26	Feb. 27
Cleveland, OH	Feb. 28–March 5	March 6
Atlanta, GA	Feb. 28–March 5	March 6
Waco, TX	Feb. 28–March 5	March 6
Miami, FL	March 7–12	March 13
Salt Lake City, UT	March 7–12	March 13
Houston, TX	March 7–12	March 13
Chicago, IL	March 14–20	March 21
Phoenix, AZ	March 14–20	March 21
Boston, MA	March 21–26	March 27
Portland, OR	March 21–26	March 27
Dallas, TX	April 11–16	April 17
Minneapolis, MN	April 11-16	April 17
Norfolk, VA	April 11–16	April 17
Las Vegas, NV	April 18–23	April 24
St. Louis, MO	April 18–23	April 24
Cleveland, OH	April 25–30	May 1
Bakersfield, CA	April 25–30	May 1
Baton Rouge, LA	May 2–7	May 8
Sacramento, CA	May 2–7	May 8

Certified Welding Inspector (CWI) Part B

Course covers only Part B of the CWI exam. The Part B exam follows the conclusion of the three-day course.

Location	Seminar Dates	Part B Exam Date
Louisville, KY	Dec. 9–11	Dec. 12
Dallas, TX	Jan. 13–15	Jan. 16
Sacramento, CA	March 10–12	March 13
Minneapolis, MN	July 28–30	July 31
Cleveland, OH	Sept. 29–Oct. 1	Oct. 2
Miami, FL	Dec. 15–17	Dec. 18

9-Year Recertification Seminar for CWI/SCWI

For current CWIs and SCWIs needing to meet education requirements without taking the exam.

Location	Seminar Dates
Miami, FL	Dec. 6–11
Phoenix, AZ	Dec. 6–11
Miami, FL	Jan. 17–22
Houston, TX	Feb. 7–22
San Diego, CA	Feb. 14–19
St. Louis, MO	March 7–12

Certified Welding Educator (CWE)

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

Certified Welding Sales Representative (CWSR)

CWSR exams are given at Prometric testing centers. More information at *aws.org/certification/detail/certified-welding-sales-representative*.

Certified Resistance Welding Technician (CRWT)

A comprehensive two-day seminar to arm attendees with the knowledge needed to take the exam with confidence. More information at *aws.org/certification/page/certified-resistance-welding-technician*.

Certified Welding Supervisor (CWS)

CWS exams are given at Prometric testing centers. More information at *aws.org/certification/detail/certified-welding-supervisor.*

Certified Radiographic Interpreter (CRI)

The CRI certification can be a stand-alone credential or can exempt you from your next 9-Year Recertification. More information at *aws.org/certification/detail/certified-radiographic-interpreter*.

Location	Seminar Dates	Exam Date
Houston, TX	Jan. 24–29	Jan. 30
Dallas, TX	April 26–30	May 1

Certified Robotic Arc Welding (CRAW)

OTC Daihen Inc., Tipp City, OH; (937) 667-0800, ext. 218
Lincoln Electric Co., Cleveland, OH; (216) 383-4723
Wolf Robotics, Fort Collins, CO; (970) 225-7667
Milwaukee Area Technical College, Milwaukee, WI; (414) 456-5454
College of the Canyons, Santa Clarita, CA; (661) 259-7800, ext. 3062
Ogden-Weber Applied Technology College, Ogden, UT; (801) 627-8448
Genesis Systems IPG Photonics Co., Davenport, IA; (563) 445-5688

IMPORTANT: This schedule is subject to change without notice. Please verify your event dates with the Certification Dept. to confirm your course status before making travel plans. Applications are to be received at least six weeks prior to the seminar/exam or exam. Applications received after that time will be assessed a $395 Fast Track fee. Please verify application deadline dates by visiting our website at *aws.org/certification/docs/schedules.html.* For information on AWS seminars and certification programs, or to register online, visit *aws.org/certification* or call (800/305) 443-9353, ext. 273 for Certification; or ext. 455 for Seminars.

Introducing the AWS A5.39 Specification

By Teresa A. Melfi

The American Welding Society (AWS) A5.39/A5.39M:2020, *Specification for Flux and Electrode Combinations for Submerged Arc and Electroslag Joining and Surfacing of Stainless Steel and Nickel Alloys*, is a new publication for the classification of consumables for submerged arc welding (SAW) using stainless steel and nickel alloys. It also includes electroslag welding (ESW) and submerged arc cladding.

Many safety-critical components and structures use stainless steels and nickel alloys, and those fabricated from thick metal are often joined by SAW. These include 9% Ni tanks used for storing liquefied natural gas (LNG) at cryogenic temperatures, components made from nickel alloys for high-temperature service, and stainless steel tanks for petrochemical refining. Some vessels are so large they are constructed from low-alloy steel and then clad with nickel or stainless steel alloys to reduce material cost. In all these cases, there was no way to appropriately classify the welding consumables used. There was little possibility to substitute consumables of one trade name for another, and there was no standardized way to compare the chemical composition or mechanical properties of the weld metal.

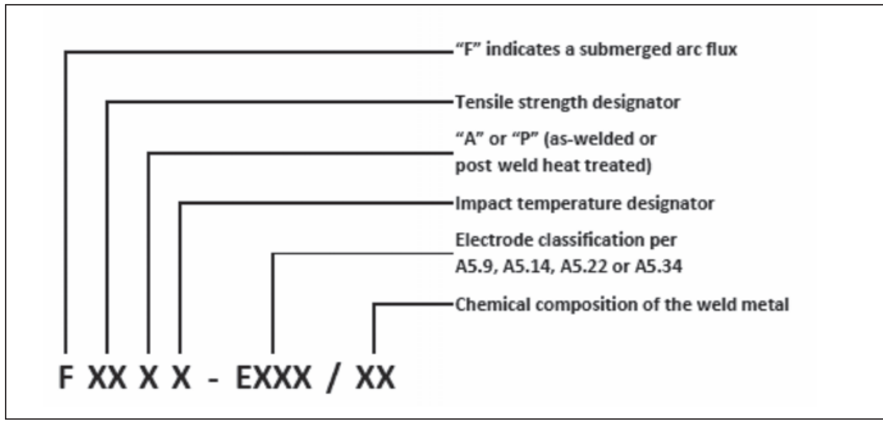

Fig. 1 — AWS A5.39 joining classification.

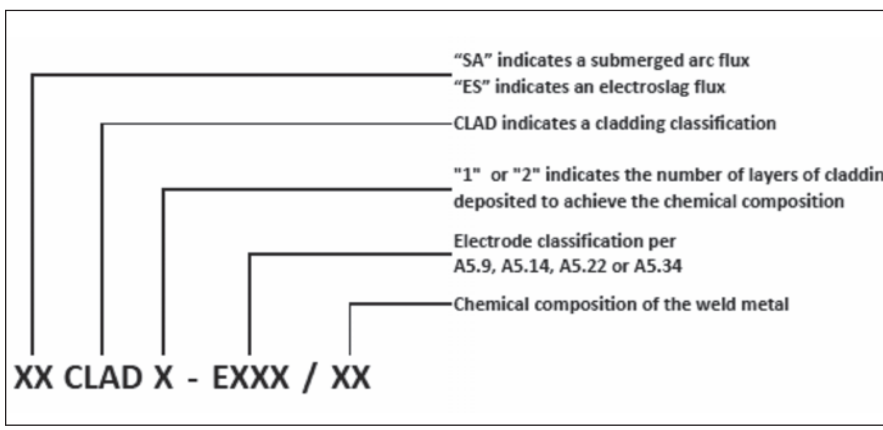

Fig. 2 — AWS A5.39 cladding classification.

Joining Classification

Two different types of classifications are used in A5.39. The first is a joining classification, which is very similar to those used for low-alloy SAW consumables in A5.23, *Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding*. It requires tests for strength, toughness, chemical composition, radiographic testing, and bend testing for austenitic stainless steels and most nickel alloys. The electrode classification refers back to a "mother" specification (e.g., A5.9, *Specification for Bare Stainless Steel Welding Electrodes and Rods,* for solid stainless steel and A5.14, *Specification for Nickel and Nickel-Alloy Bare Welding Electrodes and Rods,* for solid nickel alloys). The chemical composition of the weld metal also uses the familiar designations from other AWS specifications (e.g., 316L, NiCrMo-3, etc.). The A5.39 joining classification system is shown in Fig. 1.

The following offers two examples of the A5.39 joining classification system.

Example 1. F75A32-ER316L/316 is the designation for a flux-electrode combination that produces weld metal with a minimum 75,000 lb/in.^{2} tensile strength, a minimum Charpy V-notch impact energy of 20 ft·lbf at –320°F, and a minimum lateral expansion of 0.015 in. at –320°F using an ER316L electrode in the as-welded condition. The weld metal meets the chemical composition requirements for a 316 designation.

Example 2. F110P4-ER410NiMo/410NiMo is the designation for a flux-electrode combination that produces weld metal with a minimum 110,000 lb/in.^{2} tensile strength and a minimum Charpy V-notch energy of 20 ft·lbf at –40°F using an ER410NiMo electrode in the postweld heat-treated condition. The weld metal meets the chemical composition requirements for a 410NiMo designation.

Note that the chemical compositions of the electrode and the weld metal may be different from one another based on the alloying addition or removal properties of the flux. Also note that, when tested at cryogenic temperatures, the weld metal must meet a minimum lateral expansion requirement.

Cladding Classification

The other A5.39 classification type is used for cladding. It is a very simple classification, indicating only the chemical composition of the weld metal after one or two layers of cladding over mild steel. Radiographic testing of the overlay and bend testing of austenitic stainless steels and most nickel alloys is required. The classifications indicate whether joining was done by ESW or SAW because the fluxes used and the level of base metal dilution are quite different. The mild steel used for the cladding classification is specified to a very restricted level of any of the alloying elements (e.g., Ni, Cr, and Mo) because of the amount of base metal dilution involved. Again, the chemical composition of the weld metal uses the familiar designations found in other AWS specifications. The A5.39 cladding classification system is shown in Fig. 2.

The following offers two examples of the cladding classification system in A5.39.

Example 1. ESCLAD2-ER316L/316 is the designation for an electroslag flux-electrode combination that produces weld metal that meets the chemical composition requirements of 316 in two layers when using an ER316L electrode.

Example 2. SACLAD1-EQ309L/308L is the designation for a submerged arc flux-electrode combination that produces weld metal that meets the chemical composition requirements of 308L in one layer when using an EQ309L strip electrode.

"G" Classification

The joining and the cladding classifications allow for a general "G" classification for the weld metal chemical composition because it is common for the chemical composition of the weld metal to not exactly match that of the electrode. For example, a ERNiCrMo-4 electrode is commonly used for LNG tank fabrication, although the weld metal will often not meet the NiCrMo-4 designation for chemical composition. The annex in A5.39 provides more details regarding active, neutral, and alloying fluxes. WJ

TERESA A. MELFI (teresa_melfi@lincolnelectric.com) *is a Technical Fellow at The Lincoln Electric Co., Cleveland, Ohio, and chair of the AWS A5 Committee on Filler Metals and Allied Materials.*

TECH TOPICS

New Standards Approved by ANSI

A5.29/A5.29M:2021, *Specification for Low-Alloy Steel Electrodes for Flux Cored Arc Welding*. Approval Date: 9/11/2020.

Amendment and Errata for AWS D1.4/D1.4M:2018-AMD1

An amendment and errata for American Welding Society (AWS) D1.4/D1.4M:2018, *Structural Welding Code — Steel Reinforcing Bars*, have been identified and will be incorporated into the next reprinting of this standard. The second printing will be designated as AWS D1.4/D1.4M:2018-AMD1.

The amendment notice can be found at *aws.org/amendment#d1-4_2018*. The errata sheet can be found at *aws.org/errata#d1-4_2018*.

Opportunities to Contribute to AWS Technical Committees

The following committees welcome new members. Some committees are recruiting members with specific interests in regard to the committee's scope, as marked below: Producers (P), General Interest (G), Educators (E), Consultants (C), and Users (U). For more information, contact the staff member listed or visit *aws.org/library/doclib/Technical-Committee-Application.pdf*.

S. Borrero, *sborrero@aws.org*, ext. 334. **Definitions and symbols**, A2 Committee (E). **Titanium and zirconium filler metals**, A5K Subcommittee. **Piping and tubing**, D10 Committee (C, E, U). **Welding practices and procedures for austenitic steels**, D10C Subcommittee. **Aluminum piping**, D10H Subcommittee. **Chromium molybdenum steel piping**, D10I Subcommittee. **Welding of titanium piping**, D10K Subcommittee. **Purging and root pass welding**, D10S Subcommittee. **Low-carbon steel pipe**, D10T Subcommittee. **Orbital pipe welding**, D10U Subcommittee. **Duplex pipe welding**, D10Y Subcommittee. **Joining metals and alloys**, G2 Committee (E, G, U). **Reactive alloys**, G2D Subcommittee (G).

R. Gupta, *gupta@aws.org*, ext. 301. **Filler metals and allied materials**, A5 Committee (E). **Magnesium alloy filler metals**, A5L Subcommittee.

P. Portela, *pportela@aws.org*, ext. 311. **Additive manufacturing**, D20 Committee (C, E, G). **Titanium structural welding**, D1N Subcommittee (C, E, G, P, U).

J. Molin, *jmolin@aws.org*, ext. 304. **Structural welding**, D1 Committee (E). **Sheet metal welding**, D9 Committee (C, G, P).

K. Bulger, *kbulger@aws.org*, ext.

American Welding Society®
MEMBERSHIP

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Application for Membership

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A Ferrous Metals
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C Nonferrous Metals Except Aluminum
D Advanced Materials/Intermetallics
E Ceramics
F High Energy Beam Processes
G Arc Welding
H Brazing and Soldering
I Resistance Welding
J Thermal Spray
K Cutting
L NDT
M Safety and Health
N Bending and Shearing
O Roll Forming
P Stamping and Punching
Q Aerospace
R Automotive
S Machinery
T Marine
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W Sheet Metal
X Structures
Y Other
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1 Robotics
2 Computerization of Welding

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C Petroleum & Coal Industries
D Primary Metal Industries
E Fabricated Metal Products
F Machinery Except Electric (Incl. Gas Welding)
G Electrical Equipment, Supplies, Electrodes
H Transport Equip. – Air, Aerospace
I Transport Equip. — Automotive
J Transport Equip. — Boats, Ships
K Transport Equip. — Railroad
L Utilities
M Welding Distributors & Retail Trade
N Misc. Repair Services (Including Welding Shops)
O Educational Services (Univ., Libraries, Schools)
P Engineering & Architectural Services (Including Assns.)
Q Misc. Business Services (Including Commercial Labs)
R Government (Federal, State, Local)
S Other

Job Classification (Circle ONE Letter Only)

01 President, Owner, Partner, Officer
02 Manager, Director, Superintendent (Or Assistant)
03 Sales
04 Purchasing
05 Engineer — Welding
20 Engineer — Design
21 Engineer — Manufacturing
06 Engineer — Other
10 Architect Designer
12 Metallurgist
13 Research & Development
22 Quality Control
07 Inspector, Tester
08 Supervisor, Foreman
14 Technician
09 Welder, Welding or Cutting Operator
11 Consultant
15 Educator
17 Librarian
16 Student
18 Customer Service
19 Other

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306. **Methods of weld inspection**, B1 Committee (C, E). **Brazing and soldering**, C3 Committee (C, E, G). **Welding in marine construction**, D3 Committee (C, E, G, U). **High energy beam welding and cutting**, C7 Committee (C, E, G). **Hybrid welding**, C7D Subcommittee (G). **Welding of machinery and equipment**, D14 Committee (C, E, G, U).

M. Diaz, *mdiaz@aws.org*, ext. 310. **Resistance welding**, C1 Committee (C, E, G, U). **Friction welding**, C6 Committee (C, E). **Automotive welding**, D8 Committee (C, E, G, U). **Resistance welding equipment**, J1 Committee (C, E, G, U). **Welding in the aircraft and aerospace industry**, D17 Subcommittee (C, E, G).

S. Hedrick, *steveh@aws.org*, ext. 305. **Metric practice**, A1 Committee (C, E). **Mechanical testing of welds**, B4 Committee (E, G, P). **Joining of plastics and composites**, G1 Committee (C, E, G). **Safety and health**, SHC Committee (E, G). **Welding in sanitary applications**, D18 Committee.

J. Rosario, *jrosario@aws.org*, ext. 308. **Procedure and performance qualification**, B2 Committee (E, G). **Thermal spraying**, C2 Committee (C, E, G, U). **Oxyfuel gas welding and cutting**, C4 Committee (C, E, G). **Welding iron castings**, D11 Committee (C, E, G, P, U). **Railroad welding**, D15 Committee (C, E, G, U). **Robotic and automatic welding**, D16 Committee (C, E).

MEMBERSHIP ACTIVITIES

AWS Member Counts October 1, 2020

Sustaining	*583*
Supporting	*356*
Educational	*835*
Affiliate	*624*
Welding Distributor	*64*
Total Corporate	***2462***
Individual	*56,047*
Student + Transitional	*9651*
Total Members	***65,698***

AWS Distinguished Members

The following American Welding Society (AWS) members have attained the status of Distinguished Member for their participation in the Society's leadership, professional development activities, and membership recruitment.

• Douglas A. Desrochers, Central Massachusetts/Rhode Island Section

• Geoffrey H. Putnam, Green and White Mountains Section

To qualify for Distinguished Membership status, applicants must accrue 35 points or more from at least four categories: national AWS leadership, local AWS leadership, professional development, and AWS membership recruitment. If you believe you qualify, download the application form at *aws.org/membership/Individual* or contact the AWS Membership Department at (800) 443-9353.

2020 Membership Challenge

Listed here are the members who participated in the 2020 Membership Challenge — point standings as of September 23. The campaign runs from Jan. 1 to Dec. 31, 2020. Members receive 5 points for each Individual Member and 1 point for every Student Member they recruit.

For more information, please see page 73 of this *Welding Journal* or call the AWS Membership Dept. at (800) 443-9353, ext. 480.

J. W. Fregia, Houston — 95
A. D. Dillon, Detroit — 38
S. A. Milner, San Francisco — 36
J. W. Morris, Mobile — 35
B. J. Cain, Los Angeles/Inland Empire — 34
J. P. Theberge, Boston — 31
A. D. Stute, Madison-Beloit — 30
J. C. Durbin, Tri-River — 30
D. L. Galiher, Detroit — 29
T. A. Uff, Lehigh Valley — 29
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O. Ortiz, Los Angeles/Inland Empire — 16
G. J. Smith, Lehigh Valley — 15
C. W. Gilbertson, Northern Plains — 14
C. Consentino, Pittsburgh — 13
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San Martín de Porres
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Pellston, MI 49769

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Houston, TX 77014

Salisbury-Elk Lick School District
P.O. Box 68
Salisbury, PA 15558

The Winston School — San Antonio
8565 Ewing Halsell Dr.
San Antonio, TX 78229

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Change of Address? Moving?

Make sure delivery of your *Welding Journal* is not interrupted. Contact Kim Hugley in the Membership Department with your new address information — (800) 443-9353, ext. 204; *khugley@aws.org*.

AWS Education & Training Committee Seeks New Members

The AWS Education & Training Committee is welcoming new members from secondary education, higher education, and industry. The committee continues to work toward the betterment of welding education by reviewing present state and developing criteria to improve training standards nationwide.

If you are interested in becoming a member, contact Alicia Garcia at *agarcia@aws.org* for more information.

Nominate AWS Members to be Profiled

The *Welding Journal* is celebrating the diversity of its membership by profiling AWS members each month in its Society News section. Jessica Muñoz Reyes is profiled on the next page.

To nominate an AWS member, submit a short statement about what makes the nominee a noteworthy member, along with the nominee's contact information, to Katie Pacheco, *kpacheco@aws.org*.

To see member profiles from previous issues, visit *aws.org/about/page/diversity-inclusion*.

AWS Member Profile

Jessica Muñoz Reyes

Jessica Muñoz Reyes is confirmation that the family that inspects together stays together. Her father, Robert Bowell, has been inspecting and evaluating new and rehabilitated water tanks throughout Texas for more than 40 years. In 2013, he started Boswell's Consulting Testing Services, and in 2016, he helped launch Boswell and Reyes International LLC, which serves the water and wastewater industry. Having been raised in this environment has given Muñoz a knack for inspecting welds.

"Being involved in and growing up with structural steel, I understand what welds look like that are in compliance and welds that are not," she said. "It is really interesting to see how structural steel buildings and steel water towers are built."

