domestic Tranquility, provide for the common W ealth, order and estab-

Article 1.

All legislative Powers here granted shall be vested in a Congress of the United

States.

The House of Representatives shall be composed of Members chosen every second
Year, and shall have Qualifications requisite for Electors of the most numerous Branch of the State
Assemblies. A Representative shall not be a Representative who shall not have attained to the Age of twenty five.

Representatives and direct Taxes shall be apportioned among the several States which may be in
the United States, according to their respective Numbers, counting the whole Number of free Persons.

The actual Enumeration shall be made within three Years after the first Meeting of Congress, and, at each
Subsequent Term of ten Years, in such Manner as they shall by Law direct. The J udge, but each State shall have at least one Representative, and until such enumeration

Three, Massachusetts eight, Rhode Island and Providence Plantations one, Penns-

sylvania One, Maryland One, Virginia Two, North Carolina Five, South Carolina Six, and seven

vacancies happen in the Representation from any State, the Executive Authority here

House of Representatives shall choose their Speaker and other Officers; and shall have No

The States of the United States shall be composed of two Senators from each State; sha
have one Vote.

ed immediately after they shall be assembled in Consequence of the first Section, they shall be.
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**DW-91B3**
AWS E91T1-B3, E91T1-B3M
Circle No. 25 on Reader Info-Card

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Circle No. 21 on Reader Info-Card
The American Welding Society (AWS) has established an ISO Participation Fund in an effort to share the cost of the participation of U.S. experts in international standards development activities. The Society's startup contribution is $10,000. Once the welding manufacturing and fabrication industry has matched the AWS contribution, the funds will be used to support international meeting expenses for volunteer experts selected by the International Standards Activities Committee (ISAC).

The Society has taken this action for the following reasons:
• To ensure the U.S. welding industry has a voice at international standards meetings so that its needs are heard and addressed.
• To make certain ISO standards facilitate the acceptance of U.S. products, processes, and services in international markets.
• To enhance and protect the global competitiveness of U.S. industry and the U.S. quality of life by promoting and facilitating voluntary consensus standards developed by industry for industry.

It is the hope of the American Welding Society that the welding industry will meet the challenge grant and continue to support the fund with annual donations to ensure the continued presence of U.S. experts at the international standards negotiating table. For further information, contact Andrew Davis, International Standards program manager at adavis@aws.org.

Charter plc, parent company of ESAB, recently announced it will relocate the ESAB global headquarters from Atlanta, Ga., to Europe. The new global headquarters will utilize the resources of ESAB's European operating unit. According to Charter, the move reduces the management cost structure, while not impacting the effectiveness of the individual operating units.

In addition, Charter announced the appointment of Howard Van Schoyck as chief executive officer of the ESAB group worldwide. Van Schoyck replaces Ray Hoglund, who will be leaving the company.

Van Schoyck has served as managing director of ESAB's European operation since March 2000. Prior to joining ESAB, he was the European managing director of original equipment for Tenneco Automotive, based in Brussels. Prior to that, he served as managing director for Australia and the Far East for Walker Exhaust, Tenneco Automotive, and held other senior-level management positions at Allied Signal.

The U.S. International Trade Commission (ITC) recently voted to impose duties for at least five years against hot-rolled steel shipped to the United States from Argentina and South Africa.

The six ITC commissioners unanimously voted that Argentinian and South African steelmakers sold hot-rolled steel in the United States at prices that violated federal trade laws, a practice known as "dumping." The ITC also voted unanimously that Argentina's government provided subsidies to its steel producers, also a violation of trade laws. A ruling on subsidies involving South Africa will be made later.

Nine domestic steel companies and two unions filed a lawsuit with the ITC in November 2000, alleging pricing and/or subsidy violations against 11 countries. A ruling on the remaining countries is expected later this month.

"This is good news for Weirton Steel and America's steel industry. We thank the commissioners for their vote, which proves our claims about unfair trade. For the most part, the duties will make it cost prohibitive for these nations to ship their hot-rolled steel to our shores," said John H. Walker, Weirton Steel president and chief executive officer. He said the two countries accounted for 287,000 tons of hot-rolled shipments to the United States last year.

The ITC assessed dumping duties at 44.5% against Argentina and 9.3% against South Africa.

The Lincoln Electric Co., Cleveland, Ohio, recently appointed Christopher A. Bailey to general manager of its Automation Div., which manufactures robotic welding and cutting systems.

Bailey will be responsible for all aspects of the business, including system design, manufacturing, ongoing technical support, marketing, and overseeing key customer relationships.

Bailey is a 22-year veteran of the company. He served most recently as national sales manager.
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For a demonstration, call your independent Swagelok representative at 1-800-SWAGELOK. Or visit www.swagelok.com.
Workplace Deaths Decline in 2000

The U.S. Department of Labor has announced a decline of 2% in the number of workplace deaths last year. A total of 5915 fatal work injuries were recorded in 2000, meaning an average of 16 workers were killed on the job each day. Declines occurred in almost all sectors, including a significant decrease in manufacturing. Work-related highway deaths dropped for the first time since 1992, and construction industry deaths declined for the first time since 1996. Unfortunately, deaths among Hispanic workers, especially in construction, increased to 815 from 729 in 1999. The most fatal work injuries of any occupational group were machine operators, fabricators, and laborers. Death rates were highest in the mining industry, which recorded 30 workplace deaths per 100,000 workers.

Workplaces with Highest Injury/Illness Rates Identified

The Occupational Safety and Health Administration (OSHA) has identified the 14,000 U.S. work sites with the highest rates of injury and illness for workers. The 14,000 sites are listed, by state, alphabetically, on OSHA's Web site at www.osha.gov on the Freedom of Information Act page.

Nationwide, the average U.S. workplace had three instances of injury or illness for every 100 workers. Each of the 14,000 sites identified by OSHA exceeded that average. OSHA is "encouraging" such workplaces to improve their record with an implicit threat of inspection and further action.

Research and Development Tax Credit Prospects Dim

Efforts to make the research and development tax credit permanent appear to be failing. An amendment to this effect was recently offered to an unrelated piece of legislation but was defeated on procedural grounds. With diminishing prospects for a large business tax reduction this year and several years remaining for the current R&D tax credit to expire in 2004, passage of a permanent credit this year remains a challenge, despite overwhelming bipartisan support.

Shipyard Accounting Legislation Introduced

Legislation has been introduced in both the House of Representatives and the Senate to amend the Internal Revenue Code. The legislation intends to simplify and restore fairness to the Naval Shipyard Accounting Statutes under which shipyards pay taxes on Naval ship contracts. Put simply, this legislation would permit shipyards to use a method of accounting under which they would pay income taxes upon delivery of a ship rather than during construction. Currently, profits must be estimated during construction phases of the ship-building process and taxes paid on those estimated profits, whether they are in fact realized or not.

The legislation would not reduce the amount of taxes ultimately paid by ship builders, but would defer payment until the profit is actually known upon delivery of the ship. Adding to the problem is the fact many shipyards are not fully paid for the ship until 12 months, or more, after the ship is delivered to the Navy. This legislation has strong bipartisan support.