In 2018, Muñoz moved to Round Rock, Tex., to fully devote herself to the family business. Her job includes creating proposals, reporting on quality control, and performing field coating and welding inspections. These tasks sometimes require Muñoz to scale towering structures, but she doesn't mind the heights.

"I love climbing water tanks and poking my head in them to see what is inside. Plus, the view from that high up is a perk," she affirmed.

When inspection is needed in areas that are not easily or safely accessible by personnel, Muñoz relies on drones. In 2019, she earned a remote pilot certificate (Part 107, small unmanned aircraft) from the Federal Aviation Administration. Being a drone pilot allows her to use advanced technology to meet the diverse inspection needs of customers.

"Our clients appreciate seeing their tanks and structures at a bird's-eye view, especially when the tanks have a fresh coat of paint on them," she said. "Aerial photos of structural steel buildings and other structures help our clients understand the complexity of the structural steel projects."

The job has also allowed her to travel and be involved in many interesting projects.

"I have witnessed welded steel, stainless steel, aluminum, and bolted and riveted water tanks being rehabilitated and newly constructed. I have traveled to the shipyards in Louisiana and California and welding shops in Indiana to assist in the visual inspection and ultrasonic testing of a crane vessel and river barges," she explained. "I have assisted in the inspection of bolt and weld decking on new construction. I have assisted in gathering steel thickness measurements on the base of light poles to determine the severity of corrosion."

However, what she enjoys most about the job is spending quality time with family.

"My family bond has become much stronger," she said. "The conversations with my father are different; I can now understand him when he talks about work."

In addition to her inspection job, Muñoz is a sophomore at Austin Community College in Austin, Tex., where she is working toward an associate's in welding inspection. Despite the COVID-19 pandemic, Muñoz has been able to continue her education.

"When COVID-19 shut everything down, our classes switched to online. Fortunately, I was taking classroom classes and was able to complete my coursework through the online system," she recalled. "My instructors were very helpful and communicated throughout the entire process. It was something new we had not experienced before and they did a great job."

She is also thankful that the college is permitting her to continue the practical, hands-on portion of the welding curriculum.

"The welding department is one of the few programs that is allowing in-person teaching," she said. "I feel safe there. They make sure we have what we need, have our masks on, take our temperature before entering the building, and keep the lab clean."

Once she graduates in 2021, Muñoz will add the degree to her long list of accomplishments, which include Occupational Safety and Health Administration's certifications in confined space training, fall prevention training, and general construction (30 h). She is also a NACE Level 1 coating inspector and an American Welding Society (AWS) Certified Associate Welding Inspector.

Some of her future plans are to become an AWS Certified Welding Inspector and a certified underwater diver, which will allow her to perform underwater welding inspections. She also wants to add the following to her professional repertoire: NACE Level 2 and 3; International Code Council structural steel and bolting certification; American Society for Nondestructive Testing (ASNT) certified inspector in ultrasonic examination; ASNT Level II in visual testing; LEED project manager (advanced professional); and special inspector license.

Muñoz's long list of goals are part of her plan to follow in her father's footsteps and one day manage the family business.

"After graduation, I will continue to work in the family business and will be taking on more responsibility. I'm lucky enough to already be a part of my dream job," she affirmed. "I will continue to learn with field experience and mentoring from my dad, then be able to successfully take over the business."

Jessica Muñoz Reyes inspects a weld.

BY CINDY WEIHL — *cweihl@aws.org*

District 1
Douglas A. Desrochers, director
(508) 763-8011
dadaws@comcast.net

District 2
Harland Thompson, director
(631) 546-2903
harland.w.thompson@ul.com

District 3
Sean Moran, director
(717) 885-5039
sean.moran@phillyshipyard.com

District 4
Mr. Lynn Showalter, director
(757) 848-8029
lynneshowalter@gmail.com

District 5
Howard Record, director
(352) 816-0835
howard@rtdtools.com

District 6
Ronald Stahura, director
(716) 207-7869
rstahura@esab.com

District 7
Roger E. Hilty, director
(740) 317-9073
rhilty@comcast.net

District 8
James Thompson, director
(256) 347-6481
jim.thompson@wallacestate.edu

District 9
Michael Skiles, director
(337) 501-0304
michaelskiles@cox.net

District 10
Mike Sherman, director
(216) 570-9348
mike@shermanswelding.com

District 11
Phillip Temple, director
(734) 546-4298
nwcllc_ptemple@att.net

District 12
Dale Lange, director
(715) 732-3645
dale.lange@nwtc.edu

District 13
Ronald Ashelford, director
(815) 218-8766
r.ashelford@rockvalleycollege.edu

CHICAGO
September 16
Location: Joliet Junior College, Joliet, Ill.
Presenters: John Killion, Union Tank Car Co.; and Larry Strouse, Federal Railroad Administration
Summary: The Section held a technical meeting where Killion discussed welding procedure specifications and qualifications for AWS D15.1, *Railroad Welding Specification for Cars and Locomotives*. Strouse spoke about weld training, safety, and codes for railway welding involving the D15.1 standard.

District 14
Tony Brosio, director
(765) 215-7506
tbrosio@yahoo.com

District 15
Michael Hanson, director
(763) 221-5951
mikhan318@comcast.com

NORTHWEST
August 21
Location: Minneapolis, Minn.
Summary: First-year welding students at Dunwoody College of Technology presented a desk organizer project they completed at the end of their first week of school. Learning in a COVID-19 environment has had its challenges, but the students have met them head on.

District 16
Karl Fogleman, director
(402) 677-2490
fogleman3@cox.net

NEBRASKA
August 14
Location: Papillion, Neb.
Summary: Section members and guests played in a golf tournament

CHICAGO — *Section executive board members John Hesseltine, James Greer, and David Viar gathered with meeting attendees for a group photo.*

benefiting the welding class at the Iowa School for the Deaf in Council Bluffs, Iowa. The charitable event aids in obtaining supplies and equipment for the program.

District 17

J Jones, director
(832) 506-5986
drtourch@yahoo.com

CENTRAL TEXAS

August 21
Location: DuPuy Oxygen and Industrial Supply, Waco, Tex.
Summary: Drea Castillo, an incoming student to the applied science/welding program at Texas State Technical College in Waco, Tex., was awarded a $500 Section scholarship.

September 3
Location: Texas State Technical College (TSTC) Workforce Training Department, Waco, Tex.
Summary: Joseph Cadriel, an incoming student to the applied science/welding program at TSTC, received a $500 Section scholarship. Cadriel was the 2020 valedictorian of Methodist Children's Home, homecoming king, and recipient of the Most Improved Award in football. He also attended the welding program at Greater Waco Advanced Manufacturing Academy.

District 18

Thomas Holt, director
(409) 721-5777
tholt@techcorr.com

District 19

Shawn McDaniel, director
(509) 793-5182
shawnm@bigbend.edu

District 20

Denis Clark, director
(208) 357-6626
denis.clark.51@gmail.com

COLORADO

September 10
Location: Radisson Hotel, Denver, Colo.
Presenter: Jerry Jones
Summary: The Section's September meeting included a discussion on new innovations in induction welding.

District 21

Sam Lindsey, director
(858) 740-1917
slindsey@sandiego.gov

District 22

Robert Purvis, director
(916) 599-5561
purviswelds@gmail.com

International

TAIWAN

September 12
Location: Hoya Resort Hotel Kaohsiung, Taiwan
Summary: The Section took a new approach to hosting meetings by holding its September event at the Hoya Resort Hotel. In accordance with local government rules regarding the COVID-19 pandemic and social distancing, the total number of participants had to be limited. Sixty members participated in the monthly meeting as well as an AWS Certified Weld-

NORTHWEST — *Sessions 1, 2, and 3 of Dunwoody College of Technology welding classes show off the projects made during the first week of school.*

NEBRASKA — *The Section's golf tournament winners were (from left) Rhett Henderson, Tom Richardson, Jack Tarr, and Reid Hanny.*

ng Inspector reunion. Meeting attendees viewed virtual presentations by AWS Executive Director and CEO Gary Konarska II and Program Manager, International, Mark Pidal. Participants also discussed positive results and opinions on computer-based testing; the growing demand in coating inspection for offshore windfarm structures; and increasing interest in joining and inspecting plastic tubes or liners for the semiconductor manufacturing industry in Taiwan. The Section is thankful to all attendees and speakers; Darrill Gaschler, AWS senior manager, Sections and Student Sections, for coordinating and supporting the meeting; and Kou-Han Science and Technology Ltd. (KHST), AWS's agent in Taiwan, which was the primary sponsor/organizer of this meeting as well as the sole financial contributor for the banquet. The Section is also grateful for the outstanding efforts and contributions of May Chen, president of KHST.

CENTRAL TEXAS — *Award recipient Drea Castillo (center) is pictured with Section Treasurer Carr DuPuy and Section Chair Donnie Williams.*

CENTRAL TEXAS — *Award recipient Joseph Cadriel (second from right) is seen with (from left) Section Chair Donnie Williams, Kenneth Alexander from Methodist Children's Home, and Section Treasurer Carr DuPuy. (Photo by Sarah Wright, Methodist Children's Home.)*

COLORADO — *September meeting attendees gathered for a group photo.*

TAIWAN — *Meeting attendees enjoyed a banquet, virtual presentations, and a reunion.*

TAIWAN — *AWS CEO and Executive Director Gary Konarska II virtually participated in the meeting.*

GUIDE TO AWS SERVICES

American Welding Society®
8669 NW 36 St., #130
Miami, FL 33166-6672
(800/305) 443-9353
Phone extensions are in parentheses.

AWS PRESIDENT
Robert W. Roth..*rroth@romanmfg.com*
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SENIOR LEADERSHIP TEAM
Executive Director/Chief Executive Officer
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Gesana Villegas.. *gvillegas@aws.org* . . . .(252)

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Research, Strategy, and Membership

John Gayler.. *gayler@aws.org* . . . .(472)
Welding & Technology

EXECUTIVE OFFICE
Associate Director
Chelsea Steel.. *csteel@aws.org* . . . .(294)

Program Administrator, National Awards
Malisa Mercado.. *mmercado@aws.org* . . . . . .(293)

HUMAN RESOURCES
Director
Alex Diaz.. *adiaz@aws.org* . . . .(209)

GOVERNMENT LIAISON SERVICES
Hugh Webster.. *hwebster@wc-b.com*
Webster, Chamberlain & Bean, Washington, D.C. (202) 785-9500; Fax: (202) 835-0243
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Dept. information . . . .(273)

Managing Director
Denny Smith.. *dsmith@aws.org* . . . .(263)

ACCREDITATION
Senior Manager
Emil Pagoaga.. *epagoaga@aws.org* . . . .(448)

CONFERENCES & EVENTS
Dept. information . . . .(213)

CUSTOMER SERVICE & SUPPORT
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SALES

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Michael Rovins.. *mrovins@aws.org* . . . .(350)

Senior Sales Executive, Corporate
Sandra Jorgensen.. *sjorgensen@aws.org* . . . .(254)

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Senior Sales Executive, Expositions
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EDUCATION & TRAINING
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Alicia Garcia.. *agarcia@aws.org* . . . .(229)

INFORMATION SYSTEMS
Managing Director
John Perry.. *jperry@aws.org* . . . .(247)

ITSA — INTERNATIONAL THERMAL SPRAY ASSOCIATION
Program Manager
Alfred Nieves.. *anieves@aws.org* . . . .(467)

RWMA — RESISTANCE WELDING MANUFACTURING ALLIANCE and WEMCO — ASSOCIATION OF WELDING MANUFACTURERS
Program Manager
Adrian Bustillo.. *abustillo@aws.org* . . . .(295)

MEMBER SERVICES
Dept. information . . . .(480)

Director, Membership
Nici Banks.. *nbanks@aws.org* . . . .(270)
Serves as a liaison between members and AWS headquarters.

Senior Manager, Sections and Student Chapters
Darrill Gaschler.. *dgaschler@aws.org* . . . .(260)

PUBLISHING & EDITORIAL
Dept. information . . . .(275)

Welding Journal
Publisher/Editor
Annette Alonso.. *aalonso@aws.org* . . . .(299)

Managing Editor
Kristin Campbell.. *kcampbell@aws.org* . . . . .(257)

Society News Editor
Katie Pacheco.. *kpacheco@aws.org* . . . .(275)

Section News Editor
Cindy Weihl.. *cweihl@aws.org* . . . .(256)

***Inspection Trends* Editor**
Carlos Guzman.. *cguzman@aws.org* . . . .(348)

STANDARDS DEVELOPMENT
Dept. information . . . .(340)

Director — Standards Development
Peter Portela.. *pportela@aws.org* . . . .(311)
Technical Committee Activities, Additive Manufacturing, Structural Subcommittee on Titanium

Director — International Activities
Andrew Davis.. *adavis@aws.org* . . . .(466)
International Standards Activities, American Council of the International Institute of Welding

Program Managers

Stephen Hedrick.. *steveh@aws.org* . . . .(305)
Metric Practice, Safety and Health, Joining of Plastics and Composites, Personnel and Facilities Qualification, Mechanical Testing of Welds, Welding in Sanitary Applications

Stephen Borrero.. *sborrero@aws.org* . . . .(334)
Definitions and Symbols, Structural Subcommittees on Bridge Welding, Reinforcing Steel and Stainless Steel, Joining of Metals and Alloys, Piping and Tubing

Rakesh Gupta.. *gupta@aws.org* . . . .(301)
Filler Metals and Allied Materials, International Filler Metals, UNS Numbers Assignment, Computational Weld Mechanics

Jennifer Molin.. *jmolin@aws.org* . . . .(304)
Structural Welding, Sheet Metal Welding

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Automotive, Resistance Welding, Resistance Welding Equipment, Welding and Brazing in Aerospace, Friction Welding

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Brazing and Soldering, Methods of Weld Inspection, High-Energy Beam Welding, Welding in Marine Construction, Welding of Machinery and Equipment

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Oxyfuel Gas Welding and Cutting, Railroad Welding, Robotics Welding, Thermal Spraying, Welding Iron Castings, Welding Qualification

***Welding Handbook* Editor**
Kathy Sinnes.. *ksinnes@aws.org* . . . .(255)

AWS FOUNDATION INC.
aws.org/w/a/foundation
General Information
(800/305) 443-9353, ext. 212, *jdouglass@aws.org*

Chair, Board of Trustees
William A. Rice.. *brice@oki-bering.com*

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The AWS Foundation is a not-for-profit 501(c)(3) charitable organization established to provide support for the educational and scientific endeavors of the American Welding Society. Promote the Foundation's work with your financial support.

AWS American Welding Society

Types of Arc Welding Processes

The term *arc welding* applies to a large, diversified group of welding processes that use an electric arc as the source of heat. The creation of a weld between metals using these processes does not usually involve pressure. The process may or may not utilize a filler metal. The arc is initiated between the workpiece and the tip of the electrode. The intense heat produced by the arc melts the base metal in the area of the arc, which upon cooling results in the formation of a weld. The electric arc may be either moved along the joint to produce the weld or held stationary while the workpiece is moved under the process.

Arc welding can be performed by conducting the welding current through consumable electrodes, such as a wire or rod, or it can be done using nonconsumable electrodes of carbon or tungsten rods. Metal arc processes utilize consumable electrodes that melt the electrode filler metal along with the base metal to create the weld. Some arc welding processes may also produce a slag covering to protect the molten metal from oxidation or support out-of-position welding. The nonconsumable arc processes generate a weld by melting the base metal only, resulting in what is termed as an *autogenous weld*. The nonconsumable electrode serves only to sustain the arc. If filler metal is required in a nonconsumable process, it may be fed either manually or mechanically into the molten weld pool.

There are several types of arc welding processes. The following briefly summarizes eight of these processes.

Shielded metal arc welding (SMAW). This is used to weld ferrous and some nonferrous metals. It incorporates the use of a metal arc (an arc that transfers metal), which is formed between a covered electrode and the weld pool. The electrode typically consists of a solid wire core around which a concentric flux mixture of silicate binders and powdered materials such as fluorides, carbonates, oxides, metal alloying elements, and cellulose is extruded. This covering serves as a source of arc stabilizers and vapors to displace air. It also displaces metal and slag to protect, support, and insulate the hot weld metal.

Submerged arc welding (SAW). A versatile production welding process with high productivity, SAW joins metals by heating them with an electric arc formed between a continuously fed, bare metal electrode (either a solid or cored wire) and the workpiece. It involves establishing and maintaining the welding arc submerged beneath a mound of granular flux particles. Additional flux is continually added in front of the electrode as welding progresses. The flux helps in stabilizing the arc and protecting the molten weld metal against contamination from the ambient atmosphere.

Gas tungsten arc welding (GTAW). This process incorporates the use of a nonconsumable tungsten electrode to initiate and sustain the arc, which is shielded from the atmosphere by an externally supplied gas. The gas is almost always inert, but there are cases where an active gas can be used for very specialized applications. GTAW is one of the most versatile of the arc welding processes. Welds can be made with or without filler metal and the process can be used to weld very thin materials that are just a few thousandths of an inch thick. It can also be used in all welding positions to join just about all weldable ferrous and nonferrous alloys.

Plasma arc welding (PAW). This produces welds by striking a constricted arc between a nonconsumable electrode and the weld pool (transferred arc) or between the electrode and the constricting nozzle (nontransferred arc). PAW is very similar to GTAW because it was a technological advancement based on the GTAW process. It uses an inert shielding gas for almost all applications and lends itself to automated and robotic welding. Though classified as a gas shielded arc process, PAW functions like a high-power density process because it has the capacity to join materials with the keyhole welding technique along with the conventional melt-in welding method (involving weld pools).

Gas metal arc welding (GMAW). This process involves the use of an arc and a consumable electrode with an externally added shielding gas. With various choices of metal transfer modes, a wide range of electrode sizes, and numerous options for shielding gas mixtures, the GMAW process can be utilized to weld many ferrous and nonferrous metals. These metals can range in size from 0.020-in., thin-gauge sections to any desired plate or pipe section thickness. With the proper procedure and technique, GMAW can be performed in all positions. If the variables are properly set on the controls of the welding machine, less skill is typically required for GMAW than for the SMAW or GTAW processes.

Flux cored arc welding (FCAW). This process uses the same type of power sources, wire feeders, and welding guns as GMAW. However, FCAW incorporates the use of a tubular electrode with a core containing flux and alloying elements. A variation, self-shielded FCAW (FCAW-S), obtains its shielding gases from the breaking down of the internal flux component of the electrode as it is consumed by the arc. The FCAW-S gun differs from the GMAW gun in that it has no nozzle for shielding gas. Gas shielded FCAW is another variation of the process.

Electrogas welding (EGW). EGW is a mechanized arc welding process that utilizes either flux cored or solid electrodes. In this process, the shielding gas may be applied from an external source or produced by a flux cored electrode, or both. It has been used successfully on titanium and aluminum alloys in addition to steels. Though EGW has relatively limited use, it has been applied in the manufacture and repair of storage tanks, pressure vessels, ship hulls, and structural components.

Drawn arc stud welding (SW). SW is a versatile electric arc welding process used to join many devices — usually fasteners — to the base metal. This process utilizes an electric arc struck between a metal stud and the workpiece. It is applied without any additional filler metal and with or without shielding gas. Partial shielding may or may not be provided by a graphite or ceramic ferrule surrounding the stud. Pressure is applied when the faying (closely fitting) surfaces are adequately heated. SW is typically completed in less than a second, making it a highly productive process. WJ

Excerpted from the Welding Handbook*, Tenth Edition, Volume 1, Welding and Cutting Science and Technology.*

MANN+HUMMEL Appoints President and General Manager of Original Equipment


H. Späth

MANN+HUMMEL, Ludwigsburg, Germany, a developer of filtration solutions, has named Harald Späth as president and general manager for its original equipment business unit. For the present moment, he will continue his position as senior vice president, original equipment Europe, in addition to his new role. Späth has been part of the company since 1995, where he was responsible for the heavy duty and industrial division as vice president, global sales and project management. Following his position as the company's managing director in England, he took over worldwide sales management for the industrial filter business.

Eriez® Adds Vice President-International


J. Kohmuench

Eriez®, Erie, Pa., a separation technologies provider, has promoted Jaisen Kohmuench to vice president-international. He has been with the company since 2000, serving most recently as senior director of Asia-Pacific operations and strategy for subsidiaries in China, Japan, and Australia. During his career, Kohmuench has been the recipient of numerous awards, including the 2018 Frank F. Aplan Award presented by the Society for Mining, Metallurgy & Exploration and the American Institute of Mining, Metallurgical, and Petroleum Engineers. Additionally, he has published an array of technical papers and made dozens of professional presentations at various domestic and international conferences.