Increased Funding for Small Business Technology Program

Legislation has been approved by small business committees in both the House of Representatives and the Senate to reauthorize the Small Business Technology Transfer program and increase the program's funding 100% by fiscal year 2004. Established in 1992, this program provides grants that help research and development undertaken cooperatively between small business and a university or other research institution. The legislation would also extend the program for another eight years, under the House bill, and nine years under the Senate version.

Pipeline Safety Legislation Introduced

Additional bills have been introduced in the House of Representatives, with bipartisan support, to improve pipeline safety through mandated pipeline inspections, improved operator training, and certification of pipeline controllers. This legislation complements a pipeline safety bill unanimously passed by the Senate earlier this year. However, the House bill goes further by requiring certification of pipeline controllers and directing regular inspections of pipeline operators to ensure qualified employees. Under both the Senate and House legislation, minimum safety standards would be developed for pipeline operators. The House legislation also would require certification for employees who control pipeline operations.

In a related development, the U.S. Senate has authorized an increase in funding for pipeline safety of $11 million over last year's level.

Contact the AWS Washington Government Affairs Office at 1747 Pennsylvania Ave. NW, Washington, DC 20006; e-mail hwebster@wc-b.com; FAX: (202) 835-0243.
The Strength of Democracy

"Yesterday, December 7, 1941 — a date which will live in infamy... I assert that we will not only defend ourselves to the uttermost, but will make very certain that this form of treachery shall never endanger us again...."

The above words were etched into the fabric of our democracy by President Franklin Delano Roosevelt the day after the Empire of Japan’s bombs came out of the sky and attacked a peaceful Pearl Harbor. And, yet, 60 years later, as business men and women prepared for what was supposed to be just another day at the office, another wave of hatred against a free nation once again came from the sky.

Sixty years have seen many positive changes in our world. Computers, technology, nuclear power, and improved communications and modes of travel have made our way of life better, faster, healthier, and safer. However, the mighty oceans that once provided a safe harbor from perpetrators have now become small ponds as our world shrinks in size through technological advancements. Those guilty of the horrendous crimes against the United States used these advancements to perpetrate evil acts. We must not allow a cowardly few to undermine the progress we have made in six decades.

Welding has always been an important aspect of our country’s national security. The American Welding Society has long understood and supported the requirements of preparing U.S. warships, weaponry, aircraft, transports and other military hardware as a deterrent to our enemies. Though our enemies are not as obvious as those of 60 years ago, AWS will once again assist our nation in helping to preserve our democracy, our way of life.

America is a strong nation. I have confidence in our resilience, and confidence that we will rebuild our nation and our society. We will not allow a tragedy of Armageddon proportions to destroy that which we hold so dear — freedom and democracy. We shall overcome the horror that befell our dear nation on September 11, 2001. And this will serve as a reminder to the world that American democracy is the strongest government institution on Earth.

God bless America and God bless the souls of our fallen brothers and sisters.

Richard L. Arn
AWS President
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Individuals United by a Common Cause

Executive Director's Note: Features Editor Mary Ruth Johnson routinely provides editorial counsel to our volunteer and staff editorialists. Today, I have asked her to directly express her feelings on behalf of our staff. Her editorial follows:

The American system, it has been said, is one of “rugged individualism.” President Herbert Hoover, credited with introducing the term when he used it in a campaign speech in 1928, later denied the claim. However, “I should have been proud to have invented it,” he said. “It has been used by American leaders for over a half-century in eulogy of those God-fearing men and women of honesty whose stamina and character and fearless assertion of rights led them to make their own way in life.”

America has always depended on its rugged individualists. After all, this big, new, unsettled land needed people from smaller, older, more tradition-bound places to fill it. What it got, more often than not, when it opened its arms in welcome, were people of determination and courage, people willing to say goodbye to family and friends and take a chance on a new way of life. Many endured a crowded, arduous ocean voyage. Others loaded their possessions onto a wagon pulled by a brace of oxen, and followed it across the prairie to places where loneliness was perhaps the greatest obstacle they faced as they turned the land into farms.

Yet, for all their independence, these men and women, these Americans, while fiercely protective of their individual freedoms, have always understood their collective responsibilities. So, when the times have called for it, they have banded together. Sometimes the impetus has been aggression, such as during World War II, when disparate elements of U.S. society — the Tuskegee airmen, the Navajo code talkers, and all the rest of America’s citizen soldiers — took their places to fight a common enemy. Sometimes it’s been other types of adversity — townspeople handing sandbags from one to another to hold back a cresting river or making do, doing without, sharing what they had during the Great Depression.

We have come to another of those times that test the determination of the people of the United States of America. On September 11, we watched the world irrevocably change. Live and on countless television replays, we witnessed unspeakable cruelty, horror, and desperation. While no one knows what will happen over the next months, I believe the American spirit will prevail and we’ll meet any challenge presented to us. I know others sometimes scoff at Americans’ “can do, nothing is impossible” attitude, but that’s simply who we are. We’re rugged individualists who cherish our personal rights while working together.

Mary Ruth Johnson
Features Editor, Welding Journal
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Sulzer Metco. If you need technical information on the thermal spray process, you might want to start with this Web site. The “Tech Info” section includes a lineup of technical articles, downloadable in Adobe® Acrobat® PDF format, and technical tips and thermal spray coating process information. That segment answers the question “What is thermal spray?”, gives a process comparison table, explains key elements of the thermal spray system, and gives descriptions of the following thermal spray coating processes: combustion powder, combustion wire, electric wire, high-velocity oxyfuel, plasma, and in-chamber coating processes.

According to the “Mastering Mechanical Wear” pages, “The single most common use for thermal spray technology is to retard and control wear....Wear challenges include the geometry and environmental aspects of a contact, the state of stress and stress distribution, the dynamics of motion, the quality of lubrication, the presence of contaminants, and the finish of the surfaces themselves. While several different wear phenomena, such as abrasive wear, adhesive wear, fretting, or sliding wear, can be acting on the surfaces at once, they have a common result: surface material is lost, ultimately causing a functionally significant change in dimension and impaired performance.” The pages go on to offer solutions to mechanical wear problems and describe specific applications.

The site’s “News” section includes press releases and additional articles on topics relating to thermal spray. A detailed segment on safety can be found in the “Other Info” section. The site also includes maps showing the location of the company’s sales offices around the world and plenty of product information. Visitors can also sign up for the company’s e-commerce initiative, which it calls “Surf-Coat™.”

http://www.sulzermetco.com

Answers to Resistance Welding Questions

Unitek Equipment. The “Technical Support” section of this Web site offers answers to frequently asked questions (FAQs) about the resistance welding process or visitors can “Ask the Weld Wizard” by e-mailing questions to company representatives. According to one FAQ, resistance welding can be used to form three types of bonds, as follows:

- “Solder (<400°C) or braze (>400°C): A filler metal is added during welding or is present on one of the materials.
- “Solid state: Metals are normally heated to between 70 and 80% of their melting point.
- “Fusion: Both metals are heated to their melting point and mixed together, forming alloys of the two base metals.”