Xiris Hires Director of Sales, Americas


W. Younis

Xiris Automation, Burlington, Ontario, Canada, a developer of optical equipment, has designated Wassim Younis as director of sales, Americas. With a technical background in mechanical engineering, Wassim has experience with providing technology solutions to customers across North America, most recently as a sales manager. He will be responsible for all sales of the company's weld cameras and inspection systems across North and South America.

AEIS Promotes Vice President of Human Resources

Atlas Evaluation & Inspection Services (AEIS), South Plainfield, N.J., a testing, inspection, and certification company, has announced Sony John as vice president of human resources. Since joining the company in August 2016, she has been responsible for leading human resources functions, including talent acquisition, benefits administration, payroll, compliance, employee development and training, and more. John brings more than 20 years of professional experience across the legal, consulting, and technology sectors. Prior to joining the company, she was a human resources generalist at Gandhi & Associates, a New Jersey law firm specializing in commercial and residential real estate, family, litigation, and municipal matters. Before that, she worked in Bangalore, India, as a technical writer with Tata Consultancy Services and a business information analyst and writer with IBM Global Services India Pvt. Ltd.

S. John

Mahr Welcomes General Manager of Sales

Bill Taylor has joined Mahr Inc., Providence, R.I., a global manufacturer of precision measurement equipment, as general manager of sales for the United States and Canada. In addition to field sales, he will oversee the marketing, product management, application engineering, service, customer resource center, and distribution teams. Taylor has more than 20 years of industrial experience and has held leadership positions with companies including Kistler Instrument Corp., Kokusia Inc., and Wellman Thermal Systems. He also served in the U.S. Army as a commander and in the National Guard.

Obituaries

Jack H. Devletian

Jack H. Devletian, PhD, of Portland, Ore., passed away peacefully surrounded by his family on August 15. He was 79. Devletian earned a bachelor of science degree in mechanical engineering from the University of Massachusetts as well as master of science and PhD degrees in metallurgical engineering from the University of Wisconsin. He devoted more than 40 years to welding research, con-

J. H. Devletian

sulting, and postgraduate instruction as a professor at Oregon Graduate Institute, professor and associate dean at Portland State University, and associate professor at Youngstown State University in Ohio. He also held positions at Lincoln Electric and NASA Glenn Research Center. He further authored/coauthored more than 100 technical papers and held three U.S. patents. Devletian was also a member of the American Welding Society (AWS), joining the organization in 1972 and becoming a Life Member in 2007. Through AWS, he won numerous awards, including the Charles H. Jennings Memorial Award, Adams Memorial Membership Award, A. F. Davis Silver Metal Award, Arsham Amirikian Memorial Maritime Welding Award, and Samuel Wylie Miller Memorial Medal Award. He was an AWS Certified Welding Inspector from 1981 to 1999 and became an AWS Fellow in 2003. He also belonged to several AWS committees and was a principal peer reviewer for the *Welding Journal*. Locally, he served two terms as chair of the AWS Portland Section. He is survived by his wife of 51 years, JoAnna; three children, Amy, John, and Robert; one grandchild; and several nieces, nephews, great-nieces, and great-nephews. His family would be grateful for messages of remembrance from friends and colleagues. His online memorial can be found at *springerandson.com*.

Kenneth Arlen Poarch

K. A. Poarch

Kenneth Arlen Poarch, of Watonga, Okla., passed away August 18. He was 81. Poarch's childhood memories were filled with many shenanigans, including tractor mishaps and hiding in the fields with his 13 brothers and sisters. He graduated from Watonga High School in 1958, then joined the Army thereafter, serving in Okinawa, Japan. He began his career at Western Electric but spent more than 40 years at the Boardman Co. He started out sweeping floors before working as a welder and eventually retiring as a plant superintendent in 2002. He spent time teaching and creating his own steel artwork after retirement. Joining the American Welding Society in 1976, he proudly served as first vice chair (1979–1980), chair (1980–1981), and technical representative (1981–1991) of the Oklahoma City Section. He became a Life Member in 2011. His greatest joy was his family, and his proudest achievement was being "Grandad." Poarch is survived by his wife of nearly 52 years, Teresa; two children, Lisa and Brad; two grandsons, Jimmy and Will; eight siblings; three brother- and sisters-in-law; and numerous nieces and nephews. WJ

Statement of Ownership, Management and Circulation for U.S. Postal Service (Required by U.S.C. 3685)

1. TITLE OF PUBLICATION: Welding Journal — 2. PUBLICATION NO.: ISSN 0043-2296
3 DATE OF FILING: September 30, 2020 — 4. FREQUENCY OF ISSUE: Monthly
5. NO. OF ISSUES PUBLISHED ANNUALLY: 12 — 6. ANNUAL SUBSCRIPTION: $120.00
7. MAILING ADDRESS OF KNOWN OFFICE OF PUBLICATION: 8669 NW 36 St., #130, Miami, Florida 33166
8. MAILING ADDRESS OF THE HEADQUARTERS OR GENERAL BUSINESS OFFICES OF THE PUBLISHERS:
8669 NW 36 St., #130, Miami, Florida 33166
9. NAMES AND COMPLETE ADDRESS OF PUBLISHER, EDITOR AND MANAGING EDITOR:
PUBLISHER: Annette M. Alonso, AWS, 8669 NW 36 St., #130, Miami, Florida 33166
EDITOR: Annette M. Alonso, AWS, 8669 NW 36 St., #130, Miami, Florida 33166
MANAGING EDITOR: Kristin Campbell, AWS, 8669 NW 36 St., #130, Miami, Florida 33166
10. OWNER: NAME: American Welding Society, Inc. ADDRESS: AWS, 8669 NW 36 St., #130, Miami, Florida 33166
11. KNOWN BONDHOLDERS, MORTGAGEES, AND OTHER SECURITY HOLDERS OWNING OR HOLDING 1 PERCENT OR MORE OF TOTAL AMOUNT OF BONDS, MORTGAGES OR OTHER SECURITIES: None
12. The purpose, function, and nonprofit status of this organization and the exempt status for Federal income tax purposes: Has not changed during preceding 12 months
13. Publication Title: Welding Journal — 14. Issue date for Circulation Data Below: October, 2020
15. EXTENT AND NATURE OF CIRCULATION:

	Average No. Copies Each Issue During Preceding 12 Months	Actual No.Copies of Single Issue Published Nearest to Filing Date
A. Total No. Copies Printed (Net Press Run)	45,933	43,500
B. Paid and/or Requested Circulation		
1. Paid / Requested Outside-County Mail Subscriptions Stated on Form 3541	44,622	42,285
2. Paid In-County Subscriptions Stated on Form 3541	None	None
3. Sales Through Dealers and Carriers, Street Vendor, Counter Sales, and other Non-USPS Paid Distribution	None	None
4. Other Classes Mailed Through the USPS	None	None
C. Total Paid / Requested Circulation	44,622	42,285
D. Free Distribution by Mail (Samples, complimentary and other free)		
1. Outside-County as Stated on Form 3541	7	3
2. In-County as Stated on Form 3541	None	None
3. Other Classes Mailed Through the USPS	None	None
4. Free Distribution Outside the Mail (Carriers or other means)	None	None
E. Total Free Distribution	7	3
F. Total Distribution	44,629	42,288
G. Copies not Distributed	1,304	1,212
H. Total	45,933	43,500
I. Percent Paid and / or Requested Circulation	99.98%	99.99%

16. Statement of Ownership will be printed in the November 2020 issue of this publication.
I certify that the statements made by above are correct and complete:
Annette M. Alonso, Publisher

— continued from page 15

Damen Shipyards Cape Town Lays Keel on Second Project for BIRO Inshore Patrol Vessel

Apprentice Welder Jenny-Lee Fortuin welds the coin to the keel for the second of three multimission, inshore patrol vessels that Damen Shipyards Cape Town is building.

Damen Shipyards Cape Town, South Africa, recently held a keel laying for the second of three multimission, inshore patrol vessels it's constructing for the South African Navy's Project BIRO, which aims to develop maritime security. The event was planned to ensure the well-being of delegates during the coronavirus pandemic. In addition to stringent safety measures on site, physical attendance was reduced with remote participation.

Damen Shipyards Cape Town Board Member Sefale Montsi opened the keel laying by welcoming guests. The vessels for this project are tailored to the requirements of the South African Navy and feature the Damen Sea Axe Bow, a vertical hull form that reduces slamming for safe operations in rough seas. This project has created more than 300 direct jobs and 1000 indirect jobs in line with the South African government's Operation Phakisa objectives.

Following speeches, the tradition of welding a coin to the keel was observed. Jenny-Lee Fortuin, a second-year apprentice welder with Damen Shipyards Cape Town's Apprentice Training Centre, performed this task. The minted coin was a commemorative medal made in honor of the late President Mandela as winner of the 1993 Nobel Prize for Peace.

Damen Shipyards Cape Town is progressing with the first Project BIRO inshore patrol vessel, which it expects to deliver in 2021.

Nextant Aerospace and Veracity Technology Solutions Join Forces to Broaden NDE Services

Nextant Aerospace, Cleveland, Ohio, and Veracity Technology Solutions, Pensacola, Fla., are partnering to expand their nondestructive examination (NDE) capabilities beyond the aviation industry. While the two companies will continue to focus on business and military aircraft inspections, they will share resources to grow NDE services in outside markets from power generation and industrial services to amusement park rides.

Nextant Aerospace is dedicating five of its NDE technicians to the partnership. Veracity Technology Solutions is contributing 15 technicians. As NDE requests are received, the companies will work together to dispatch technicians from the pool of 20 to complete each job. All technicians are Level II certified, meaning they are qualified to set up equipment, conduct testing, and provide on-the-job training.

Bombardier to Supply 27 Additional Trains for France's Normandy Region

The OMNEO *Premium train has been designed to offer France's long-distance passengers a travel experience with high standards of comfort.*

Global mobility solution provider Bombardier Transportation has received an order for 11 additional *OMNEO* Premium, double-deck, electric multiple unit trains (110 cars) from French National Railway Co. (SNCF) on behalf of the Normandy region.

This extra order amounts to $182 million and is part of the framework contract signed with SNCF in 2010 to provide up to 860 trains for France's regions. Previously, the provider received a separate firm order for 16 additional trains.

The Normandy region plans to issue these trains on the highly frequented lines linking Paris to Vernon-Rouen and Paris to Evreux-Serquigny. The first trains of this order will be delivered at the end of 2023. Once released, the region will have a fleet of 67 *OMNEO* Premium trains, which will be maintained mainly in the new Sotteville-lès-Rouen SNCF technicenter, as well as in Caen and Le Havre.

Both in first and second class, each passenger can enjoy two individual armrests, reclining seats, a reading light, USB and power plugs, and a large table. The train's floor plan has also been slightly adjusted to reach 550 seats for each 443-ft trainset, in addition to space for 12 bicycles.

Industry Notes

• **AVATAR Partners**, Huntington Beach, Calif., a provider of software solutions, has been awarded a contract to provide its Mixed and Augmented Reality for Nondestructive Evaluation offering for the **U.S. Air Force**. The custom solution will be used by Air Force inspectors to access and interact with nondestructive examination instrumentation and sensor information. They will be able to perform electromagnetic procedures on an inspection device designed to detect tiny defects in scanning equipment.

• **Solar Atmospheres of Western PA**, Hermitage, Pa., is installing a rapid-quenching vacuum furnace that will ultimately eliminate the need for helium. The company's 10-bar vacuum furnace will mimic an older 2-bar Solar furnace in size. However, this new 48 × 48 × 96 in. deep, 10-bar furnace is equipped with a 600-hp blower designed motor. It will outperform the older model by processing larger, heavier workloads with the use of nitrogen only.

• Brazing machines by **Castolin Eutectic**, Menomonee Falls, Wis., have been awarded with The Solar Impulse Efficient Solution Label. Dyomix® OHM 2.4 and 3.0 have earned this certification, which applies to products, processes, and services combining economic profitability along with environmental sustainability.

• **ASTM International**, W. Conshohocken, Pa., recently revealed its third round of funding to support research that helps expedite standards in additive manufacturing. This year, more than 60 ideas for projects were submitted by members; after review, eight were approved by the ASTM executive section on research and innovation within the committee on additive manufacturing technologies.

• **PaR Systems**, Shoreview, Minn., is poised to bring its proprietary friction stir welding expertise to assist high-tech manufacturers in creating lighter, stronger welds of higher quality in less time than traditional processes. Its friction stir welding technology, known as I-STIR™, can be used in manufacturing processes from semiconductors to computer monitors and electric vehicles to bridge decks and more.

• **Buehler Ltd.**, Lake Bluff, Ill., has webinar videos ranging from metallography of fasteners to composites materials, all available for viewing at *buehler.com/buehler-webinars.php*.

• **Cincinnati Inc.**, Harrison, Ohio, a build-to-order machine tool manufacturer, has partnered with **Multiax America**, Grandville, Mich., a custom designer of computer numerical control machining centers. The partnership will allow each to offer products in the additive manufacturing space.

• **Custom Steel Fabricators Inc.**, Columbia, Tenn., has invested in **Pemamek's** PEMA automated welding solutions. "As the scope of our work and our customer base grew, one of the challenges we faced in our fabrication process was the fitting and welding of large-diameter shells. The utilization of turning rolls and a welding manipulator with SAW [submerged arc welding] process assisted, but as the required sizes kept growing, these solutions proved to be inadequate," said Tony Sciotto, president, Custom Steel Fabricators. The PEMA assembly station TW5000-25, with side support arms and integration to PEMA MD 4.5 × 5 column/boom with a single SAW welding head, tackled the challenge. WJ

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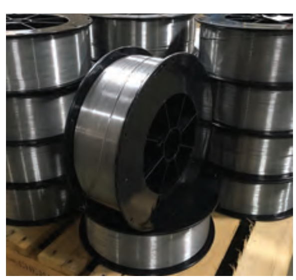

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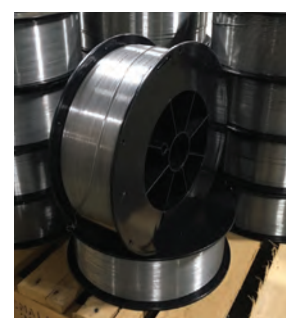

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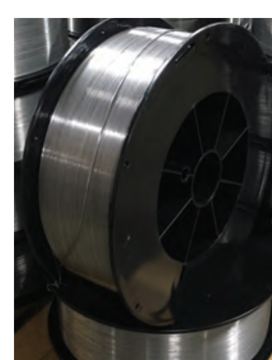

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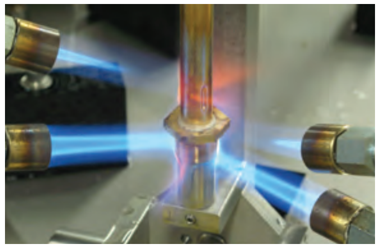

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Metal Transfer Mechanisms in Hot-Wire Gas Metal Arc Welding

Hot-wire polarity influences bead geometry in this process

BY P. P. G. RIBEIRO, R. A. RIBEIRO, P. D. C. ASSUNÇÃO, E. M. BRAGA, AND A. P. GERLICH

ABSTRACT

The hot-wire gas metal arc welding (HW-GMAW) process is widely used to increase the melting rate of a secondary wire through Joule heating without significantly increasing the total heat input to the substrate. Because there is limited knowledge regarding the associated arc dynamics and its influence on bead geometry, the present study considers how these are affected by the hot-wire polarity (negative or positive), hot-wire feed rate, and hot-wire orientation using a two-factor full factorial experiment with three replicates. During welding, high-speed imaging synchronized with current and voltage acquisition to study the arc dynamics. After this, each replicated weld was cut into three cross sections, which were examined by standard metallography. The preliminary results suggest that the arc was stable within the range of process parameters studied. The arc polarity played a role on arc position relative to the hot wire, with a decrease in penetration depth observed when the arc was attracted to the hot wire.

KEYWORDS

- Hot-Wire Gas Metal Arc Welding (HW-GMAW)
- Arc Blow • Metal Transfer • Rykalin Number (*Ry*)
- Depth of Penetration • Finger Like Penetration
- Dilution

Introduction

Progressively higher demands for efficiency and productivity in manufacturing processes have spurred development in welding processes for new applications. Arc-based welding processes present higher productivity compared to laser-based welding technologies, due to potentially high deposition rates and versatility in joint design. This has driven the use of arc welding in critical applications, including shipbuilding (Ref. 1), lightweight transportation with dissimilar welding (Ref. 2), and hardfacing of surfaces subjected to wear (Ref. 3).

Among the welding processes used for hardfacing against erosion, hot-wire gas tungsten arc welding (HW-GTAW) is commonly used due to the advantage of high deposition and controlled dilution coupled with good penetration (Ref. 4). Other processes commonly utilized for hardfacing include plasma transferred arc (PTA), submerged arc welding (SAW) (Ref. 5), cold wire GTAW, tandem gas metal arc welding (GMAW) (Ref. 6), and laser cladding (Ref. 7). However, laser-based processes are less common due to lower productivity and high costs associated with operation and maintenance of equipment.

Hot-wire gas metal arc welding (HW-GMAW) is another promising technology used for welding and hardfacing applications. It is characterized by higher deposition and versatility along with low operational costs. The core advantage of HW-GMAW for overlays are the characteristics that allow reduced nominal heat input with increased deposition. This stems from the decoupling of heat input and deposition by introducing a secondary welding wire, which is resistively heated. Another important feature of these processes is their inherently lower dilution (Ref. 8), and this can help to suppress dissolution of carbides in Ni- and Fe-based composite overlays.

Although HW-GMAW can be easily used for overlays where low dilution is needed, few studies are available in the literature dealing specifically with the process characteristics and their influence on the final bead shape. In particular, the interactions between process parameters remain largely unreported. For instance, fundamental features such as thermal efficiency of HW-GMAW are unknown. Most of the applications of this process do not consider this important parameter, and few reports are available that describe successful welding parameters. The net result of this lack of information is an underutilization of HW-GMAW for structural applications.

The objective of the present study was to detail the influence of the hot-wire polarity (hot-wire negative or positive),

https://doi.org/10.29391/2020.99.026

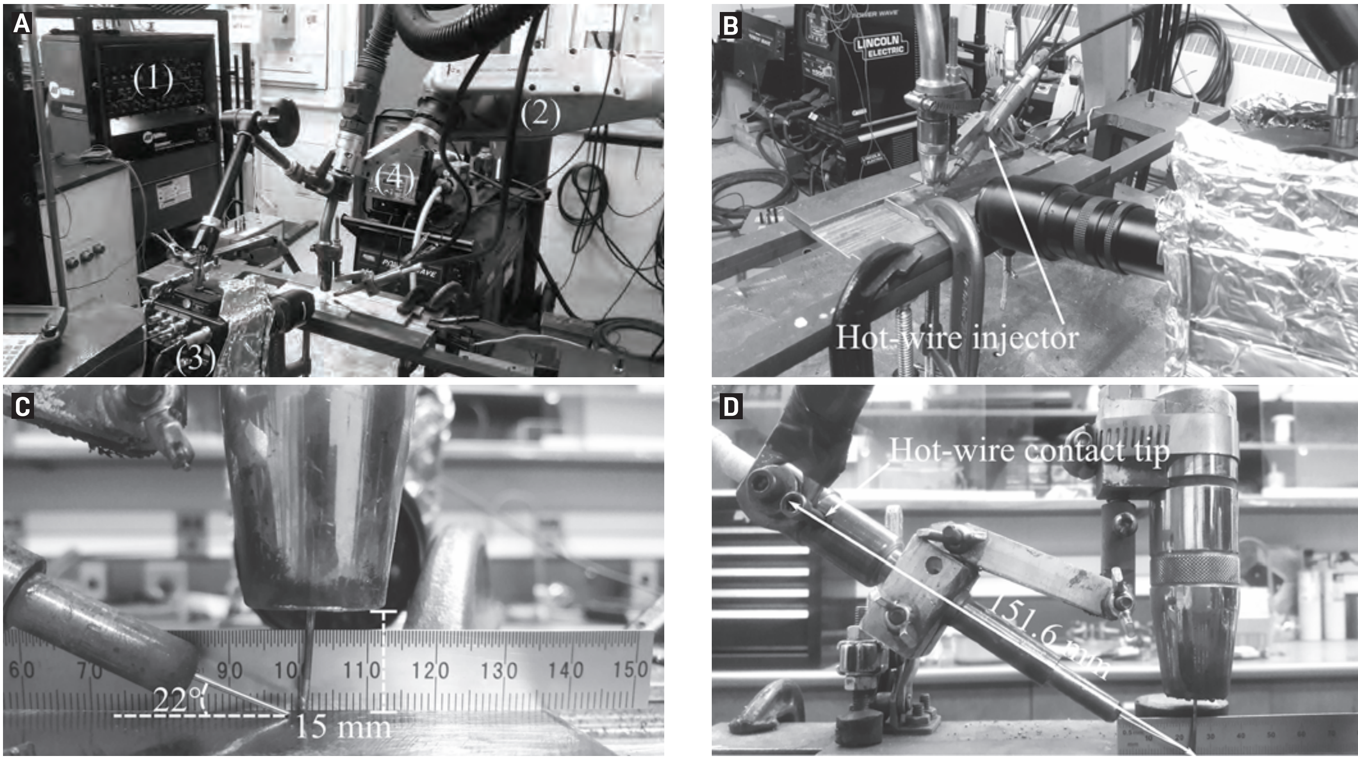

Fig. 1 — Experimental set-up: A — General view with numbers indicating (1) hot-wire power source, (2) FANUC robotic arm, (3) high-speed camera, and (4) hot-wire feeder; B — detail showing the hot-wire injector; C — detail showing CTWD (mm) and hot-wire angle; D — the distance of the contact tip to the weld pool.

welding direction (hot-wire pushing or pulling the weld pool), and hot-wire feed rates (as a percentage of the main electrode wire feed rate). The role of these hot-wire parameters was examined for the overall stability of the welding process, arc dynamics, metal transfer mode, and consequent geometry of the final bead shape.

Experimental Methodology

Welding Parameters and Experimental Set-Up

Sections of ⅜-in.-thick (9.5-mm) AISI 1020 steel were used as base metal for bead-on-plate welds. The wires used were ER70S-6 (Ref. 9) with diameters of 1.2 and 0.9 mm for the electrode and hot-wire, respectively.

The welds were deposited with a Lincoln Electric Power Wave® R500 used for robotic welding as the main electrode power source and a Miller Electric Aerowave welding power source as the hot-wire (secondary) power source. A robotic arc welding system was used to perform the welds, which incorporates a FANUC ARC Mate 120*i* arm, equipped with a BINZEL VTS 500 gun. The wire feeders used were Lincoln 10R wire drive systems integrated to the robotic arm. During the experiments, the main source was operated in the constant voltage (CV) mode, while the hot-wire source was

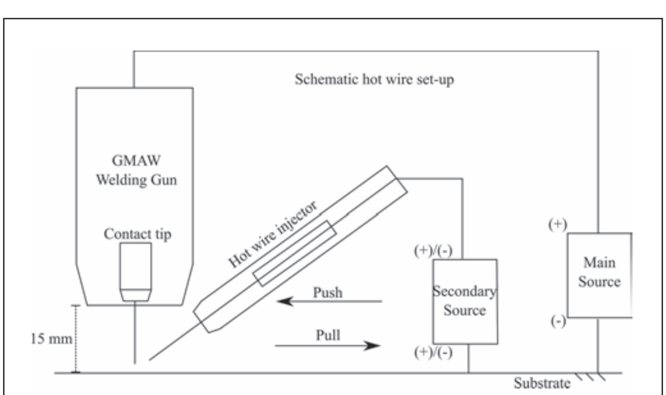

Fig. 2 — Schematic of the HW-GMAW set-up, indicating the weld directions push (hot-wire trailing the arc) and pull (hot-wire leading the arc).

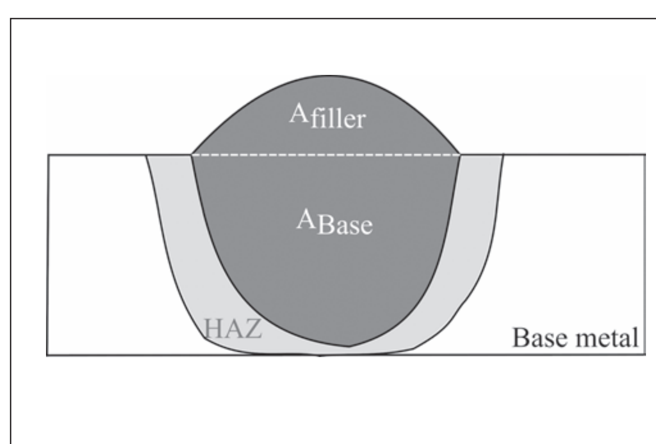

Fig. 3 — Schematics for dilution calculations.

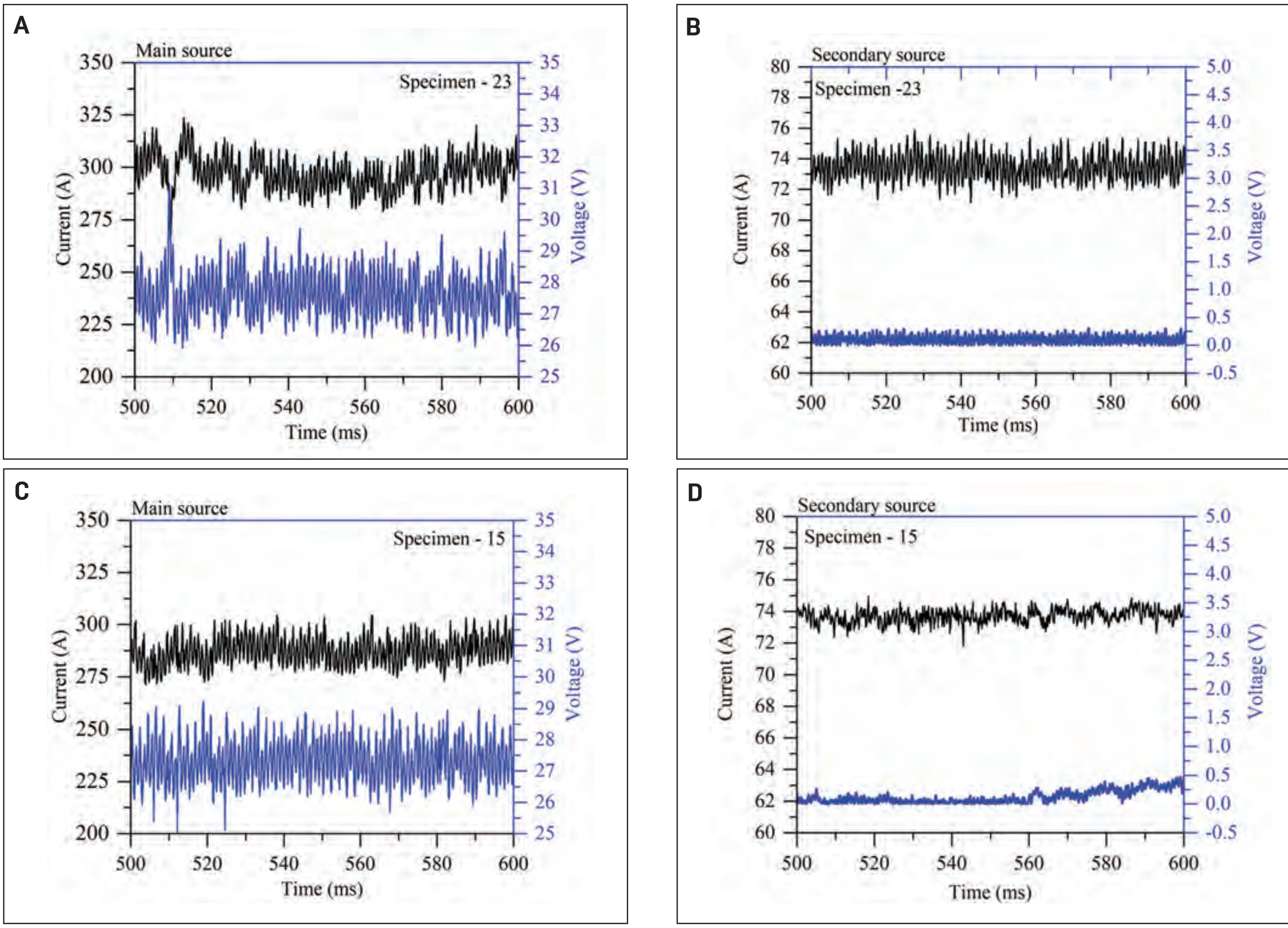

Fig. 4 — Current/voltage signals of the main source and the secondary source comparing two different specimens: A and B — Specimen 23 (run #1, negative polarity, pull, 20%); C and D — specimen 15 (run #3, negative polarity, pull, 100%).

kept in the constant current (CC) mode. The polarity of the hot wire (HW) was changed to either positive or negative during the experiments to study its effect on metal transfer. The HW contact point was kept constant and equal to 151.6 mm (Fig. 1D) from the substrate. Figure 1A and B show the experimental set-up used to investigate the metal transfer. During all the experiments, the HW angle of 22 deg and contact tip to work distance (CTWD) of 17 mm were kept constant. Figure 1C shows the nozzle-to-workpiece distance (NTWD), which was 15 mm.

Figure 2 shows a schematic of the experimental set-up highlighting the welding directions, push and pull. In the first case, the HW pushed the weld pool, while in the second case, it pulled the weld pool. It is important to emphasize the welding gun angle was kept straight (90 deg to the plate) throughout the experiments.

During the experiments, current and voltage were logged at 10 kHz for 2 s for the main wire and hot wire. The voltage of the main source was measured as the difference of potential between the welding gun and the substrate, and the current of the main source was measured through the ground cable using a Hall sensor. On the other hand, the voltage on the hot wire was measured as the difference of potential the between the hot-wire contact tip (shown in Fig. 1D) and the substrate; the current in the hot wire was measured through the ground cable of the secondary welding power source. The ground connections of the main and secondary power sources were connected to the substrate. The values of current and voltage measured for both welding power sources are reported as absolute values.

In parallel, synchronized high-speed imaging was employed to study the electric arc dynamics. The videos were taken at 5000 fps, with a shutter speed of 25 μs using a band pass filter of 900 ± 10 nm. The average voltage ($\bar{U}$), current ($\bar{I}$), and power ($\bar{P}$) reported in this work were calculated using the following equations as reported by Joseph et al. (Ref. 10):

$$\bar{U} = \frac{1}{n} \sum_{i=1}^{n} U_i(t) \tag{1}$$

$$\bar{I} = \frac{1}{n} \sum_{i=1}^{n} I_i(t) \tag{2}$$

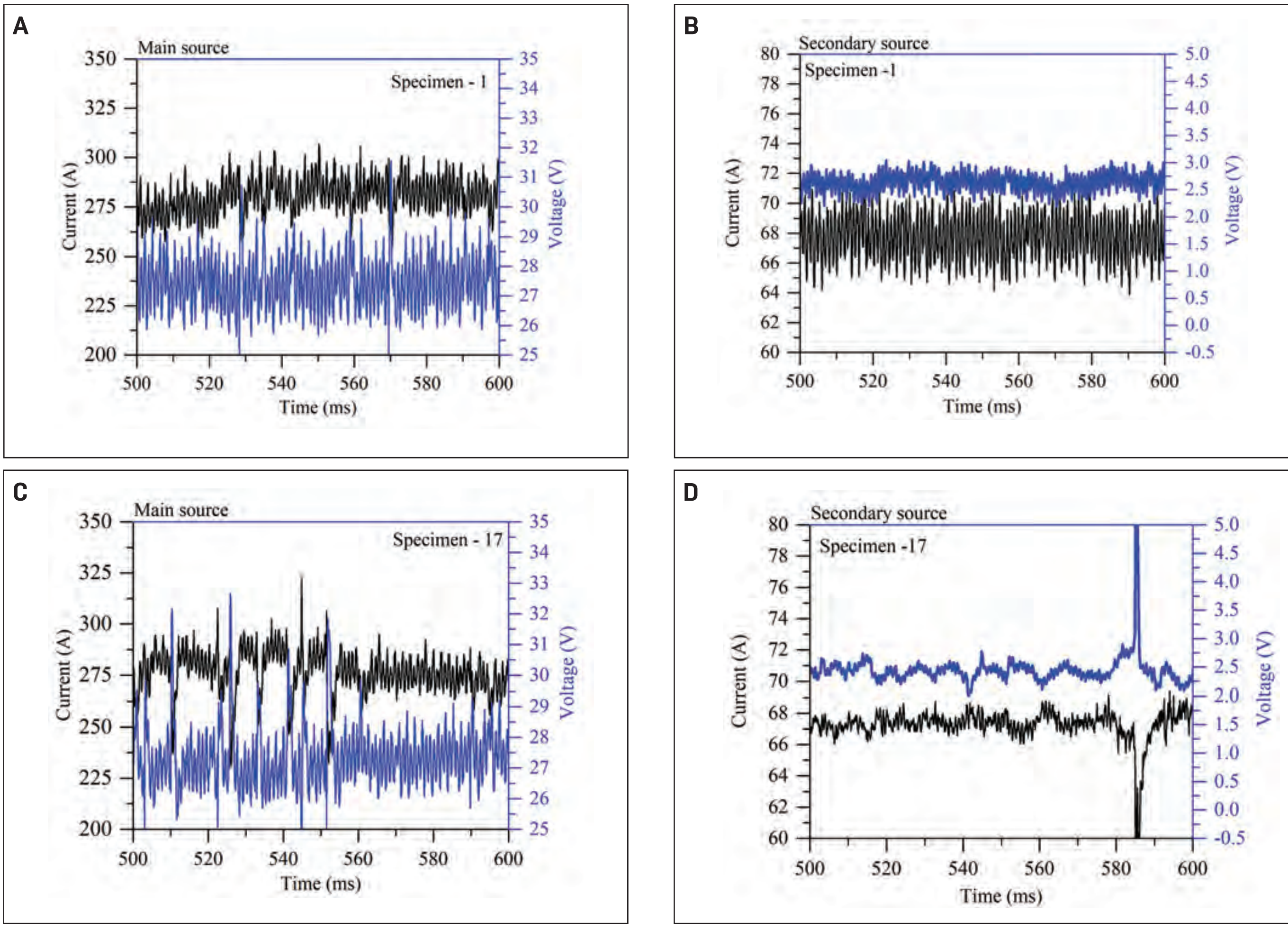

Fig. 5 — Current/voltage signals of the main source and the secondary source comparing two different specimens: A and B — Specimen 1 (run #2, positive polarity, pull, 20%); C and D — specimen 17 (run #4, positive polarity, pull, 100%).

$$\bar{P} = \frac{1}{n}\sum_{i=1}^{n} U_i(t)\cdot I_i(t) \qquad (3)$$

where U_i, I_i represent the instantaneous values of voltage and current, respectively; while n represents the number of current and voltage measurements.

Table 1 presents the values of parameters under variation in this study, namely, HW polarity, HW mass rate (%), and welding direction, while other values were kept constant. It should be noted that 20 and 100% hot-wire feed rates are equivalent to deposition rates of 0.96 and 4.80 kg/h, respectively. For all welding conditions, three replicates were taken to determine the reproducibility of the observed phenomena.

The shielding gas used was Ar-15% CO_2 at a flow of 40 ft^3/h (19 L/min). The HW mass rate was calculated as a percentage of the main wire feed rate. The parameters chosen gave a natural spray transfer associated with high current and arc power. The polarity of the HW was manually changed by reversing the position of the connecting wires in the HW source terminals and was checked using a standard multimeter. The value chosen for the HW nominal current was set to avoid completely melting the hot-wire or arcing between the two wires and consequent damage of the HW power supply. During welding, the behavior of the main source did not appear to have been influenced by the secondary HW source.

Metallography and Dilution Measurements

After welding, all three replicates were sectioned into thirds, resulting in nine cross sections that were examined for each welding condition. After standard metallographic polishing procedures, consisting of final polishing with 1 µm alumina polishing, all nine cross sections were etched with 2% Nital solution to reveal macro and microstructures. Figure 3 shows a schematic of a weld cross section.

Dilution was calculated using Equation 4 and is reported as an average following examination of nine cross sections.

$$D = \frac{A_{base}}{A_{base} + A_{filler}} \qquad (4)$$

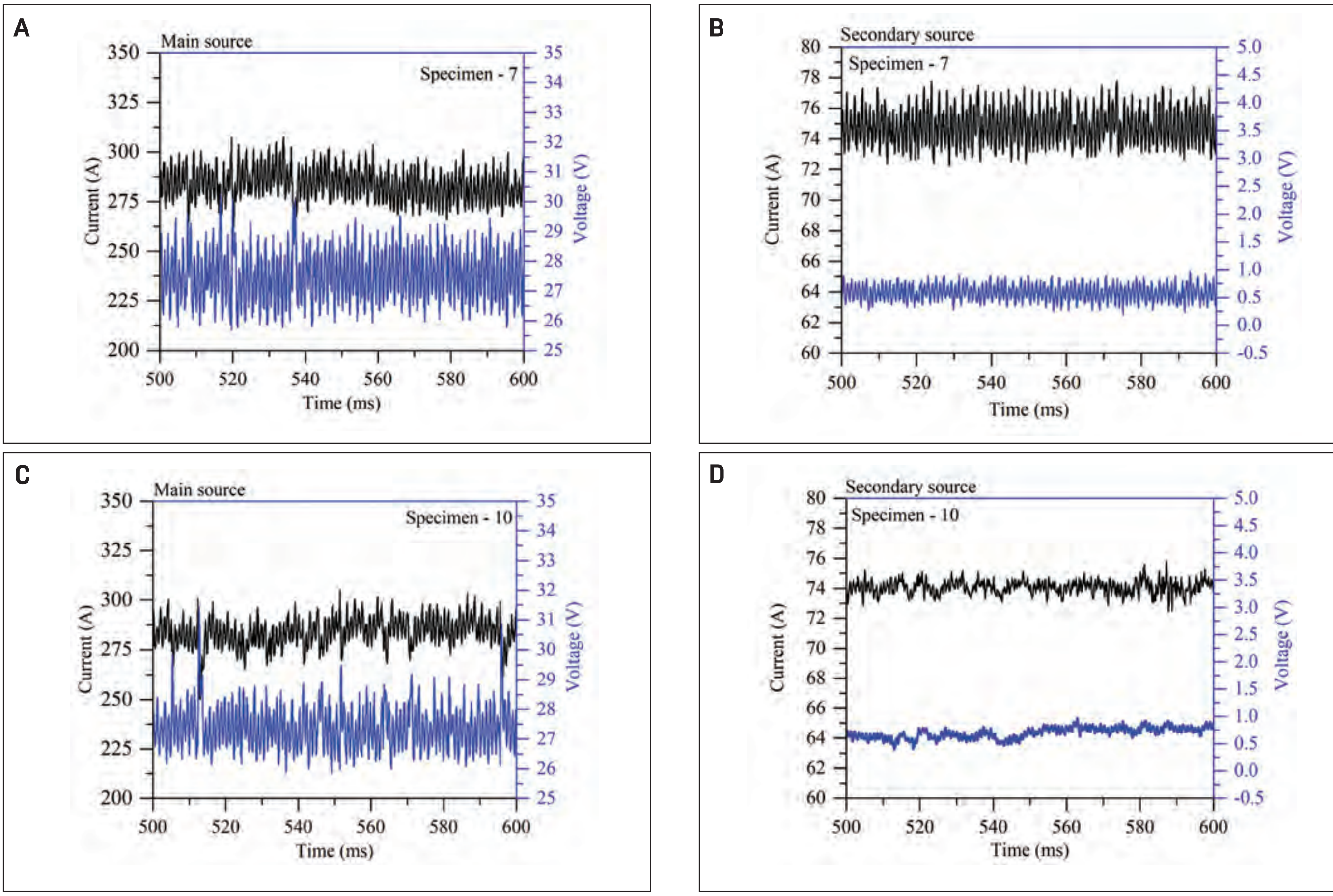

Fig. 6 — Current/voltage signals of the main source and the secondary source comparing two different specimens: A and B — Specimen 7 (run #5, negative polarity, push, 20%); C and D — specimen 10 (run #7, negative polarity, push, 100%).