Tech support also includes copies of The Pulse newsletter, examples of welding applications, and what the company calls “technical nuggets,” such as a discussion of the effects of polarity on resistance welding. Several articles can be downloaded in PDF format, including an eight-page article on “The Fundamentals of Small Parts Resistance Welding.” The article describes the resistance welding process, gives information on materials and material properties, and provides examples of welding sequences, which are also called heat profiles.

Visitors can use keywords or a scroll-down menu to search the site. Also included are links to related industry Web sites; information on the company’s line of resistance welding and reflow soldering power supplies, weld heads, monitors, and accessories; contact information for its sales network; company profiles; and career opportunities.

http://www.unitkequipment.com

Materials Testing Services Detailed

Laboratory Testing, Inc. The products and services of this independent materials testing laboratory based in Hatfield, Pa., are detailed on its Web site. The site includes a news page, a map with directions to the laboratory, and photographs of the testing, calibration and machining departments. Information is also provided on its accreditations and the company’s quality program. Visitors can utilize an e-mail form to request literature or ask questions.

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News of the Industry

Railcar Manufacturing Businesses to Merge

Trinity Industries, Inc., Dallas, Tex., and Thrall Car Manufacturing Co., Chicago Heights, Ill., recently agreed to merge Thrall's operations with Trinity's railcar manufacturing business in exchange for cash and Trinity stock. Trinity will pay approximately $165 million in cash and issue 7.15 million shares of its common stock to the shareholders of Thrall. Trinity has also agreed to make additional payments, not to exceed $45 million over five years, based on a formula related to annual railcar industry production levels. Trinity currently has 37 million shares of common stock outstanding.

A combination of senior officers from the two companies' railcar manufacturing businesses will lead the merged railcar manufacturing operation. Michael E. Flannery, currently vice chairman of Thrall, will serve as chief executive officer. He will report to Timothy R. Wallace, chairman, president, and CEO of Trinity Industries. Martin Graham, currently president and chief operating officer of Thrall, will be president of the Thrall-Trinity Freight Car Div. Jeffrey Marsh will remain in his current role as president of Trinity's Tank Car Div. Patrick Wallace, currently president of Trinity's Freight Car Div., will be president of Trinity's Rail Component Parts Div., which will be part of the new entity.

Both companies design and manufacture a wide variety of railcars for freight transportation. Over the past three years, Trinity's railcar business had average annual revenue of more than $1.3 billion and an average operating profit of $96 million. Over the comparable period, Thrall had average annual revenue of more than $700 million and an average operating profit of $57 million.

Grant Helps Pittsburgh Initiative Expand Work Force Training Program

The Manufacturing Pathways Initiative of the Pittsburgh Technology Council and the Southwestern Pennsylvania Industrial Resource Center have been awarded a $200,000 grant from the Claude Worthington Benedum Foundation. The grant will enable greater outreach of the organizations' work force training program to schools in Allegheny, Washington, Greene, and Fayette counties.

Introduced in spring 2001 to schools in Westmoreland County, the Manufacturing Pathways Initiative was started to prepare students for careers in the manufacturing industry or postsecondary education directly upon graduation from high school. It is a partnership of employers, high schools, vocational-technical schools, postsecondary institutions, community programs, parents, and students. One of its key objectives is to combat negative perceptions about today's manufacturing careers.

"Manufacturing workers today are educated technicians who earn high wages and possess highly marketable, specialized skills in great demand," said Dave Nelson, CEO of CoManage Corp. and member of the Council's executive committee. "The Manufacturing Pathways Initiative seeks to educate students and their families about that demand."

Manitowoc to Build Two 155,000-Barrel Petroleum Tug/Barge Units

The Manitowoc Co., Inc., Manitowoc, Wis., recently received a contract from Vessel Management Services, Inc., Seattle, Wash., to construct two double-hull tank barges and ocean tugs, with an option to purchase two additional tug/barge units. The vessels will comply with provisions of the Oil Pollution Act of 1990. Terms of the contract were not disclosed.

The first two units under contract consist of two 155,000-barrel double-hulled tank barges and two 9280-hp, twin-screw ocean tugs. The contracts are expected to create a backlog of work that could extend more than 30 months.

ISO and IIW Cooperate on Welding Standards

The International Organization for Standardization (ISO) and the International Institute of Welding (IIW) recently signed an agreement that will reinforce their cooperation on standardization for welding.

Under the agreement, ISO can adopt IIW-developed standards as ISO standards or ISO deliverables such as Technical Specifications, Publicly Available Specifications, or International Workshop Agreements. ISO deliverables use more streamlined procedures than does the conventional ISO standards development process. The agreement is expected to significantly increase the number of welding standards published under the joint ISO/IIW logo.

"The purpose of the ISO/IIW agreement is to avoid duplication of efforts and avoid confusion amongst users," said Daniel Beaufils, chief executive of IIW. "It is envisaged the cooperation will serve as an invaluable tool to help harmonize and globalize the standardization needs of welding."
Industry Notes

- American Torch Tip Co., Bradenton, Fla., recently formed the Thermatec Division to produce replacement consumable parts used on various types of thermal spray equipment. Thermatec will produce replacement parts for use on most major brands of thermal spray equipment such as those made by Tafa, Metco, Stellite, and Norton.
- AlcoTec, Traverse City, Mich., a subsidiary of the ESAB Group, Inc., recently donated professional lecture services, faculty training, and welding wire to the Welding Engineering Technology department of Ferris State University, Big Rapids, Mich.
- The average aluminum content in 2002 model year cars and light trucks will increase to 268 pounds per vehicles on average from 255 pounds last year, according to a report from American Metal Market, a metal trade journal. The amount will be an all-time high. While casting alloys make up much of the gain, AMM reports sheet, extrusion, and forging alloys are also gaining acceptance in the automotive marketplace.
- BOC Gases, Murray Hill, N.J., recently received a Supplier Excellence Award from Calsonic North America for consistently providing quality components and services during calendar year 2000. BOC supplies Calsonic with stainless steel wire, welding expertise, and supplies.

Arc Machines Celebrates 25th Anniversary

Arc Machines, Inc., Pacoima, Calif., recently celebrated its 25th anniversary at a party attended by more than 400 people, including representatives from the United States, Canada, and Japan. The company manufactures orbital tube, pipe, and tubeshot welding equipment.

Awards were presented to the company's 10-, 15-, and 20-year employees. President M. E. Gedgaudas, Executive Vice President L. V. Reivydas, and Vice President Vic Fukumoto gave speeches.

Vice President Vic Fukumoto, President M. E. Gedgaudas, and Executive Vice President L. V. Reivydas (from left to right) are shown during the 25th anniversary party for Arc Machines.

U.S. Steel's New Dual-Phase Steels Hold Promise for Making Lighter-Weight Autos

United States Steel LLC has developed a family of dual-phase steels engineered to meet the demands of automakers for high-strength, lightweight materials with improved formability. The steels will help reduce vehicle weight and cost while improving crash safety performance.

The steelmaker claims it is the first American steelmaker to commercially produce such steels, which derive their strength from a unique combination of ferrite and martensite. The company is marketing the product under the trademark Dual-Ten™.