Table 1 — Experimental Parameters and Welding Conditions

Run #	WFS (in./min) [m/min]	U (V)	Travel Speed (in./min) [cm/min]	HW Nominal Current (A)	HW Polarity	HW Mass Rate (%) [in./min] {m/min}	Welding Direction	Specimens Codes*
1	350 [8.89]	28	25 [63.5]	70	Negative	20 [124] {3.15}	Pull	**23**, 24, 25
2	350	28	25	70	Positive	20	Pull	**1**, 2, 3
3	350	28	25	70	Negative	100 [622] {15.8}	Pull	13, 14, **15**
4	350	28	25	70	Positive	100	Pull	**17**, 18, 19
5	350	28	25	70	Negative	20	Push	7, **8**, 9
6	350	28	25	70	Positive	20	Push	**4**, 5, 6
7	350	28	25	70	Negative	100	Push	10, **11**, 12
8	350	28	25	70	Positive	100	Push	20, **21**, 22
9	350	28	25	70	—	—	—	**26**, 27, 28

*Specimens for which the videos were captured are noted in bold.

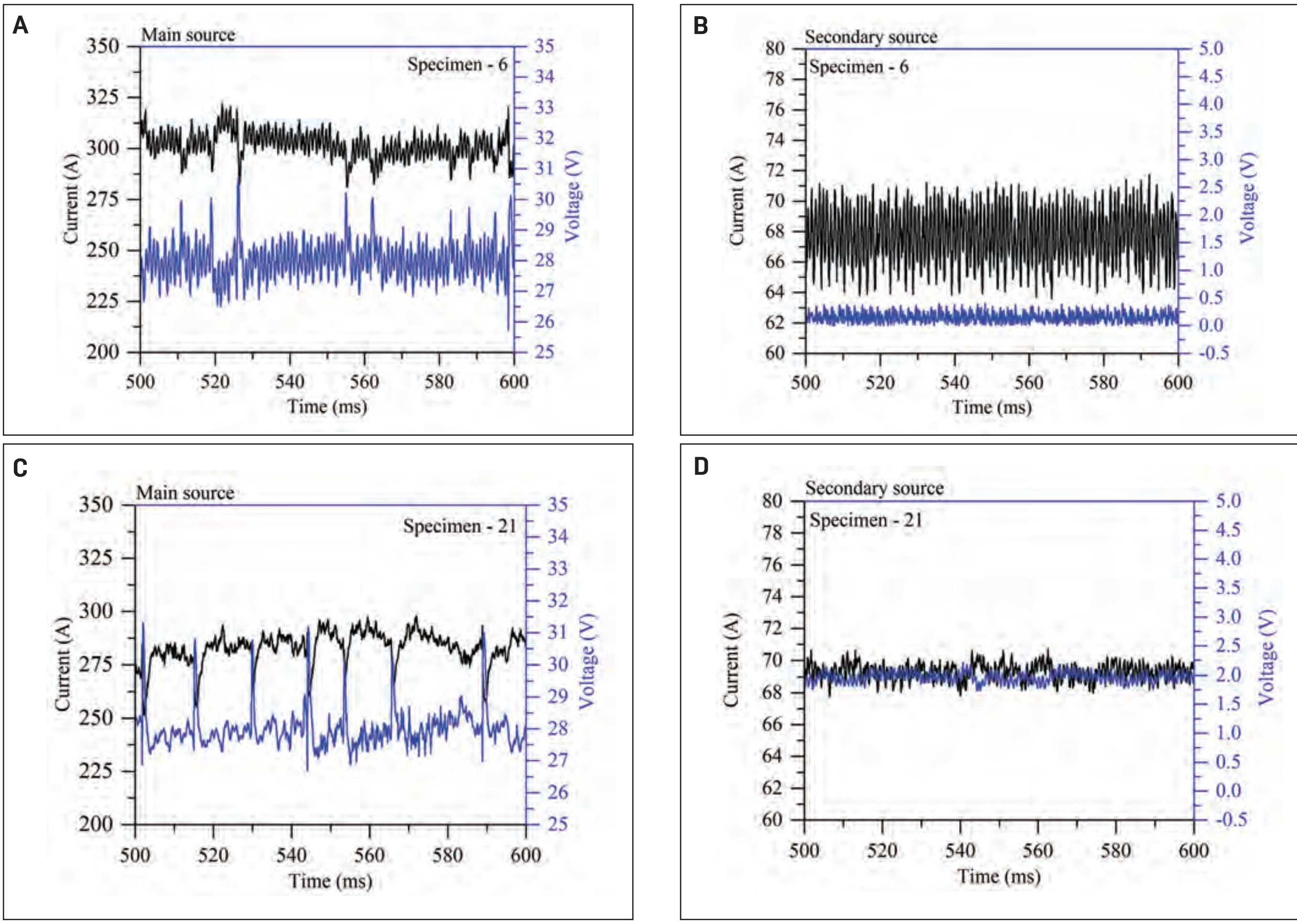

Fig. 7 — Current/voltage signals of the main source and the secondary source comparing two different specimens: A and B — Specimen 6 (run #6, positive polarity, push, 20%); C and D — specimen 21 (run #8, positive polarity, push, 100%).

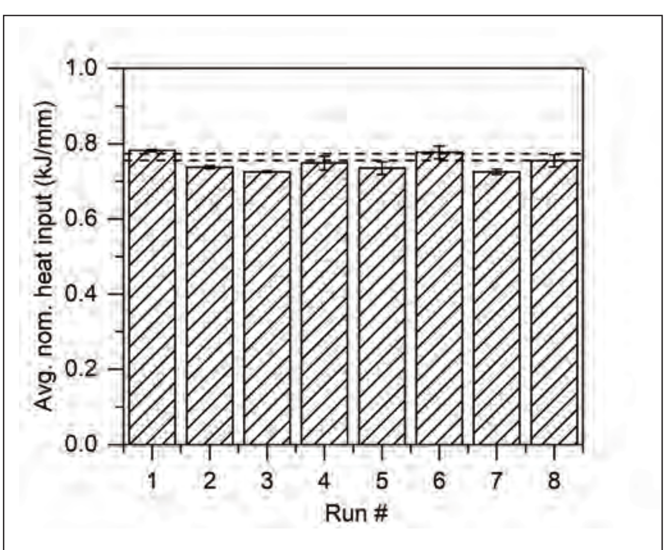

Fig. 8 — Average total nominal heat input between the specimens of an experimental run. The dashed lines indicate the range of variation of the standard GMAW. The total heat input is calculated from the total power, which is the sum of the electrode power and hot-wire power.

Results and Discussions

Current/Voltage Signals

All the experiments utilized a main electrode feed rate of 350 in./min, a main source voltage of 28 V, a travel speed of 25 in./min, and a hot-wire nominal current of 70 A. The only variables that were changed were welding direction (pull or push), HW feed rate (20 or 100%), and HW polarity (negative or positive). Only the variables that emphasize the difference in the observed results will be discussed in this section.

Figure 4 shows the voltage/current signals comparing the role of the hot-wire feed rate in specimen 23 (negative polarity, pull, 20%) and specimen 15 (negative polarity, pull, 100%), such that these two specimens involve the same hot-wire voltage. However, comparing Fig. 4 with specimens 1 and 17 (which correspond to negative vs. positive HW polarity) shown in Fig. 5, the voltage applied in the secondary source changes from an average of 0.092 and 0.208 V, respectively, when using negative polarity of 2.62 and 2.46 V, respectively, with positive HW polarity.

Summarizing these results, when one compares specimens 23 and 15, which have negative polarity, to specimen

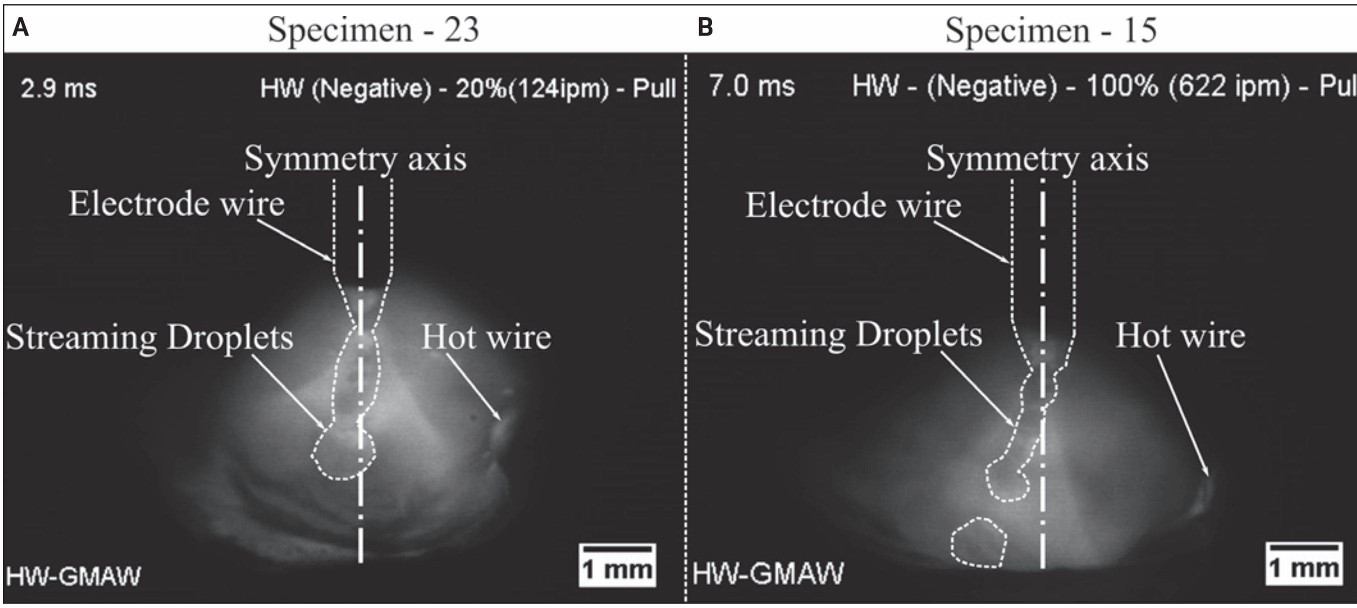

Fig. 9 — Hot-wire GMAW metal transfer: A — Specimen 23 (negative polarity, pull, 20%); B — specimen 15 (negative polarity, pull, 100%). (Note: ipm = in./min.)

17 (which uses positive polarity, pull, and 100%), it is clear a different hot-wire polarity causes a difference in measured voltage. Comparing Figs. 4 and 5, it can be seen that the former situation is more stable than the latter based on the larger fluctuations and transient behavior observed in the voltage, in particular, possibly due to the higher HW feed rate in specimen 15, which might stabilize the wandering of the cathode spots in the weld pool, accounting for superior arc stability.

Comparing specimen 7 (negative polarity, push, 20%) and specimen 10 (negative polarity, push, 100%) in Fig. 6, it can be seen that though the secondary source responds similarly, the current and voltage amplitude in it are higher in specimen 7 than in specimen 10. The basic difference between these is the hot-wire feed rate. In specimen 10, the higher fraction of hot-wire stabilized the response of the secondary source, accounting for the lower amplitude variability of current and voltage; the mechanism can be explained in prior work (Ref. 11).

Table 2 — Sampled Electrical Parameters for Run #9 (Standard GMAW)

Run	Specimen	Inst. Avg. Current (A)	Inst. Avg. Voltage (V)	Inst. Avg. Power (W)	Nom. Heat Input (kJ/mm)	Avg. Nom. Heat Input (kJ/mm)	Standard Deviation (kJ/mm)
9	26	295.1	27.5	8113	0.767		
(Standard GMAW)	27	290.3	27.5	7988	0.755	0.76	0.009
	28	291.5	28.0	8176	0.772		

Table 3 — Percentage of Total Power Due to Hot-Wire Joule Heating Dissipation

Experimental Runs #	Hot-Wire Avg. Inst. Power (W)	Total Power (W)*	Power Ratio (%)**
1	4	8242	0.05
2	177	7804	2.26
3	10	7676	0.14
4	167	7922	2.11
5	20	7778	0.25
6	2	8224	0.03
7	36	7675	0.46
8	146	7085	2.06

*Total power is the sum of the electrode and hot-wire avg. inst. power.
**Power ratio is the ratio of hot-wire power (W) over total power (W).

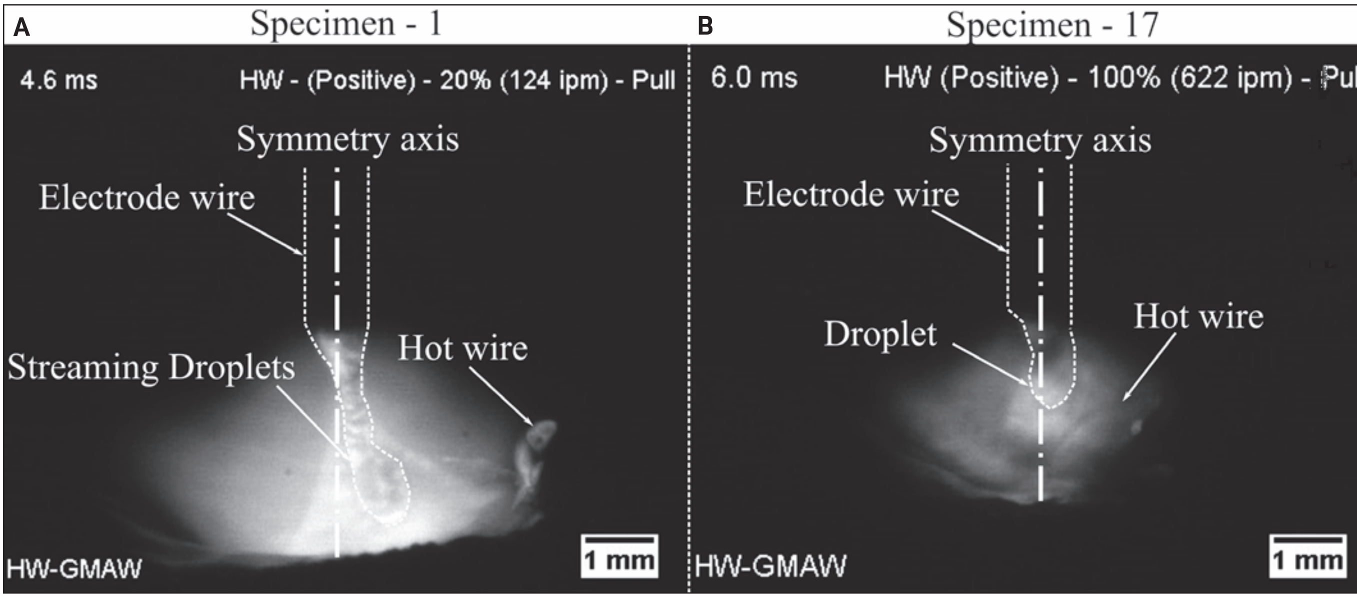

Fig. 10 — Hot-wire GMAW metal transfer across the arc: A — Specimen 1 (positive polarity, pull, 20%); B — specimen 17 (positive polarity, pull, 100%). (Note: ipm = in./min.)

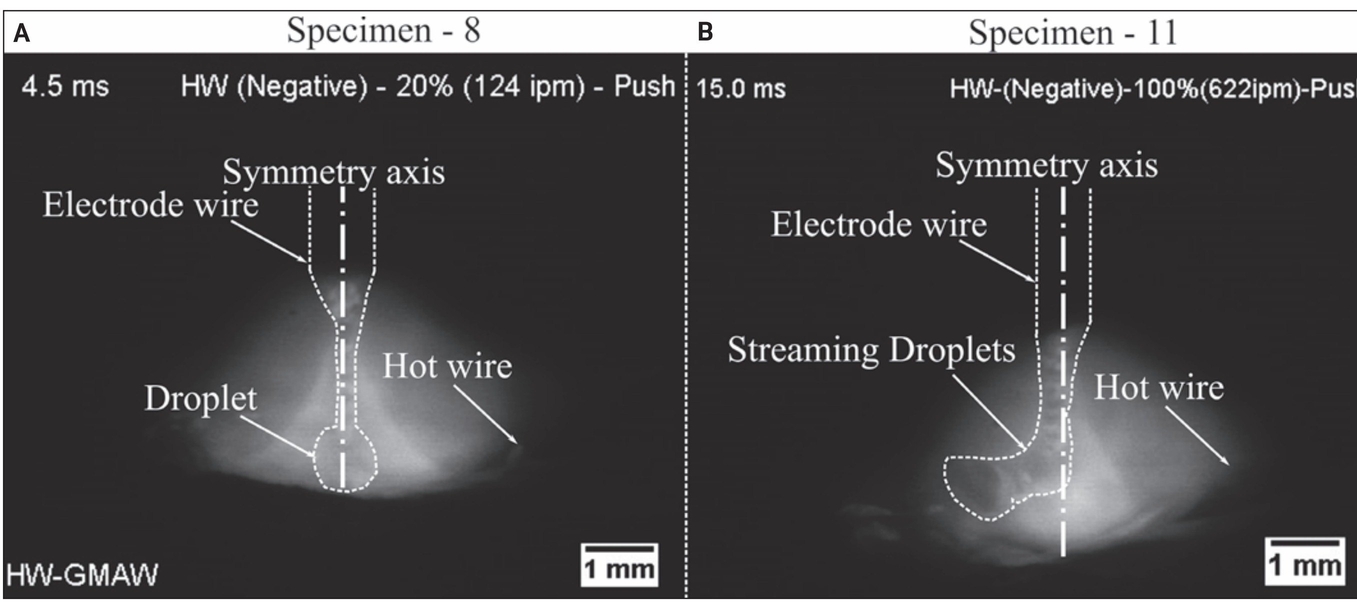

Fig. 11 — Hot-wire GMAW metal transfer across the arc: A — Specimen 8 (negative polarity, push, 20%); B — specimen 11 (negative polarity, push, 100%). (Note: ipm = in./min.)

Comparing specimens 6 (positive polarity, push, 20%) and 21 (positive polarity, push, 100%), refer to Fig. 7. It can be noted that by increasing the hot-wire feed rate while using positive polarity in the push orientation, the output is dominated by sudden variations in current and voltage. This is due to the intermittent contact of the electric arc with the hot-wire, which causes brief changes in the arc attachment locations or length.

Comparing the effect of polarities in Figs. 4 and 5, hot-wire negative polarity provides a more stable arc than when hot-wire positive polarity is used, as can be inferred from the variation of current and voltage in the secondary source, as well as the sudden variations of current and voltage in the main source. This is probably due to the fact that a negative hot wire repels the arc, avoiding short circuits. Comparing the stability for different hot-wire feeding orientations in Figs. 4 and 6, it appears when the hot wire is pushing, the welding pool is more unstable than when the hot-wire is pulling it.

When placing the hot-wire in the pushing orientation, there is a tendency to push the welding pool or to submerge the wire below it, rather disturbing the cathode spots wandering on its surface. Conversely, when the hot-wire is in the pulling orientation in front of the weld pool, there is a tendency for the weld pool to be stretched and the hot-wire droplets be transferred more easily than when pushing it. Again, when the addition of hot-wire increases, the stabilization of the cathode spots (electron emitting sites) can be observed due to cooling of the weld pool (Ref. 12), which results in a more sta-

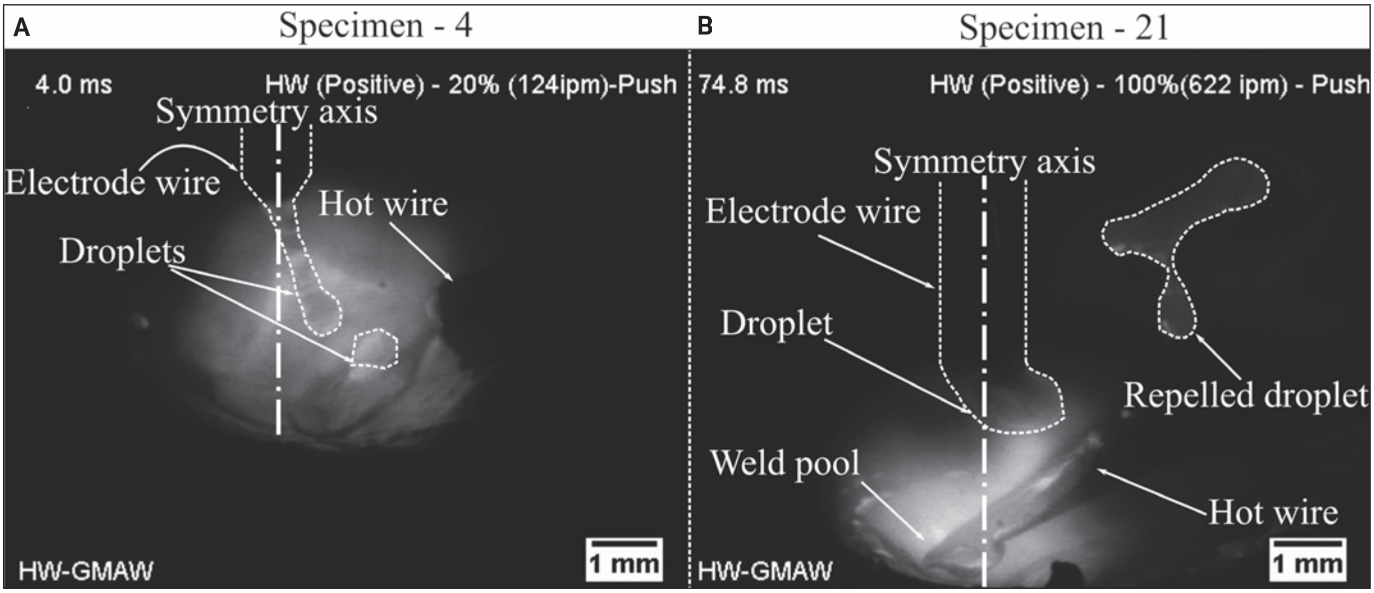

Fig. 12 — Hot-wire GMAW metal transfer across the arc: A — Specimen 4 (positive polarity, push, 20%); B — specimen 21 (positive polarity, push, 100%). (Note: ipm = in./min.)

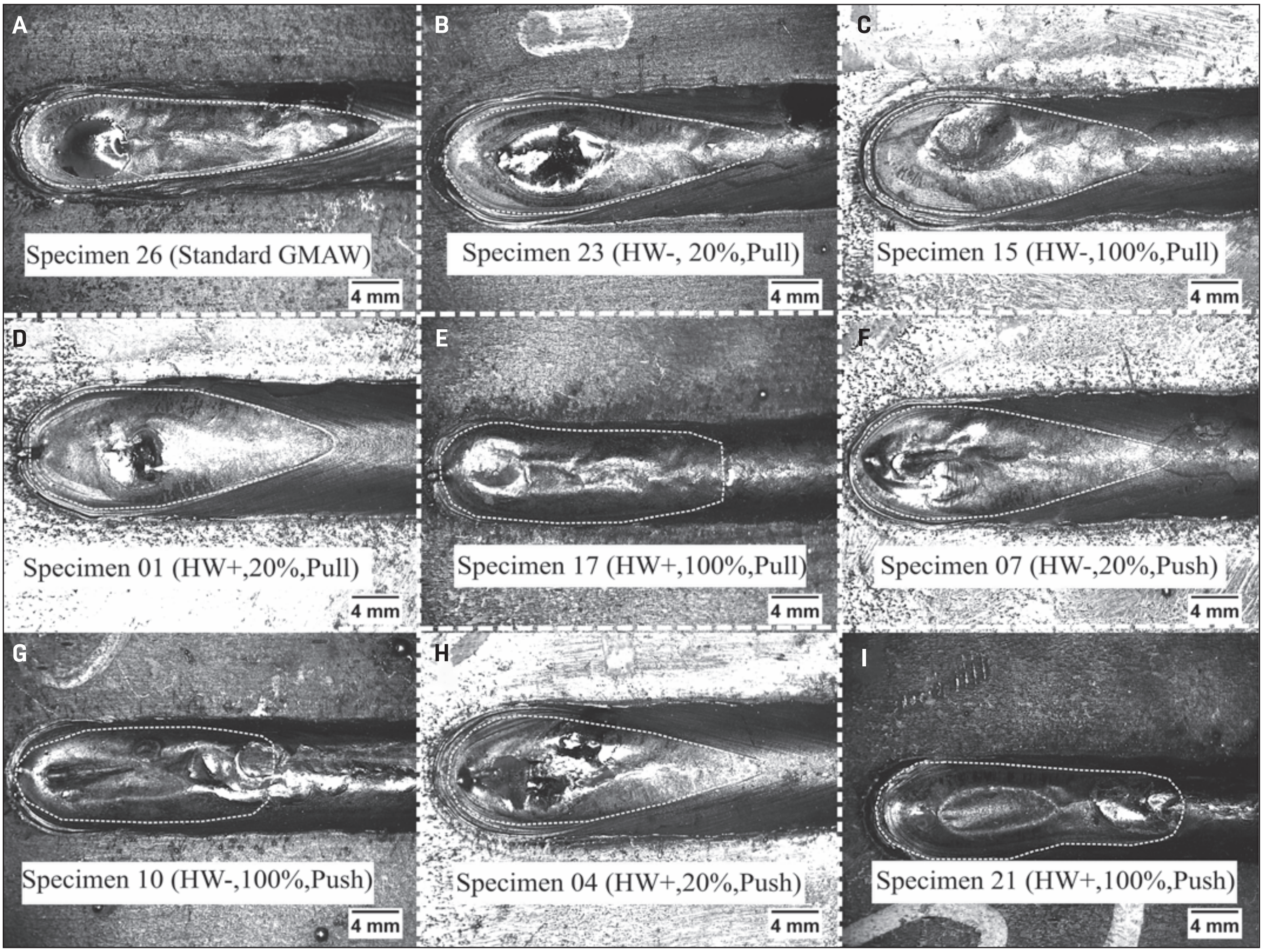

Fig. 13 — Representative bead aspects for these produced welds: A — Standard GMAW; B–I — HW-GMAW. For all the conditions WFS = 350 in./min, U = 28 V, TS = 25 in./min, and CTWD = 17 mm. Hot-wire feeding is 20% (124 in./min) and 100% (622 in./min).

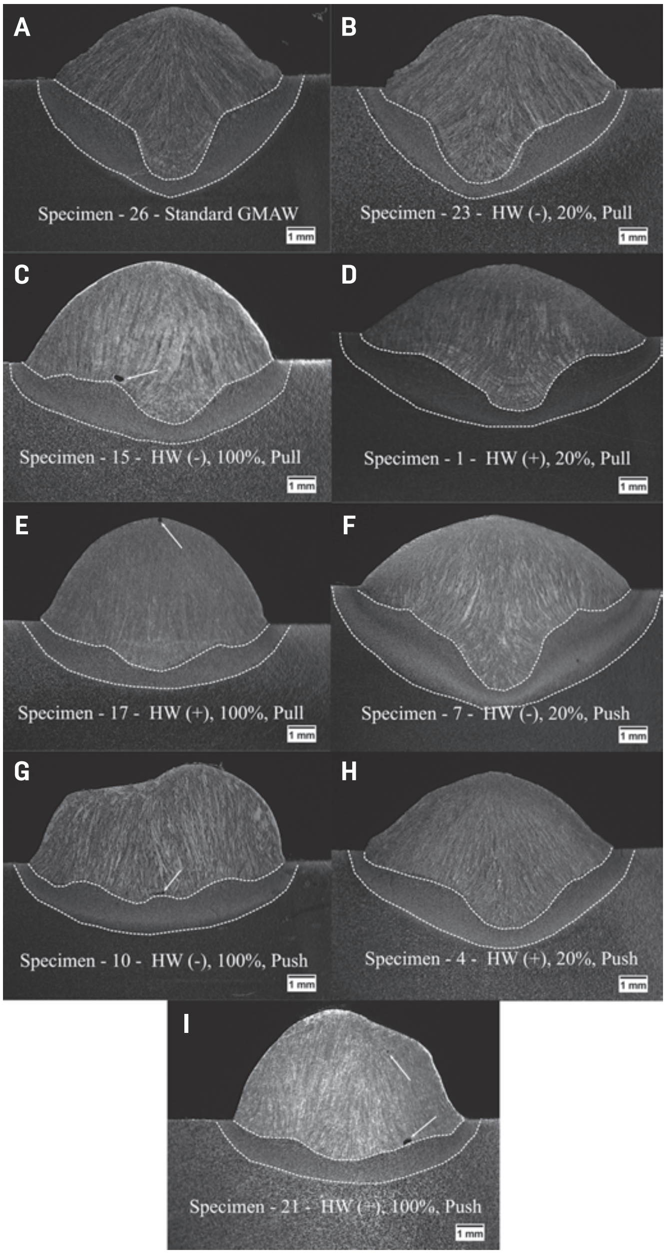

Fig. 14 — Representative cross sections for the welds manufactured. The arrows indicate discontinuities in the cross sections. Specifically, the arrow in C indicates an inclusion; in E indicates porosity; in G indicates an inclusion; and in I indicates an inclusion (upper arrow) and porosity (lower arrow). The conditions of each specimen are embedded in each cross section.

ble arc signal (current and voltage response).

It can be seen that the nominal heat input calculated as the instantaneous arc power (kJ/s) over travel speed (mm/s) is slightly lower for HW-GMAW, for some experimental runs, compared to standard GMAW — Fig. 8. For example, negative polarity associated with higher hot-wire feed rates produced the lowest nominal heat inputs that can be seen in runs #3 and 7. Both runs had negative polarity and 100% hot-wire feed rate, but operated in pull and push welding directions, respectively.

For the sake of comparison, the electrical parameters of the standard GMAW (run #9) are given in Table 2. The average nominal heat input (kJ/mm) for all other experimental runs is given in Fig. 8. Moreover, in Fig. 8 the heat input range of standard GMAW is shown in dashed lines to facilitate the comparison between HW-GMAW and GMAW.

The discussion about the nominal heat input provides an introduction to the next section where the phenomena of metal transfer is examined further. Since different hot-wire feed rates and polarities produced similar nominal heat inputs, it is likely that only the combination of these variables affected the metal transfer, rather than one exclusive parameter.

Metal Transfer Mechanisms

The arc dynamics during HW-GMAW depend on the polarity of the hot-wire and the current in the electrode wire, which can be modelled as two cylindrical conductors. When a current passes through two cylindrical conductors with different polarities, the magnetic field induced by the current flow produces a resultant force that repels both conductors. Conversely, if the conductors have the same polarity, the resultant force tends to attract both conductors.

As expected, when the hot-wire was kept in negative polarity, the resultant force from the hot-wire current repelled the arc, as can be seen by the deflected streaming droplets in Fig. 9. For low (20%) and high (100%) hot-wire feed rates, the hot-wire melted within the weld pool. Even at higher feed rates, the hot-wire was easily melted by the arc, due to the additional energy provided by Joule heating (Table 3).

Figure 10 indicates when the hot-wire polarity changed to positive, the arc was attracted to the hot-wire. In this case, the hot-wire still melted in the weld pool; however, when the higher hot-wire feed rate increased further, the arc was strongly attracted to the hot-wire, inducing an instantaneous reduction of arc length causing the metal transfer to momentarily become globular. Due to the self regulation of the main source operating in constant voltage mode, this reduction in arc length was counterbalanced by an increase in current to maintain the melting rate and preset arc length by compensating with voltage. This dependence of metal transfer on the arc length was also observed by Xiang et al. (Ref. 13) when studying twin GMAW.

Figure 11 shows the situation where there was only a slight repulsion of the arc by the hot-wire (specimen 8: negative polarity, push, 20%). Due to the low hot-wire feed rate, it was easily melted and did not exert a strong influence on the arc. Conversely, when a high hot-wire feed rate was used, this strongly repelled the arc, which subsequently repelled the droplet, causing droplets to transfer toward the leading region of the weld pool as shown in Fig. 11B.

Figure 12A shows the strong attraction of the arc to the hot-wire when it was positive, and this displaced the welding pool. The hot-wire melted in the welding pool, but the arc was not pinned to the hot-wire in this situation, and the metal transfer was directed toward the back of the welding pool. In Fig. 12B, the arc was completely pinned to the hot-wire, which caused a notable reduction of arc length and led to more severe short circuits, since the droplet could then touch the hot wire easily. Differences between these two transfer modes could be clearly noted in terms of the influ-

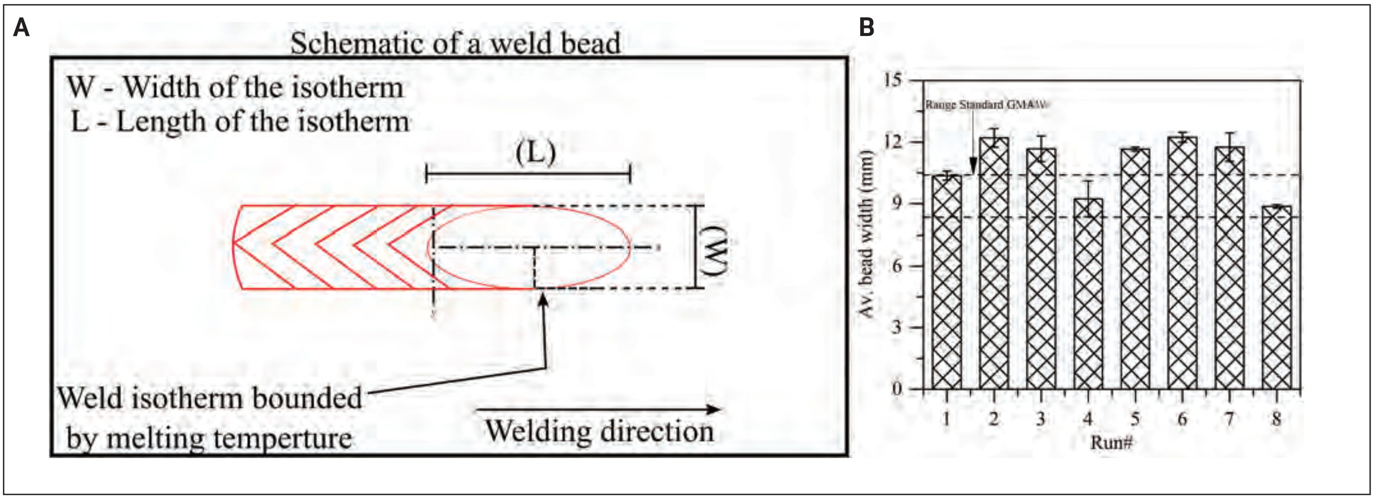

Fig. 15 — A — Schematic showing the relationship between the maximum width of the weld pool isotherm and the bead width; B — variation of bead width. The dashed line indicates the range for GMAW (run #9).

ence on the final bead geometry. Moreover, the presence of short circuits led to an increase in spatter.

Bead Profiles and Cross Sections

Figure 13 presents the bead aspects for produced specimens. The isotherm contours (dashed lines) in the bead aspect provide evidence that the introduction of hot-wire, hot-wire polarity, and weld direction changed the shape of the isotherm, consequently, varying the heat distribution in the plate. However, it is not possible to affirm that the heat transferred to the plate changed, since no calorimetric measurements were performed.

Figure 14 presents the cross sections for the manufactured welds in this study. As can be seen in Fig. 14A, the standard GMAW specimen exhibited higher penetration and dilution than those produced with HW-GMAW. The modifications induced by changing polarity, welding direction, and hot-wire feed rates led to changes in the geometry for the same value of wire feed and travel speed.

The addition of a hot-wire decreased the depth of penetration while simultaneously causing a change in the electric field near the weld pool, which either promoted repulsion or attraction of the arc to the hot-wire. It is understood that penetration is a function of the droplet momentum, which excavates the weld pool (Refs. 14, 15). If the arc is pinned to the hot wire, this acts to shield the welding pool from droplets and consequently reduces the penetration.

However, varying the polarity of the hot-wire led to increased deposition rates via the hot-wire feed and also repulsion or attraction of the arc. This repulsion or attraction of the arc moved the weld pool away or to the hot-wire, and increased or suppressed the droplets touching the weld pool. Figure 14 indicates that the amount of hot-wire rate exerted a more significant effect than just polarity, particularly based on Fig. 14B and G, where there was a

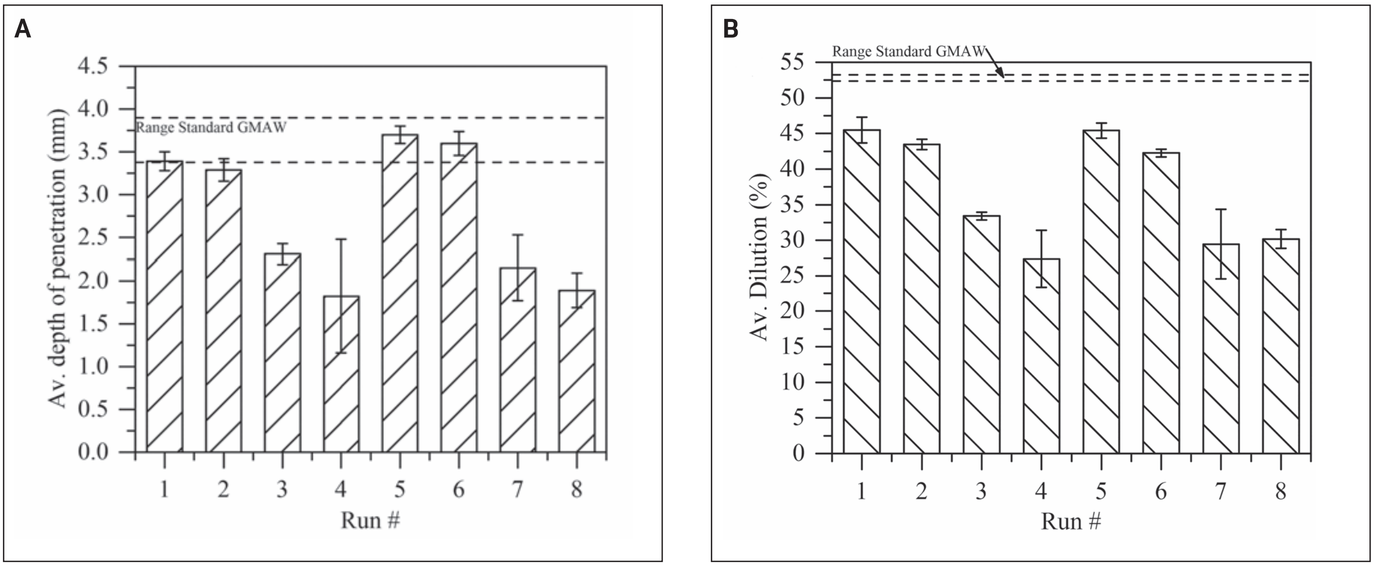

Fig. 16 — A — Average depth of penetration for all the experimental runs; B — average dilution for all runs. The dashed line indicates the range for GMAW (run #9). The results are an average of nine cross sections.

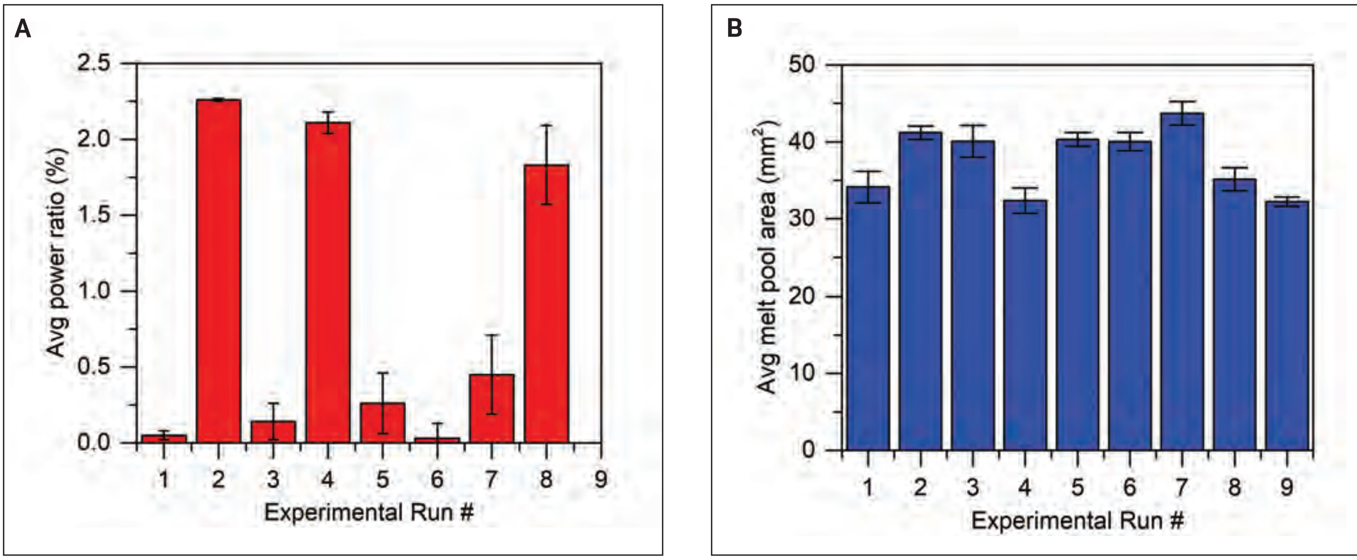

Fig. 17 — A — Average power ratio, which is the ratio of the hot-wire Joule heating dissipated power over the total power (sum of hot wire and electrode power); B — area of the weld pool calculated through the cross sections.

difference in feed rates but the polarity was the same. On the other hand, comparing Fig. 14H and I, the increase in hot-wire feed rate appeared to drastically decrease penetration depth.