U.S. Steel is demonstrating the advantages of the new steels through testing and simulation at its automotive center in Troy, Mich. Studies investigating fatigue performance are also currently under way. According to the company, the inherent strength of Dual-Ten steels is enhanced through rapid work hardening during the stamping process, and again during the painting process when the steel becomes bake hardened. Both processes can increase steel strength as much as 80% over the virgin sheet.

Lehigh Heavy Forge Invests $21 Million in Capital Improvements, Including Weld Shop

Lehigh Heavy Forge Corp. is expanding and upgrading its facilities in Bethlehem, Pa., through a $21 million capital improvements program that includes a new state-of-the-art welding facility.

"The bulk of the improvements involves upgrading our forge shop, heat treating, and machine shop facilities to meet our growing customer needs," explained Charles Novelli, Lehigh's president and chief executive officer. "A major component is rebuilding our 10,000-ton hydraulic forging press with advanced computer systems, as well as increasing the capacity of the manipulator from 75 to 150 tons."

The 40-ft-high, 10,000-ton press had sustained damage in a fire in June. It is the largest open die press in the western hemisphere and one of the largest in the world, capable of forming ingots in excess of 600,000 lb. The press is expected to be fully operational early this month.

The new welding facility is being built to accommodate the company's expanding customer base in the marine industry. The shop will be used to clad ship shafts, weld split sleeves, and repair damaged shafting. Newport News Shipbuilding recently awarded the company a contract to produce eight propulsion shafts for the U.S. Navy's newest Nimitz-class, nuclear-powered aircraft carrier.
Welding Lens Optimized for Use with Low-Amp Inverters

The company’s 9000Xi autodarkening welding lens has been developed for use with low-amp, GTAW inverter technology. When a welder strikes an arc, the lens autodarkens from shade 3 to the user-selected dark state of shades 9, 10, 11, 12, or 13. At the same time, the lens also switches to a high-sensitivity mode so its photosensors can sense the steady arc produced by GTAW inverter machines. When the user stops welding, the lens automatically changes back to shade 3. The lens has a 4.09 x 2.13 viewing area and a solar cell that extends average battery life to 3000 h. The lens comes with the company’s breathable helmet; both lens and helmet meet the ANSI Z87.1 standard for industrial eye and face protection.

Hornell, Inc.
2374 Edison Blvd., Twinsburg, OH 44087

Vacuum Lifters Handle Large Loads

Custom-configured, high-capacity vacuum lifters for large, flat loads such as concrete panels, aluminum tread plate, and hot-rolled steel are offered by the company. The lifters feature 18- x 34-in. rectangular pads with a 3200-lb capacity. Pads are available with rubber or foam seals for handling smooth or rough surfaces. Custom solutions include adjustable beams, cross arms and pads, vacuum warning devices, and gauges that can be fully integrated with other lifting equipment.

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Emergency Eyewash Rinses Out Contaminants

The company’s emergency eyewash attaches directly to faucets, making treatment available at all times without interfering with normal faucet operation. When activated, dual-aerated streams of water flow upward from the fountain tips to irrigate both eyes and rinse out contaminants. Dust covers keep fountain tips and aerators clean between uses and slide off.

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automatically with water flow. No extra plumbing is needed. Units have adjustable fountain tips (2 in. apart), an automatic diverter valve that returns the faucet to normal operation when the water is shut off, a connection ring to facilitate difficult installations, and are constructed of chrome-plating and solid brass.

Gateway Safety, Inc.
4722 Spring Rd., Cleveland, OH 44131-1045

Half Mask Offers Respiratory Protection and Comfortable Fit

The company's half face piece, Xcel™, available in four sizes, provides respiratory protection against gases, vapors, fumes, and other airborne particulates. Molded from thermoplastic elastomer, the half mask's flex-fold over the bridge of the nose minimizes stress yet seals tightly to protect against leakage. An optional voicemitter is available for enhanced personal communication. A head harness with wide elastic bands provides broad coverage of the crown of the head, making it easy to don and doff without interference from glasses, goggles, head gear, or ear protection. A D-ring and clip offer one-step adjustment, even with gloved hands.

Scott Health & Safety
360 W. Crowell St., Monroe, NC 28112-4449

Safety Light Curtain Has Ultra-Compact Transmitter and Receiver

The company offers the MC4700 series of safety light curtains featuring an ultra-compact (1.02 x 1.1 in) transmitter and receiver that offer protected heights from 3.94 to 70.87 in. The transmitter and receiver dimensions allow the curtains to be mounted on small automatic assembly machines and in other applications where a light curtain was previously too large. In-line, quick disconnect cables allow mounting in crowded locations where a standard connector would not fit. Additional features include adjustable mounting brackets, exact channel select, floating blanking, auxiliary outputs, restart interlock, machine test signal, MPCE monitoring, two-digit display diagnostic, two PNP safety outputs, and simple three-box design.

Scientific Technologies, Inc.
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Precision Quincy Corp. 105
1625 W. Lake Shore Dr., Woodstock, IL 60098

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The company offers low-temperature microwelding systems and technical support for mold repair welding. Welding at lower temperature avoids metallurgical damage resulting from the intense heat of other welding processes. The systems include high-tech optics and lighting, offering a magnified image that helps maintain the small arc necessary for low-amperage welding. The systems also provide a platform for efficient preweld and postweld preparations, including inspection and analysis of damaged areas, elimination of surface contaminants and oxidation, and the ability to produce a weld with less than 0.0005 in. of sink in the heat-affected zone.

NovaTech, Inc. 106
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Smith Equipment 107
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Active Solder Joining of Metals, Ceramics and Composites

Lead-free active solder alloys can be applied at low temperatures and without flux

BY RONALD W. SMITH

Active solder joining is an emerging technology based on alloys with active elements. These active solders are lead-free, join at low temperatures (<450°C), need no flux, join in air, and require no premetallization.

Active solders are metallic joining alloys that can join most inorganic materials in an economic, one-step joining process. Applications include joining thermal management devices because of the filler metals' high thermal conductivity; joining electronic packages that utilize new ceramics and composite materials; and a host of other joining applications where adhesives or conventional solders have not worked.

"Active" solder implies a reaction occurs between elements in the solder filler metal with compounds on surfaces being joined, such as the surfaces of titanium, stainless steel or ceramics. The surface oxides and nitrides of these materials typically disrupt wetting, thus fluxes or premetallizations are normally used to provide a layer of fresh metal. Active elemental additions to filler metals, such as In, Ti, Hf, and Zr, have been reported and shown to reduce surface compounds and form fresh metal surfaces (Refs. 1-4). Active solders have been previously reported (Ref. 1), but until recently (Refs. 5, 6), have had to be processed at brazing temperatures in protective atmospheres.

Active Solder Technology

Active solders have reactive elements (i.e., Ti, Hf, Zr, and Ta) added that enable the molten solder to directly wet and bond to oxides and other ceramic-like substrates or layers that exist on many corrosion-resistant metals, such as aluminum, titanium, and stainless steels. These active solder alloys do not flow; therefore, techniques to distribute them are integrated into processing methods. These techniques overcome the alloys' low capillarity, however, this characteristic prevents the molten filler metals from infiltrating into unmasked areas, foams, or other porous materials.