Another feature that can be analyzed from the weld pool aspect is a variation in the Rykalin number (*Ry*) (Ref. 16). This parameter is defined in Equation 5 as follows:

$$Ry = \frac{\eta Q v}{\alpha^2 \delta h} \qquad (5)$$

where η is the thermal efficiency of the welding process, *Q* is the gross heat-input (J/s), *v* is the travel speed in (m/s), α is the thermal diffusivity at the liquidus temperature in (m^2/s), and δ*h* is the enthalpy of melting in (J/m^3).

It has been proposed that this dimensionless parameter, according to Fuerschbach, is similar to the Peclet number in terms of comparing the importance of conduction and convection as the main form of heat transfer in welds (Ref. 17). According to Mendez et al. (Ref. 17), two types of heat sources can be distinguished: fast-heat sources (Regime I, $Ry > 1$) and slow-heat sources (Regime II, $Ry \leq 1$). In fast-heat sources, the heat transfer is dominated by convection, while in slow-heat sources, conduction dominates. Murray and Scotti (Ref. 14) have modelled penetration as a function of *Ry*, though in their work *Ry* is referred to as *B*, the dimensionless heat transfer parameter.

The *Ry* number has been shown to vary with the aspect ratio (*AR*) of the welding isotherm (Ref. 18). For Regime I, the increases are steeply in relation to the *Ry* number but remain constant for Regime II. The isotherm aspect ratio is defined as isotherm length (*L*) over the isotherm width (*W*), as seen in Fig. 15 and Equation 6. As the value of *W* decreases, the value of *AR* increases, provided that *L* remains constant. Given that, an increase in *AR* increases the value *Ry*. Some experimental conditions in HW-GMAW suggest there is an increase in width, which causes a decrease in *Ry*, for example in Fig. 13D.

$$AR = L/W \qquad (6)$$

Figure 15A compares the bead width to the width of the melting temperature isotherm. Consequently, if there is a change in bead width, there are also changes in the heat transfer mode in the weld pool. Figure 15B shows the range of bead width for the standard GMAW in a dashed line; it can be determined for certain conditions the bead width increased, and consequently, so did the role of convection in heat transfer, taking into account the proportionality between bead width and *Ry*. The increase in convection leads to the increase in the convection currents inside the weld pool, which can improve the metal mixture inside the melt pool.

It seems that this shift in weld width is correlated to a combination of polarity and hot-wire feeding, since in runs #2 (positive polarity, pull, 20%) and 6 (positive polarity, push, 20%), the width increased more on average compared to other specimens, independent of welding direction. However, more experiments are required to clarify this subject, as it has implications on melting efficiency, since it is a function of *Ry*.

Penetration and Dilution

Figure 16A shows the depth of penetration for all experimental runs calculated using all specimens. The dashed lines show the range of penetration for standard GMAW specimens. Except for 20% hot-wire feed rate, all other runs had a decreased depth of penetration on average in comparison to standard GMAW. Runs #5 and 6 had the same common welding direction and hot-wire feed rate of 20% with a push orientation, however, with negative and positive polarities, respectively.

The combination of low hot-wire feed rate and push welding orientation increases penetration. A possible mechanism is the hot-wire causes the pressure adjacent to the weld pool to increase since it pushes the melt pool, causing the molten metal to fill the weld pool cavity. Regarding the other runs, all had lower penetration than the standard GMAW, which implies reduced dilution.

An attractive application of HW-GMAW appears to be weld overlays, since it offers lower heat input and dilution compared to the standard GMAW with superior deposition rates (Ref. 8). Dilution is a critical property for weld overlays, and in principle, overlays should exhibit lower dilution due to the reduced penetration rates.

Figure 16B shows the dilution for all the runs calculated using all three specimens with the range of dilution of the conventional GMAW presented in dashed lines. It can be noted for all the conditions assessed in the experimental runs, the dilution decreased compared to the standard GMAW condition. For example, introduction of a hot-wire can decrease dilution by 25% on average, considering run #4 shown in Fig. 16B. Also, Fig. 16A and B indicate that runs #5 and 6 had higher penetration than the lowest value of GMAW range with lower dilution compared to the GMAW range.

Meanwhile, the specimens in run #6 exhibited slightly reduced finger-like profiles, with similar penetration to specimens in run #5 coupled with reduced dilution — Fig. 13H. It is suggested the polarity plays a role in the development of finger-like penetration in hot-wire welding, though further experiments are needed to clarify this matter. According to Lancaster (Ref. 19), the finger-like penetration mechanism results from a cavity formed below the weld pool, which is sustained by the plasma jet pressure. One of the forces that opposes the formation of this cavity is surface tension. Another theory explains finger-like penetration by the momentum transferred by the droplets to the center of the weld pool, which causes enhanced convection and leads to a local increase in substrate melting.

As the specimens in run #6 were welded in positive polarity, the arc was deflected toward the hot-wire due to the interaction of their electromagnetic fields. This displacement of the arc changed the droplet path, thus attracting the droplets toward the hot-wire. However, the welds were performed with 20% HW-feed rate, which was unable to completely shield the weld pool from the droplets. The droplets were directed toward the side of the weld pool close to the wire, promoting sideways droplet impact, thus reducing the finger profile while keeping the penetration similar to specimens in run #5.

Average Power Ratio and Melt Pool Cross-Sectional Area

Figure 17 shows the relationship for all experimental runs of the average power ratio (defined as the ratio of the hot-wire Joule dissipated power (W) over the sum of the hot wire and electrode wire power) and the area of the melt pool, taken from the cross sections. Calculating the effects, using analysis of variance (ANOVA) (Ref. 20), of hot-wire polarity, hot-wire feed rate, and hot-wire orientation, it can be identified which of those parameters plays a higher role in the area of the melt.

The highest effects governing power ratio are due to hot-wire polarity and the combination hot-wire polarity and hot-wire orientation — Fig. 17A. This means that changing from negative to positive hot-wire polarity increases the power ratio, which is consistent with Fig. 17A, where runs #2, 4, and 8 had positive polarity. This happens due to the fact that in positive polarity, the voltage of the secondary source is higher than in negative polarity, possibly due to repulsion of the arc.

The combination of hot-wire polarity and hot-wire orientation indicates that when both change to the highest levels (positive and push), the power ratio decreases (refer to runs #5 and 6, in Fig. 17A), since again the voltage in the secondary decreases. The reason behind this is likely due to the fact that while operating in hot-wire positive, the difference of potential of the hot-wire and the electric arc decreases, since they attract each other.

Figure 17B shows the variation of weld pool area for all the experimental runs. The main effects that govern the cross-sectional area of the melt pool are hot-wire polarity, hot-wire feed rate, and hot-wire orientation combined. The ANOVA suggests the combination of hot-wire polarity and feed rate has the highest effect on increasing the area of the melt pool. This seems logical since higher feed rates increase the volume of molten metal introduced into the melt pool, and negative hot-wire polarities offer higher melting rates than positive hot-wire polarities. An example of this is run #7 in Fig. 17B.

Comparing runs #2, 4, and 8 in Fig. 17A, they provided the higher power ratios and all were positive hot-wire polarity, and that due to attraction of the electric arc, there was possibly an increase in difference of potential between the hot-wire and the electrode wire, which accounted for a higher power ratio. However, a higher power ratio did not necessarily reflect a higher weld pool area — Fig. 17B. This is because the hot wire introduces additional heat into the melt pool, but also increases losses to the environment, particularly when the hot-wire has higher power.

Conclusions

Standard GMAW and HW-GMAW welds were fabricated and assessed using high-speed imaging and standard metallographic procedures. Metal transfer dynamics and its implication in bead geometry and welding bead formation were analyzed. Based on the observations, the following conclusions can be drawn:

1. Hot-wire feed rates can decrease penetration up to 45% and dilution up to 25% compared to standard GMAW when HW feed rate is 100%, for instance;

2. Hot-wire polarity can attract or repel the arc and, coupled with the HW feed rate, can alter bead geometry through changes in penetration depth and bead height;

3. Welding direction and hot-wire feed rates are the parameters that mostly affect the arc stability of the welding process based on the current/voltage signals for the range of parameters in this study;

4. HW-GMAW provides low values of dilution while keeping depth of penetration similar to standard GMAW, particularly when the hot-wire feed rate is 20%, as for example in run #1 (HW negative, 20%, and pull orientation), run #2 (HW positive, 20%, and pull orientation), run #5 (HW negative, 20%, and push orientation), and run #6 (HW positive, 20%, and push orientation). For all other welding runs, the penetration is lower than in standard GMAW.

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P. P. G. RIBEIRO, P. D. C. ASSUNÇÃO, and E. M. BRAGA are with the Metallic Materials Characterization Laboratory (LCAM), Federal University of Pará (UFPA), Belém – PA, Brazil. R. A. RIBEIRO (rdearauj@uwaterloo.ca) *and A. P. GERLICH are with the Centre for Advanced Materials Joining (CAMJ), University of Waterloo, Waterloo, Ontario, Canada.*

Prediction of Weld Penetration Using Dynamic Weld Pool Arc Images

An improved approach correlates weld penetration with fused images through a convolutional neural network

BY W. JIAO, Q. WANG, Y. CHENG, R. YU, AND Y. M. ZHANG

ABSTRACT

This work aims to study an improved method to predict weld penetration that is not directly observable during manufacturing but is critical for the integrity of the weld produced. Previous methods used signals acquired at a time, typically a single image or multiple images/signals from the process, to derive the penetration at that given time. Although deep learning appears to extract data well, analyses of weld pool physics, previous studies, and skilled weld operation all suggest that the dynamic welding phenomena give a more solid mechanism to assure the adequacy of the needed information. Therefore, this paper proposes to fuse the present weld pool arc image with two previous images, acquired ⅙ and 2⁄6 s earlier. The fused single image thus reflects the dynamic welding phenomena. Due to the extraordinary complexity, the weld penetration is correlated to the fused image through a convolutional neural network (CNN). Welding experiments have been conducted in a variety of welding conditions to synchronously collect the needed data pairs to train the CNN. Results show that this method improved the prediction accuracy from 92.7 to 94.2%. Due to the critical role of weld penetration and the negligible impact on system/implementation, this method represents major progress in the important field of weld penetration monitoring and is expected to provide more significant improvements during welding using pulsed current, where the process becomes highly dynamic.

KEYWORDS

• Weld Penetration • Fused Single Image • Early Fusion • Convolutional Neural Network (CNN) • Weld Pool Arc Image • Dynamic Weld Phenomena

Introduction

Welding has been automated/robotized greatly. However, in typical automated/robotic welding applications, the welding parameters are preset and not adjusted adaptively to overcome the effect from unpredicted disturbances. This imperfection cannot meet the increasing requirements from the welding/manufacturing industry on quality, efficiency, and flexibility. Combining information sensing/processing with traditional welding manufacturing techniques has been a major directive to revolutionize the welding industry (Ref. 1). In practical welding, the weld penetration, as measured by the back-side weld bead width, is a critical factor determining the integrity of the weld produced. However, the back-side bead width is difficult to monitor directly during manufacturing because it occurs underneath the surface of the workpiece being processed. Therefore, predicting the back-side bead width using conveniently sensible information from the welding process becomes a fundamental issue in intelligent welding.

Many studies have been done to predict the weld penetration using different characteristic information from the welding process. They typically 1) sense observable phenomena from the welding process using, or based on, different sensors/phenomena such as infrared, pool oscillation, laser ultrasonic, and active vision methods (Refs. 2–5); 2) define and extract characteristic features from sensed phenomena; and 3) build a model to correlate the extracted characteristic features to the penetration state (Refs. 6, 7). However, the characteristic features are proposed subjectively based on the individual's understanding of the physics, thus lacking a systematic way to ensure success in leading to a good model. Iteration is often needed such that the development efficiency is low. To address this general challenge, researchers recently started to apply deep-learning-based methods to extract the information automatically. Therefore, the major remaining challenge is reduced to acquiring adequate information from the welding process.

Skilled welders can judge the weld penetration per their observed welding phenomena during the process. The welding community believes that images from the observable welding scene, including the 3D weld pool surface, contain sufficient information to predict the weld penetration (Ref. 8). While earlier efforts followed the aforementioned procedure to first propose characteristic features, the deep learning method has recently been applied, with a concentration on using convolutional neural networks (CNNs), to directly map images to the penetration (Refs. 9–14). The training for the parameters, including the convolutional kernels and

https://doi.org/10.29391/2020.99.027

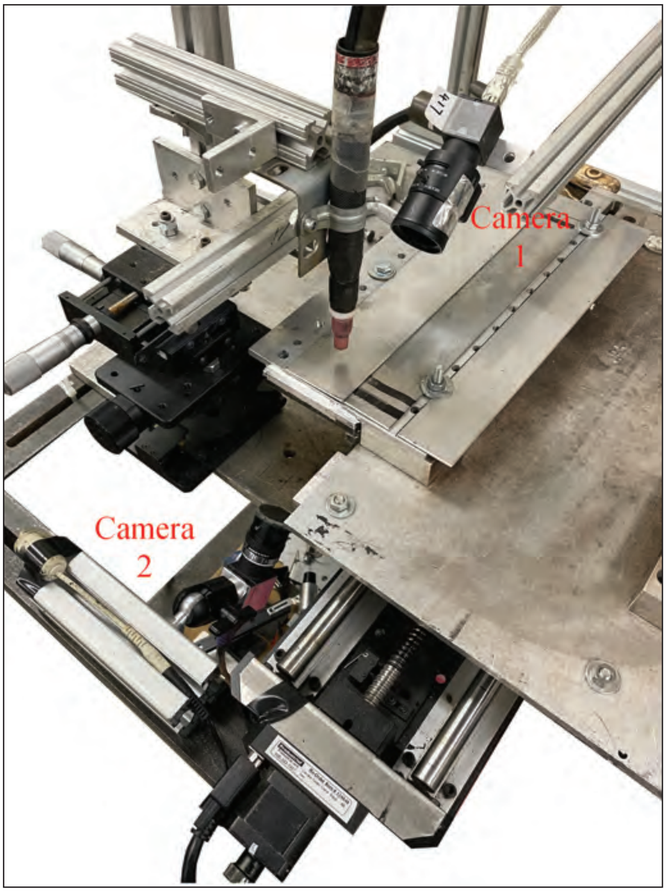

Fig. 1 — Welding experiment platform.

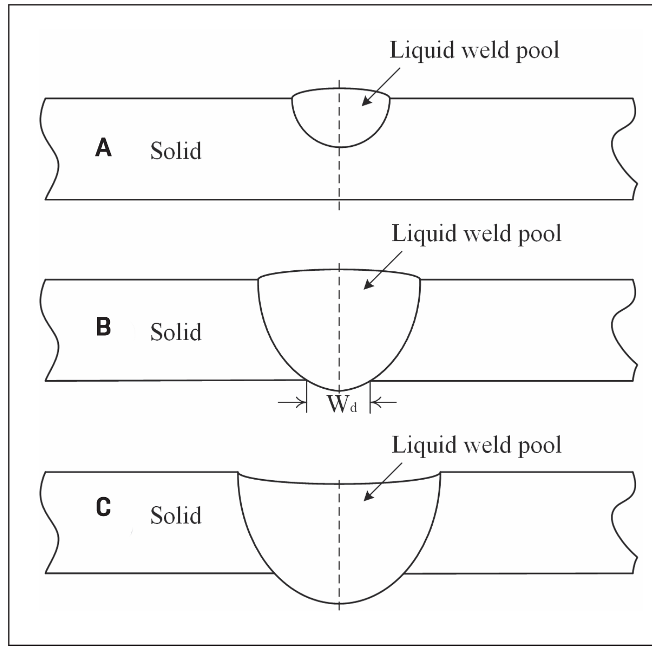

Fig. 2 — Weld pool evolution: A — Incomplete joint penetration; B — complete joint penetration; C — excessive penetration.

weights in fully connected layers as well as the feature extraction and reasoning, is done automatically. However, these images of the observable weld scene and the weld penetration state are collected synchronously for use in training CNN models. There is an implied assumption that the current weld pool/scene can fully determine the weld penetration. The temporal dynamic information may have been missed, and the operation of skilled welders may have been interpreted incompletely. In a previous effort, the temporal dynamic weld pool surface has been used to predict the weld penetration using an adaptive neuro-fuzzy inference system model (Ref. 15).

Deep learning facilitates an appreciated automatic process to directly map images as original process information to the process outputs without tedious, trial-and-error, handcrafted feature extraction. However, the information must be adequate; although, it may be redundant and complex. For the prediction of weld penetration, a possible inadequacy in temporal dynamic information needs to be addressed. Because weld pool arc images are easier to measure than 3D weld pool surfaces, this paper proposes to fuse three consecutive images, each taken ⅛ s apart, into a composite image as the input of a CNN to predict weld penetration.

Table 1 — Camera Configuration Applied

Configuration	Value
Filter Center (nm)	685 ± 2
Filter FWHM (nm)	10 ± 2
Image size (pixel)	480 × 640
Format	Mono8
Frame rates (FPS)	30
Shutter time (s)	0.03
Sharpness	3000
Gain	0
Gamma	2.5

System Configuration

As shown in Fig. 1, a weld torch was set vertically in the experimental platform with a rectangular hole directly below to facilitate the camera and observe the workpiece backside information. A passive vision system (camera 1) observed the weld scene and acquired the images to be fused to form the input of the CNN. A second camera observed the back side of the workpiece to obtain the actual weld penetration to be predicted. The welding torch and two cameras were set stationary, and the workpiece was moved by a stepper motor. This design ensured that the cameras could always capture high-resolution paired images from the top side and back side of the workpiece. To eliminate the strong interference from the arc radiation, camera 1 (Point Grey FL3FW03S1C) used a 685-nm, center-wavelength bandpass optical filter. The same filter was also used by camera 2 for the same reason. The configurations for both cameras are shown in Table 1. The operations of the system and sensors were controlled by the same computer, in particular, con-

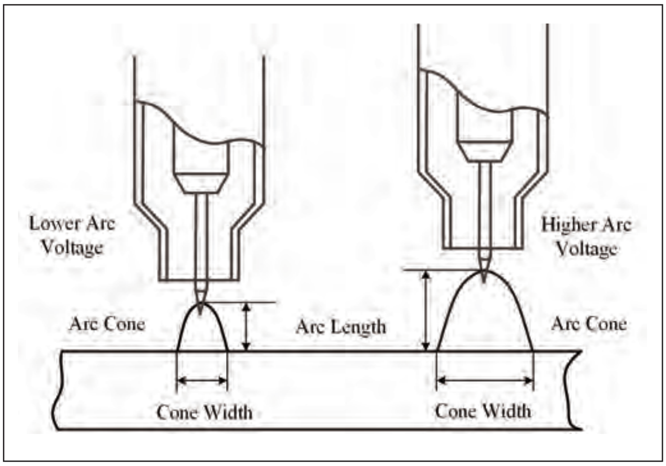

Fig. 3 — Weld arc cone and length.

trolling the cameras, collecting the images with a peripheral component interconnect (PCI) expansion card (IEEE 1394), and controlling the welding power supply and stepper motor using a data acquisition card (PCI 6229).

Weld Penetration Analysis

Welding Process Analysis

When welding started, the solid metal melted and the liquid metal expanded due to thermal expansion, such that the surface started to rise as shown in Fig. 2A. Under the continuous application of the heat from the arc, the volume of the liquid weld pool increased. As a result, the surface area of the weld pool increased, and the penetration depth also deepened until the liquid weld pool completely penetrated the solid metal. The width of the back-side weld bead (W_d) increased after the solid metal was fully melted as shown in Fig. 2B, and W_d was the key parameter to quantify the penetration state. The weld integrity requirement was considered satisfied when W_d reached a certain width in actual production. If the liquid weld pool continuously increased, the back-side weld pool surface would become more convex due to gravity. When the convex volume was greater than the thermal expansion volume, the top-side surface became concave as shown in Fig. 2C. It is thus clearly suggested that the top- and back-side weld pool must follow this physical relationship, and the use of the observable weld scene from the top side to predict the back-side bead width is justifiable. In addition, the dynamic evolution of the top-side weld scene is even more informative and can better correlate with what occurs on the back side.

We note that welders can see not only the surface of the weld pool but also the welding arc. Until recently, the arc was regarded as a strong light interference affecting the effective processing of images to extract more critical information, such as the weld pool boundary. Efforts were thus taken to filter the arc out. Possible information from the arc relevant to the development of the weld pool was ignored. In fact, because the heat is directly applied by the arc, the arc cone directly affects the energy density distribution and the heated area, which is related to the direction and speed of the weld pool extension.

Table 2 — Welding Parameters Applied

Welding Parameters	Value
Welding type	GTAW
Welding current (A)	60–110
Welding time (s)	4–12
Tungsten diameter (mm)	2.4
Shielding gas	Argon
Gas flow (L/min)	7
Workpiece material	304L

As shown in Fig. 3, as the arc voltage increased, the arc length became longer, causing the arc cone to widen and the arc heating area to become broader. Conversely, when the arc voltage decreased, the arc length shortened, the arc cone became narrower, and the heating area was more focused (Ref. 16). The surface of the weld pool will constantly change with the development of the weld pool, and the deformed surface also affects the arc cone. As a result, we collected the top-side image, which included both the arc and weld pool as the raw information of the relevant welding phenomena.

While the complex raw information increases the redundant information, it increases the difficulty in extracting the characteristic information and computational complexity. Fortunately, the deep-learning-based, data-driven approach was expected to be capable of analyzing the top-side images effectively despite the increased complexity.

Image Sequence

An image sequence contains more information than any of its constituent images. For this reason, image sequence analysis has been used in computer vision for quite a long time. Especially for relatively moving objects, analyzing image sequences is very effective for object detection (Ref. 17). In addition, camera noises may corrupt individual images, but such noises can be suppressed using an image sequence to reliably detect low-contrast objects (Ref. 18). For our particular application, the analysis of the weld pool dynamic evolution also illustrates the necessity to use the dynamic welding phenomena.

The top-side images in our case had the following characteristics: dark chroma, low contrast, and relatively slow development of the weld pool and arc. The top-side images in the same process thus had a high degree of similarity. What's more, in the welding process, the characteristic information was dynamic while the surrounding environment was static, as can be seen from the sequence of the top-side images in Fig. 4. The development of the weld pool and arc cone can be observed from this sequence, but the harsh imaging conditions made extracting image features a challenge. Processing the image by a CNN directly without extracting image features first may thus be a right choice. In this paper, we further designed an image sequence dataset to increase the temporal information in the raw data, which enabled the CNN to extract dynamic characteristics from the process.

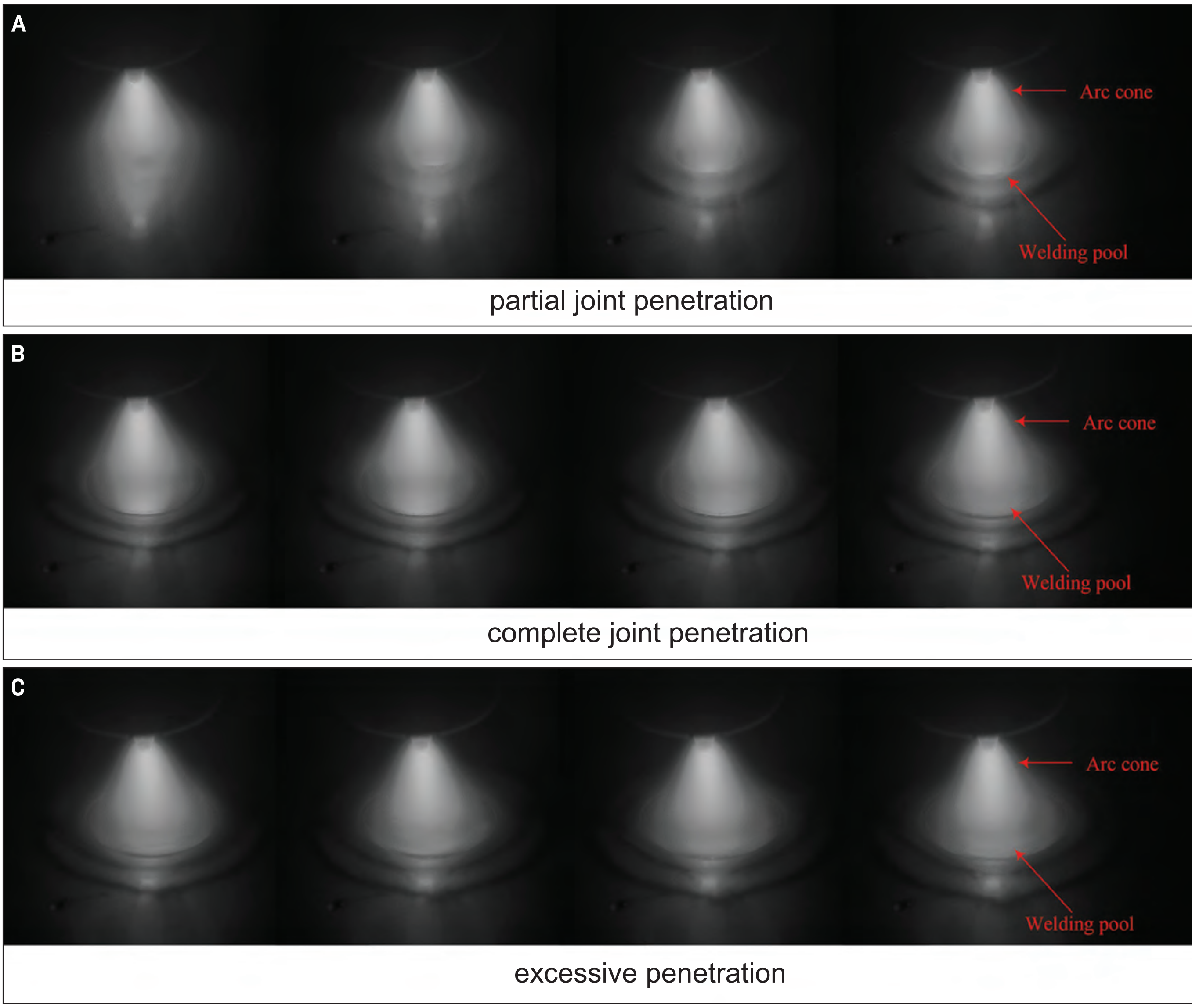

Fig. 4 — The sequence of top-side images.

The main connectivity pattern category for fusing temporal information through the CNN includes early fusion, late fusion, and slow fusion (Ref. 19). The early fusion is to fuse multiple features that are extracted from early layers in the CNN and then use the fused features to train a predictor (later layers). The late fusion uses separate networks to predict and then fuse the prediction results from these networks together. The slow fusion model needs a much larger dataset and computation time, which makes it difficult to predict the penetration states in real time. The goal of our design was to find the hidden dynamic features in the feature space so the neural network could use the dynamic features to predict the weld penetration status. The early fusion appeared to be more appropriate than the other two choices for our application.

Dataset and Model

A series of experiments were designed to perform spot welding using the gas tungsten arc welding (GTAW) process. Each 1.85-mm-thick stainless steel sheet was welded in 12 spots with a 2-cm distance between them. For completeness and reasonableness of the experiments, the range of welding currents and time were designed to simulate a wide range of conditions. The detailed parameters are shown in Table 2. During each experiment, cameras captured the images of the entire welding process from incomplete joint penetration to excessive penetration, with 28,494 image pairs collected as raw data from more than 120 experiments. Image pairs were segmented into training, validation, and test datasets with sizes of 22,794, 2849, and 2851, respectively.

Image Sequence Design

In the typical CNN model, the input images are passed through the network one by one. The image generator yields N, W, H, C data, where N is the batch size, W and H are the width and height of the images, and C is the number of channels (three for RGB images and one for grayscale images). The

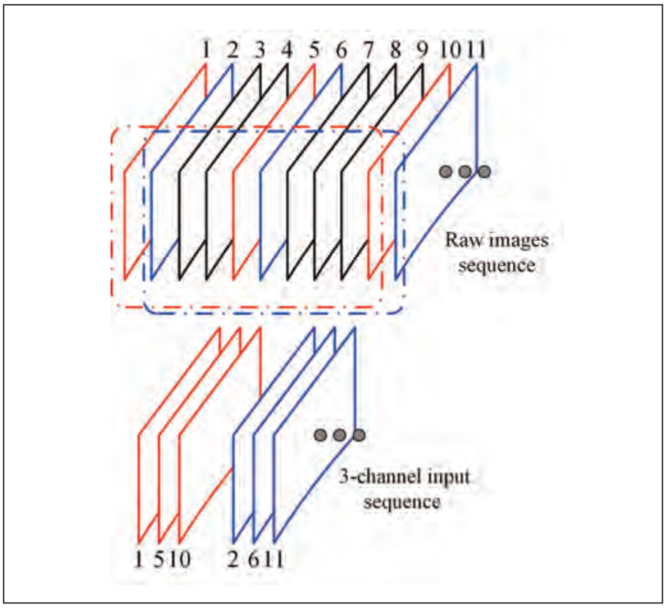

Fig. 5 — Image sequence design.

Table 3 — Labels and Penetration States

Label	Number of Images	Back-Bead Width (mm)	Penetration Status
0	11474	< 4	Under penetration
1	5268	4–6	Desirable penetration
2	11755	> 6	Excessive penetration

image sequence dataset needs several frames in a sequence, and the data dimension becomes N, W, H, C, F, where F is the number of frames in a sequence. In our system, the frame rate of the camera was 30 frames per second, so we set every sequence to be $\frac{1}{3}$ s, which had ten frames (grayscale images), and the stride was set to one to prevent missing critical information. In our application, every frame in the sequence was not equally important as it was in other applications, such as motion analysis and video classification (Refs. 20, 21). We picked the last image (image 10), the image in the middle of the sequence ($\frac{1}{6}$ s earlier or image 5), and the first image (image 1) in the sequence as the samples from the sequence, which effectively reduced the computation costs of redundant information. The sampled sequence was used as the input of the CNN. The image sequence design is shown in Fig. 5. This design can effectively control the size of the input data, and the neural network can control the stride size to gradually fuse dynamic information from the whole image sequence.

Labels

The back-side images were used as the penetration state labels for training the CNN model. The penetration state is defined by the range of the real back-bead width. However, it is not possible to be measured simultaneously with the top-side images in real time during the welding process. Therefore, we calculated the back-bead width value through a model that correlates the back-side image to the real back-bead width. To this end, we first defined a bright area using a threshold and then calculated it from the back-side image as shown in Fig. 6. In this paper, we set the threshold at 170. Then, the relationship between the area and the actual back-bead width was established through calibration experiments. Since the square of the actual back-bead width was proportional to the area (number of pixels), we proposed the following formula:

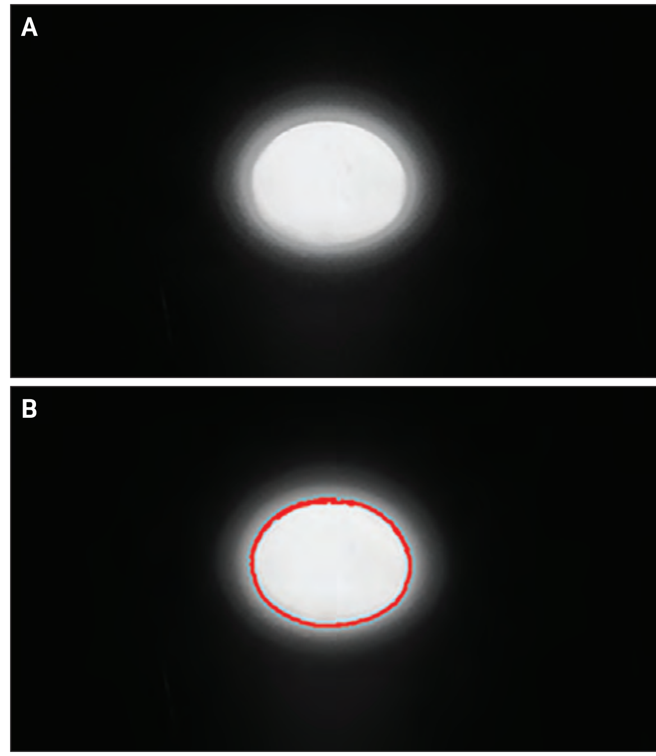

Fig. 6 — Back-side image and thresholding: A — Original images; B — boundary of the bright area with a threshold of 170.

$$Width = k \times \sqrt{Area - Error} \qquad (1)$$

where k and $Error$ are unknown parameters determined by least squares approximation, and the fitting curve is shown in Fig. 7. The coefficient of determination is 0.9879, which indicates that the regression predictions well approximate the real data.

With Equation 1, the back-bead width was calculated from the back-side images, and the penetration state was classified by the back-bead width into three categories: under penetration, desirable penetration, and excessive penetration. Table 3 shows the detailed classification criteria used in this paper. Such penetration states from the back-side images were used as labels for CNN model training.

CNN Model

Early fusion can immediately expand the entire time win-

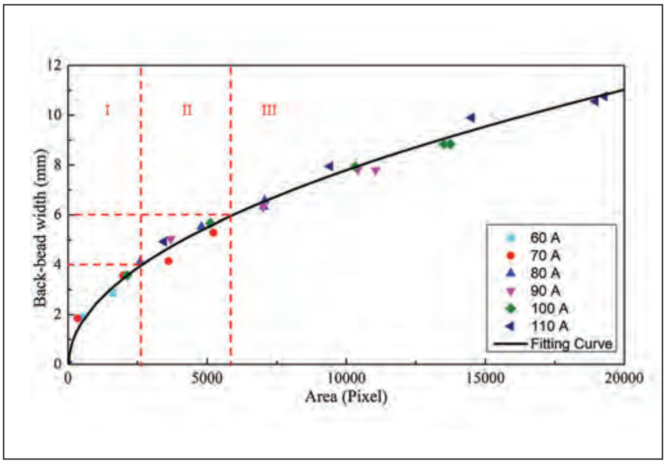

Fig. 7 — Fitting curve between the pixel area and back-bead width.

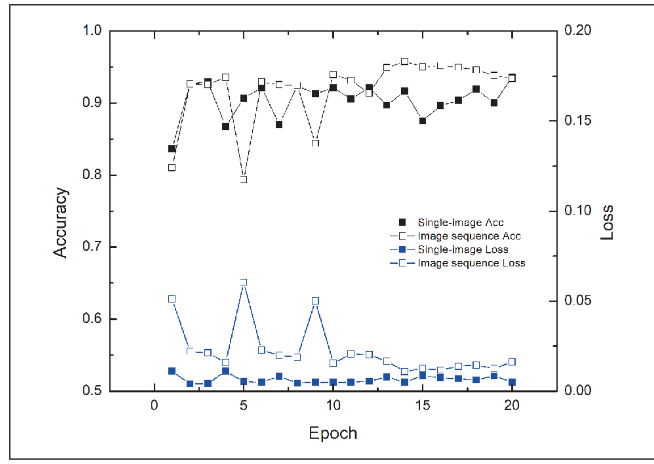

Fig. 8 — Single image data and image sequence data in the validating process.

Table 4 — The Architecture of the CNN (Early Fusion)

Layer Name	Kernel Size	No. of Filters	Output Size	CNN (Early Fusion)
Conv1	5 × 5	32	476 × 636	Batch normalization, ReLU
Pool1	3 × 3	–	158 × 212	Max pool
Conv2	3 × 3	64	156 × 210	Batch normalization, ReLU
Pool2	3 × 3	–	52 × 70	Max pool
Conv3	3 × 3	128	50 × 68	Batch normalization, ReLU
Pool3	3 × 3	–	16 × 22	Max pool
FC1	–	–	1080	–
FC2	–	–	64	–
FC3	–	–	3	–

Table 5 — Confusion Matrix

		Actual Class		
		0	1	2
Predicted Class	0	1073	44	0
	1	11	429	102
	2	0	4	1131

dow to fuse information at the pixel level. In the first convolutional layer of an early fusion, the kernel size will extend through the full depth of the input volume. This is achieved by modifying the filters of the first convolutional layer in the single-frame model by expanding the size to be W × H × (C × F). The designed image sequence can thus be merged into three channels, and the neural network can easily find the pixel changes at the same location by the same receptive field. This matches with our design sequence data. The network can then accurately detect local motion directions and speeds (Ref. 19). With the early fusion method, the proposed CNN model is shown in Table 4, which includes three convolutional layers (Convs), three max-pooling layers (Pools), and three fully connected layers (FCs). The CNN early fusion takes 480 × 640 and three-channel images as input, and its Conv1 has 32 kernels of 5 × 5 to fuse the temporal information at the pixel level by convoluting over the three-channel raw images. A 3 × 3 max-pool layer follows the Conv1 to reduce the computation cost of the whole neural network. Three sequential grayscale inputs are then due to the inputs. The feature information has brighter pixels in the grayscale images, making max pool useful, as it is when the background of the images is dark and the target information has lighter pixels. On Pool1, the max pooling is used to extract the extreme features and give the neural network robustness to position variation. The similar processes with different kernel size and kernel number are applied on Conv2, Pool2, Conv3, and Pool3, respectively, to further extract the features. The CNN model is a tradeoff between speed and accuracy; the 5 × 5 kernel is used in Conv1 to better fuse information from three-channel images, and the 3 × 3 kernels are used in Conv2 and Conv3 to reduce memory usage and compute faster (Ref. 22). Then, the data is flattened and connected with three FC layers to output the classification of the weld penetration state.

A batch normalization (BN) and rectified linear unit (ReLU) function follow each Conv to improve the performance of the CNN model. BN has the effect of stabilizing the learning process and dramatically accelerating the neural network training speed by reducing internal covariate shift and reducing generalization error (Ref. 23). The ReLU is used as an activation function; compared with other activation functions such as tanh and sigmoid, ReLU can overcome vanishing gradient problems and allows the model to learn faster and perform better (Ref. 24). In addition, the CNN model is trained using a mini-batch back-propagation algorithm. The loss function is set as the cross entropy for this multiclass classification problem, and the Adam optimization is used to reduce the computation cost and improve the convergence rate in the training process (Refs. 25, 26). All training was done on a computer with an Intel® Core ™ i7-6700K central processing unit and an NVIDIA® GeForce GTX 1080 graphics processing unit.

Results and Analysis

Figure 8 shows the validating results after each CNN parameter was updated at each epoch during the training. The validation accuracy for the model using the image sequence data fluctuated significantly during the first ten epochs and then slowly stabilized and reached the best value in the 14th epoch, which was 95.8%. However, using a single image, the highest validating accuracy was 93.6%. We note that the corresponding cross-entropy loss did not exactly match: The loss using single image data was less than that using image sequence. The loss value is not a necessary nor a sufficient condition for accuracy in the neural network. The image sequence data increases the size of the input while increasing the temporal information. To prevent running out of memory, we set the batch size at 10, and the batch size of single image data was 40. The large batch size can reduce the loss value due to the relationship between batch size and speed and stability of the learning process (Ref. 27). However, the accuracy achieved using image sequence data was higher than that using single image data, proving that the designed image sequence was effective and met the design requirements. The model producing the highest validating accuracy was saved to predict the test data: The model using image sequence data had an accuracy of 94.2%, while the model using single image data had an accuracy of 92.7%. The testing results are shown in Table 5. Data examination shows that most incorrect predictions occurred in the neighboring classes.

The prediction using the trained model is considered real time. It requires 0.0254 s for the computer to transfer the image sequence to the CNN and for the CNN to output the classification of the weld penetration. It is less than the time for acquiring one image, which is 0.033 s.

Conclusion and Future Work

In this paper, the image sequence was used to include the dynamic welding phenomena to improve the accuracy for weld penetration prediction. The proposed network used the early fusion method to fuse the dynamic information. In comparison with the model trained using the single top-side image data, using the image sequence data had a higher prediction accuracy. We found 1) the designed sequence of top-side images can effectively add temporal information and improve the accuracy of the prediction; 2) the early fusion approach can enable the CNN to find the dynamic information from the sequence data quickly and accurately; and 3) the data-driven and end-to-end prediction is an efficient and simple method to predict the weld penetration state from top-side images in the complex welding process.

The work was performed in laboratory conditions using bead-on-plate experiments without a gap and filler metal for stainless steel. Future work should extend experiments to butt joints with filler metal as well as to other materials to further verify the effectiveness of the proposed method that is based on dynamic weld pool arc images in predicting weld penetration.

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WENHUA JIAO, QIYUE WANG, YONGCHAO CHENG, RUI YU, and YUMING ZHANG (yuming.zhang@uky.edu) *are with the Department of Electrical and Computer Engineering and the Institute for Sustainable Manufacturing, University of Kentucky, Lexington, Ky.*


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