Currently, two alloy-based systems have been developed. One is based on Sn-Ag-Ti and the other on Zn-Ag-Al. Both alloy bases have rare earth elemental additions that catalyze wetting and surface reactions at normal soldering temperatures (below 450°C). Once active solders are molten, their active elements migrate to the joint interface and react with the joint surface compounds. Their rare earth element (lanthanides) additions are believed to lower the energy of reaction with oxides, nitrides, and other surface compounds during heating in air, allowing the active elements in the solders to interact with the joint metal surfaces and diffuse into the surface of the two opposing joint materials to form bonds.

Fig. 1 — Schematic illustration of active solder under mechanical agitation.
metallic, or atomic, bonds.

Since no chemical fluxes are used, the oxides that naturally form on molten solders must be mechanically disrupted. Activation implies the active elements in the solders are "released" to permit wetting and joining to the faying surfaces. The schematic in Fig. 1 illustrates how a molten active solder's surface oxide is disrupted by mechanical agitation, thus permitting the molten active solder to be spread.

Mechanical agitation has been accomplished by metal edge abrasion, brushing, vibration, or a combination of these methods. Figure 2 illustrates one method used to mechanically activate the molten alloys. Once an active solder layer is melted onto a heated surface, ultrasonic polishing/spreader tools and/or ultrasonic soldering irons can be used to mechanically vibrate the molten alloy layer and initiate wetting. Figure 2 shows how active solder can be activated (initiate wetting) through mechanical agitation via a pneumatic driven ultrasonic polishing tool. In this joining method, molten active solders are preapplied to both joint surfaces prior to joint assembly. More aggressive wetting is produced through ultrasonic-induced cavitation of molten active solder pools as they are spread across a surface for wetting, employing either ultrasonic soldering irons or another type of ultrasonic vibrating tool tip, as seen in Fig. 2.

Other means of spreading include wire brushes, metal edge spatulas, or abrasive porous metals. Assemblies are made after the active solder has been preapplied or preplaced in the joint. Assemblies must be agitated when the active solders are molten (assembled molten or reheated after assembly) after the joints are assembled. This can be done by relative spinning, oscillation, or vibration of the components. One specific joining technique incorporates the use of ultrasonic "plastic" welding equipment that combines a press with the ultrasonic horn that mechanically agitates the joint, normal to the surface (at ultrasonic frequencies), while maintaining a mean pressure that, after ultrasonic agitation for 1-2 seconds, holds the joint together during solidification. Figure 3 illustrates such equipment showing an ultrasonic horn in direct contact with the surface of a heated assembly (in this case an aluminum fin-copper base plate).

These equipment/process examples demonstrate mechanical agitation during active solder joining can be adapted to controllable production methods.

It is important to note active solders do not flow and must be preplaced and mechanically activated. This method may be limiting for some joint configurations, but in applications where the flow of excess solder needs to be controlled, such as in closed passages or in large joint clearances, active solders are advantageous. Supplemental solder filling with conventional solders (Sn- and Pb-based) can also be used since all conventional solders will wet, without flux, any preplaced molten active solder layer. Supplemental soldering enables natural joint fillets to form, whereas active solders do not flow to form natural fillets.

**Structures, Properties, and Comparisons**

Active solders join most materials, wetting (with mechanical agitation) metals, ceramics, and composites without flux, in air, with no requirement for special atmospheres or preplating.
These features make active solders capable of joining a wide range of materials. The microstructures of solder joints in Figs. 5-11 show active, Sn-based, solder filler metals to be multiphase with intermetallic (Sn-Ti) phases dispersed in a Sn-Ag eutectic structure. One can see the range of joints achieved between difficult-to-solder and dissimilar materials.

Aluminum, copper, and even more difficult materials with tenacious oxide surface compounds, such as titanium and stainless steel, have been joined. Examples of such joints are shown in Figs. 5 and 6. Note there is a metallurgical reaction between the active solder and the aluminum, whereas the titanium interface, although coherent and adhered, does not have discernable reaction. In these joints, tensile strengths of 10,000 lb/in.\(^2\) for aluminum and up to 6000 lb/in.\(^2\) for titanium were achieved. Similar joint structures have been produced between stainless steels, nickel alloys, and refractory metals.

In electronic and electrical applications, metals, ceramics, semiconductors, and metal matrix composites (MMCs) need to be joined. Research on active solders, such as the Sn-Ag-Ti alloy, showed a capability to join this range of electronic materials, using essentially the same active soldering process used in other metal joining.

Figures 7-10 depict active solder joints with various metals, ceramics, semiconductors, and composites. Figure 7 illustrates the structure of aluminum oxide joined to copper demonstrating a metallurgical (Cu-Sn phase) reaction at the Cu-solder interface and a coherent, adherent interface with the (dark) alumina substrate. Figure 8 is a high-magnification photomicrograph of the active solder joined to AlN (ceramic) showing the Sn-Ag-Ti active solder has formed an irregular, faceted interface, indicating some reactions have occurred, despite only a 250°C joining temperature. Microprobe analysis showed Ti and the lanthanides (rare earth) elements partitioned the AlN interface. Figure 9 illustrates an active solder joint structure joined to a silicon (Si) semiconductor with an application in electronics. Figure 10 shows the structure of an active solder (Sn-Ag-Ti) joined aluminum-silicon carbide (Al:SiC) composite. Note the active solder filler metal integrates itself into the composite structure, joining to both the aluminum matrix and the SiC particles.

Aluminum, copper, and even more difficult materials with tenacious oxide surface compounds, have been joined.
Active solders have been able to wet, join, and even metallurgically interact with various structural and conductor metals, including, but not limited to, aluminum, copper, titanium, stainless steel, nickel alloys, magnesium alloys, and refractory metals. Figure 11 shows the ultimate capacity of the active solders — joining graphitic foams to metals and MMCs. Figure 11 shows the layered structure of a graphite foam web with active solders penetrating, an excellent sign of wetting.

**General Active Solder Joint Characteristics**

Active solders in the Sn and Zn systems have been the subject of most research to date. These alloys, unlike conventional solders, have limited capillarity and require nonconventional solder joining methods, as previously described. The important aspect of their joining is that since chemical fluxes are not used and generally are incompatible, mechanical agitation of the solder must be used as it melts and completes the joint. However, once processed correctly, active solder filler metals yield strong joints, with a range of joint tensile strengths from 5,000–12,000 lb/in.², depending on the materials being joined. Active solder creates two classes of bonds, either metallic or atomic. With some metals (aluminum, copper, and nickel), metallurgical interactions occur through surface compounds. These metallic bonds occur without flux, but require mechanical agitation to interrupt the oxides on the molten active solder. The elements in the active solders (titanium, lanthanides, and gallium) are able to "flux" the oxides of aluminum, copper, and nickel. A subsequent reaction occurs between elements in the active solders (e.g., Sn, Ag, Ti) and the elements of the base materials to form an intermetallic bond. In the case of more stable metal surface compounds, or in ceramic and semiconductors, active solder elements do not "flux" the surface (e.g., TiO₂, Cr₂O₃). The same is true for stable oxide ceramic surfaces. In this class of materials, bonding is achieved as molten active solders are mechanically spread, and upon solidification, develop an attraction of "atomic atmospheres" between the active elements in the solder and the surface atoms in the materials being wetted and joined, thus developing strong adherence forces.

Joints with active solders are metallic and yield low electrical resistance and high thermal conductivity, 1.7 micro-ohm-meter and 48–90 W/m-K, respectively. Active solder joints have been shown to be hermetic when used for ceramic, metal, and metal-ceramic seals. Such joints have been accomplished without gold, silver, or nickel metallizing the ceramic surfaces. These metal-ceramic joints, although initially hermetic, can fail under...
Active solder joining is a lead-free process with no volatile organic compounds (VOC) or long cure times. Also, premetallizations are not required on many joints, providing an economic advantage over multistep solder joining methods. With these advantages, active joining is finding applications in electronics, heat exchangers, magnets, aluminum tooling, aluminum matrix composites, glass-metal seals, houses, sports equipment, and satellite components.

Three specific applications seemly well suited for active soldering are presented in more detail below.

### Applications

The advantages and capabilities of active solder technology enable it to be considered for a wide range of applications. Active solder alloys can join many materials, including all metals, most ceramics, metal matrix composites, glasses, carbon (graphite/diamond), and ceramic.

Active solders provide metallic, thermally and electrically conductive joints that are tough but have sufficient ductility to effectively join many dissimilar material combinations. Its low-temperature joining, compared to brazing (for example in joining aluminum alloys, metal-to-glass, or ceramic joints), offers advantages when joining mismatched materials with large coefficients of thermal expansion (CTE).

Active solder joining is a lead-free joining alternative and offers a flux-free process with no volatile organic compounds (VOC) or long cure times. Also, premetallizations are not required on many joints, providing an economic advantage over multistep solder joining methods. With these advantages, active joining is finding applications in electronics, heat exchangers, magnets, aluminum tooling, aluminum matrix composites, glass-metal seals, houses, sports equipment, and satellite components.

Three specific applications seemly well suited for active soldering are presented in more detail below.

### Thermal Management

Cooling of electronic components and enclosures require devices through which air or other fluids are forced. Convection and conduction passes heat from one media to another carrying heat out of the enclosures by the flow of cooling fluids. In open systems, fins, and more recently foams, have been used as the heat transfer surface. Currently, fin-based heat exchangers are the most common, however, as the need for more efficient heat transfer increases, more innovative heat exchanger designs and devices are emerging. Many times, the parts being cooled are attached to copper or aluminum base plates, but more recently composites such as AlSiC or AlGraphite are being substituted to control CTE mismatch.

Active solders are well suited to join all the conventional, and many of the new materials, being considered for advanced thermal management devices.

Active solders are used by NASA to bond stainless steel tubes to aluminum fabric to produce a large, flexible heat exchanger panel that can be mounted on the outside of space station modules and interiors. The nature of active solder not to flow, minimized the flow of the solder though the aluminum fabric. Figure 12 illustrates a more "down-to-earth" active solder joining application used to join dissimilar metal (Al-Cu) thermal heat sinks used to cool electronic components. Such fin-plate heat exchangers have found use in cooling of high-speed processor chips running at speeds over 1 GHz.

In other applications, NASA was looking to take advantage of carbon fiber/carbon (C:C) matrix materials for heat transfer components in avionics, space station, and satellite components. However, the joining of C:C materials has presented a major challenge. Wetting the carbon with active brazes while not melting the base metals, typically aluminum, has prevented components from being fabricated. Additionally, C:C materials with high inherent porosity have easily wicked (pulled) any conventional braze materials with high capillarity away from the joint. Active solder alloys have been found to be effective in joining C:C to aluminum and a variety of other metals and ceramics.

Active solder alloys, through various processing methods, can wet and bond carbon, metals, and ceramic using no flux, which could contaminate the surface pores in C:C and graphite foams. It also has low capillarity, which keeps the filler metal at the joint and reduces wicking into the porous C:C materials. The lower active solder joining temperatures 250–450°C (480–840°F) were also found to better accommodate the thermal expansion mismatch that occurs between low-expansion C:C and graphite with high-expansion metals such as aluminum and copper. Compared to brazing, active solder joining is conducted in air, eliminating vacuum processing, that can impose cost and size limitations. These attributes and the ability to join a wide range of thermally conductive materials, including conductive, low-thermal expansion composites, increases the potential for active solder joining in the field of thermal management.

These active solders are also an enabling technology for the fabrication of an emerging set of thermal management designs that utilize MMCs, graphite and metallic foams, and conductive ceramics. The fabrication of a new radiator core design has been made possible by active solder joining. In this design, graphite foam fins have been active solder joined to aluminum cross flow tubes. The increased thermal heat transfer of such radiator cores promises to significantly reduce the size and weight of automotive heat exchangers. Some of the first applications of such technology will be in high performance race cars.

Figure 13 illustrates the bonding of aluminum foams to copper-based plates. The active solders were able to wet and join the porous aluminum to the copper-based plates. The use of increased surface area metallic foams for improved heat exchangers is growing. Active solders enable the fabrication of radiators without using metallization and corrosive fluxes that might not be effectively removed from such foam core heat exchangers.

The fabrication of a new radiator core design has been made possible by active solder joining.
Electronic Packaging

Electronic packages contain, support and/or shield electronic devices and require material combinations that manage thermal and electrical conductivity while having low thermal expansion. Applications include satellite electronics, power devices, radiation shields, avionics, computers, microwave/radar, low CTE substrates, and power interconnections.

Typically, such packages use metallic materials for good thermal conductivity, but then need to have electrically insulating substrates joined to them. In the past, Kovar®, Invar®, herylhum, and aluminum alloys were used to join alumina and/or zirconia ceramics using gold metallization. Increasingly, electronic devices are using AlN (aluminum nitride), Be/BeO, diamond, and A355C composites for increased thermal conductivity, lightweight and excellent thermal stability. However, joining these materials present challenges since fluxes, normally used to strip oxides, can contaminate devices. Active solders solve some of the problems associated with brazing and conventional soldering of such material combinations.

Active solder's capability to bond many materials used in electronics make it ideally suited for package assemblies, which include multiple soldering steps. Figure 14 illustrates an integrated chip package that requires bonding of the semiconductor chip to a thermally conductive/insulating substrate that must be bonded to a heat spreading device with a low CTE metallic base, then to a thermal heat transfer component, such as graphite foam. In another application a graphite foam fin plate is active soldered directly to an alumina base plate. Such an integrated design eliminates thermal interfaces and processing steps.

Consumer Applications

Applications in the consumer market range from cooking utensils to sports equipment that involve the joining of aluminum, stainless steel, copper, and titanium. There is also an increased use of materials such as carbides, diamond, and MMCs. Pots and pans are fabricated from aluminum or copper due to their high thermal conductivity. Aluminum and/or copper joining to stainless steel has been done by brazing, but it is difficult because of their differing oxide films, which must be removed by chemical fluxes. However, zinc-based active solders with joining temperatures above 400°C have the potential to meet such needs in housewares. Golf and tennis equipment is increasingly using titanium that could benefit from soldering fabrication. Additionally, composite/dissimilar material joints are being required for new golf club designs, which incorporate carbides and even diamonds for club faces. High-density refractory metals such as tungsten have also been added to modify swing stability. Active solders have the potential, and are being considered, for such joining needs.

Future Developments

Active solders are an emerging class of joining filler metals and combined processes for use in low-temperature (lower than brazing) joining of dissimilar material combinations. The needs of hierarchical joining are driving interests in a wider range of active solder compositions that offer a broader range of soldering temperatures. Additionally, the emergence of opto-electrical devices, aimed at increasing the bandwidth in telecommunication, is increasing the need for glass/ceramic/metal joining, a niche that active solders could fill. Provided filler metal compositions and processing methods suitable for microjoining and high production rates become available. Developments in active solder joining are beginning to focus on these needs.

Acknowledgements

Active solders have been the exclusive development of Materials Resources International and Euromat, GmbH, who have introduced S-Bond® alloys and joining processes. The author would like to acknowledge Prof. Erich Lugscheider, Materials Science Institute, RWTH, for the developments of active solders and their initial compositions; Dr. Ino Rass and Frank Hillen, Euromat, GmbH, Heinsberg, Germany, for their manuscript contributions and their advancements in active solder technology; and Dr. Paul Vianco, Sandia National Laboratories, Albuquerque, N.Mex., for assistance in determining the suitability of active solders for application in electronics, under CRDA No. SC99/01552. The author would also like to recognize the Small Business Innovative Research (SBIR) Program for active solder technology development support under contracts NASS-97011, DASG60-00-0056, and N00167-00-051.

References

Variable Polarity Improves Weld Brazing of Galvanized Sheet

Experiments showed variable polarity gas metal arc welding reduced zinc coating loss when welding galvanized steel

BY ANDY JOSEPH, CHRIS WEBB, MIKE HARAMIA, and DAVID YAPP

Requirements for improved durability in domestic consumer goods have invariably led to the application of more corrosion-resistant materials. Sheet steel is the basic material used by many industries, including automotive, ventilation and heating, construction, appliances, and furniture. Zinc-coated or galvanized sheet steels are the obvious corrosion-resistant material choice for these industries. Steel sheet can be coated with zinc (galvanized) through either electrolytic or hot-dip processes, with coating weight between 0.1 and 1.2 oz/ft² (approximately 0.001-0.020 in. thick) depending on process conditions.

Joining galvanized materials is difficult using most arc welding techniques. Many of the problems associated with zinc-coated steels are due to the low melting (420°C) and evaporation (906°C) temperatures of zinc compared to the melting temperature (1538°C) of steel. Zinc vapors and oxides cause porosity, incomplete fusion, cracking, spatter, and erratic arc behavior. Process optimization is the best method for preventing welding-related discontinuities and defects.

Lower-melting-temperature welding wires offer one process solution when welding galvanized sheet materials. The use of a copper-based welding wire (i.e., silicon bronze) and a standard DC constant voltage welding power source can be used with gas metal arc welding (GMAW) to lower the temperature of the welding process while effectively joining coated steels. Gas metal arc brazing filler materials have a low melting temperature; ideally no melting of the base metal occurs. Previous research has shown gas metal arc brazing can overcome the problems coated materials pose, while maintaining sufficient joint strength (Refs. 1-3).

Pulsed gas metal arc welding (GMAW-P) has been used to further reduce heat input and improve the process stability of GMA brazing. Current pulsing permits spray transfer welding at mean currents below the globular-to-spray transition current. Pulse parameters are critical to maintaining a stable arc and a spatter-free process. Robust, spatter-free GMAW-P parameters have been developed that have good aesthetic properties and sufficient joint strength. Typically, however, a significant amount of zinc is burned off the backside of most welds. This zinc burnoff is a result of excess heat input that is still too high despite the lower melting temperature of the welding wire and use of GMAW-P.

An investigation into the use of variable polarity GMAW (VP-GMAW) with standard weld brazing filler metals was conducted to determine the potential of this process for further reductions in weld heat input. VP-GMAW uses a current waveform similar to AC current in that it alternates between positive and negative polarities. It is different from AC in that the balance of the two polarities can be varied, hence the term "variable polarity" — Fig. 1. Variable polarity provides more control of the heat balance in the welding arc by taking advantage of the different arc characteristics obtained with each of the two polarities, direct current electrode positive (DCEP) and direct current electrode negative (DCEN). Each polarity has a different heat balance. Variable polarity allows this heat balance to be controlled over a range, thus allowing more control of the penetration characteristics and heat input of the process.
Experimental Procedure

This investigation compared the potential of GMAW-P to VP-GMAW. Lap joint tests were made using a stationary, straight machine welding gun and a linear table that moved the base material at a constant speed — Fig. 2. This setup allows the high-speed video equipment to be stationary. The lap joints were made using 1.2-mm galvanized sheet with a 1.2-mm root opening and were welded in the horizontal (2F) position. Shielding gas was 100% argon at 40 l/h. All hydrocarbons were removed from the material with acetone prior to welding.

The filler materials were 0.045-in. (1.2-mm) ER CuSi-A (typically called silicon bronze) and 0.045-in. (1.2-mm) ER CuAl-A2 (typically called aluminum bronze) wires. These are standard wires commonly used in industry. U-groove drive rolls and Teflon™ wire guides were used to prevent wire feed problems such as bird-nesting and unstable arcing.

GMAW-P uses a high-current pulse for a finite period of time followed by a low-current background period. The low-current-level background period primarily maintains the arc, while the high-current-level pulse forms and transfers one or more small drops from the electrode to the weld pool. This pulsing waveform of high and low currents transfers small drops at a mean current level that would normally produce the less desirable globular transfer.

Robust GMAW-P parameters were developed for ER CuSi-A and ER CuAl-A2 electrodes using a Lincoln Powerwave 455 with Waveform Designer Pro software — Fig. 3. The power supply and software allowed manipulation of the pulses-current parameters during welding. The main parameters of interest were peak and background current, peak time, and frequency. The software was used to adjust pulse parameters until a consistent one drop per pulse was observed on high-speed video, and when the resultant weld exhibited little to no spatter.

Pulse parameters were developed at wire-feed speeds of 106, 167, 234, 296, and 362 in./min. Travel speeds were such that an equal weld size (constant wire-feed speed/travel-speed ratio) was produced throughout the range of testing. A wire-feed speed to travel-speed ratio of 8 was used, and corresponded to travel speeds of 13, 21, 29, 37, and 45 in./min.

High-speed video was used to observe the metal transfer during the test welds. The camera was set up to allow viewing of both the weld pool and the droplet detachment. A 940 ± 5-nm optical filter was used to allow viewing of the metal transfer without using laser backlighting. The sampling rate was 4500 Hz, which is high enough to see all the details of the weld transfer.

An Analysator Hannover (AH) data acquisition system was used to determine the electrical waveform characteristics — Fig. 4. Voltage was measured between the contact tip and the work. These points were considered as close to the arc as possible and best represent the arc voltage. Current was measured using a Hall effect current sensor, and the wire-feed speed of the electrode was measured using a tachometer. The AH data acquisition system gave waveforms of voltage and current vs. time, as well as statistical histograms of voltage, current, and short-circuiting time. The histogram was essentially a fingerprint of the weld and quantified repeatability. To determine the repeatability of weld parameters, identical welds were made and the histograms superimposed on top of each other. Any variances from histogram to histogram showed instability, which allowed for fine-tuning of the pulsing parameters.

Spatter levels were directly related to the short-circuiting time, as well as the percentage of time the voltage was at zero. Figure 3 shows a weld that had low amounts of short circuiting and spatter since only 0.15% of the sample time was at a voltage of zero. Less than 0.0015% would mean close to zero spatter.

Variable Polarity GMAW Parameter Development

With the exception of the power supply, identical conditions were used to develop VP-GMAW welding parameters. A Kobelco AL-350 VP-GMAW power supply was used. It is a constant current inverter-type machine with a preprogrammed electrode positive/electrode negative (EP/EN) ratio control. The Kobelco AL350 was developed for aluminum and provided a pulsed, globular-free, flight transfer mode. It automatically controlled the relationship between the pulse parameters, which included the EN peak current and time, the EP peak current and time, the EP background current, and frequency, depending on the wire-feed speed and EN setting on the control pendant. The EN setting automatically changed the pulse-parameter relationships for each wire-feed speed, providing a range of arc power. All the pulsing parameters were controlled synergically via wire-feed speed (i.e., one knob controls all pulsing parameters), so the individual pulsing parameters could not be changed.
Testing

Tensile tests were taken from the weld tests that represented the maximum productivity for each process combination. The tensile tests were made according to ASTM E8. Three specimens were taken transverse to the centerline of the weld. Cross sections of each weld were mounted and polished to ensure proper bead shape and wetting characteristics. Visual inspection of the weld surface and spatter levels were also made.

Experiment Results

GMAW-P Metal Transfer

The GMAW-P welding parameters were adjusted to make “one drop per pulse” transfer — Fig. 5A. Each drop was approximately the size of the wire or slightly larger, and detached just after the peak time at the peak current level. The droplet detached cleanly with no spatter. The most common problem during pulsed-parameter optimization was that, occasionally more than one droplet would detach — Fig. 5B. Although most of the time this did not pose a problem in the weld, sometimes the “extra” droplet would miss the weld pool and end up as a large spatter ball on the base material. Pulse parameters were adjusted to eliminate this problem.

Satisfactory welds were also produced using the ER CuSi-A braze wire in a “two pulses per drop” mode. The first pulse (following a drop detachment) would grow a molten droplet on the end of the wire, and the second pulse detached the molten droplet and transferred it to the weld pool. According to most
Fig. 6 — A — Tensile specimens from pulsed GMA braze welds using ER CuAl-A2 with failure in the base metal; B — tensile specimens from pulsed GMA braze welds using ER CuSi-A with failure in the base metal; C — tensile specimens from variable polarity GMA braze welds using ER CuSi-A with failure in the base metal.

GMAW-P experts, one drop per pulse is considered optimal; however, the reasons are often debated. This research found a two-pulses-per-drop mode of transfer was acceptable at low wire-feed speeds (up to approximately 250 in./min). At higher wire-feed speeds, this mode of transfer was unstable, and therefore not used.

Variable Polarity GMAW Metal Transfer

The VP-GMAW testing began using the ER CuSi-A wire. The metal droplet formation process started with the EN pulse and was completed during the EP peak pulse. It was observed through high-speed video that the metal drops were formed during the EN-polarity pulse. Here, the drops grew rapidly as the arc climbed the tip of the electrode. The drops were typically 1.5 to 2 times the wire diameter, or larger. The arc then switched polarity, becoming dim as the current passed through zero. The EP background current was used to maintain the arc and drop size created during the EN pulse. The drop quickly responded to the high-current EP pulse, where it gained some additional size before being transferred to the weld pool.

Since the individual pulsing parameters on the AL-350 power supply could not be adjusted, spatter could not be completely eliminated. This particular power supply was specifically designed for both hard and soft aluminum wires, but not for braze wire. Despite the spatter, the integrity of the joint was still found to be satisfactory for the ER CuSi-A wire. The AL-350 was unable to make a satisfactory weld using the ER-CuAl-A2 braze wire. Refinement of the VP-GMAW parameters is possible with a power supply that has parameter manipulation available and should make spatter-free welds using both wires possible.

Material Properties

Tensile specimens were tested for each of the wire/power supply combinations. All specimens tested failed in the base material. Figure 6 shows each tensile specimen as it failed. The lap joint tensile specimen actually puts the specimen in both a tensile and a shear load, as the axis of tension is not initially straight. The specimens tend to straighten first, then load in pure tension. Since all the specimens failed in the base metal, nothing can be said about the ductility of the weld metal; however, given the ductile nature of the copper-based weld metal and the fact the weld goes through shear and tensile loading, it is assumed the weld properties were satisfactory.

Weld Quality

Spatter-free GMAW-P welds (Fig. 7) were made throughout the range of wire-feed speeds tested. The GMAW-P process minimized distortion; however, a heavy, black soot was produced by excessive burning of the zinc in the heat-affected zone and on the weld back side. The black soot indicated a loss of zinc and, therefore, a lack of corrosion protection for the HAZ and the back side of the weld.

The VP-GMAW process reduced the heat input, which resulted in significantly less zinc burnoff on the back side of the weld — Fig. 8. The back side of the GMAW-P weld had more soot than did the back side of the VP-GMA weld. The darkest area of the GMAW-P specimen indicated where the weld bead was located, and shows a complete loss of all zinc. The weld made using VP-GMAW showed significantly less zinc burnoff, with almost no dark soot.
Another indication of weld quality was found in the macro photographs of the weld cross sections. Figure 9A shows a cross section of the pulsed gas metal arc weld at 236 in./min wire-feed speed. Significant melting of both the top plate and the bottom plate occurred, resulting in a high base metal dilution of the weld. Figure 9B shows a cross section of the VP-GMA weld at the same speed. There was little melting of the top plate, and no melting of the bottom plate, resulting in a low base metal dilution. The low levels of base metal dilution produced a low level of contamination in the weld. The smaller heat-affected zone of the VP-GMA weld compared to the pulsed GMA weld also verifies that the heat input is lower in the pulsed GMA weld.

**Conclusions**

The following conclusions were made upon completion of this project:

- The GMAW-P and variable polarity GMAW processes were used to produce sound welds with minimal distortion for two standardized braze wires at travel speeds ranging from 12 to 47.6 in./min (0.3–1.2 m/min).
- The variable polarity GMAW process, when compared to GMAW-P, produced a significant reduction in zinc coating loss.
- Mechanical testing and metallurgical cross sections confirmed that joint integrity, wetting, and bridging of root openings was acceptable for both the GMAW-P and variable polarity GMAW processes.

**References**

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Determining the Strength of Aluminum Braze Joints

Various alloy material forms and brazing methods were employed on samples to test tensile strength.

BY CHET WESOLEK

The physical properties of aluminum braze joints are often assumed to be the same as the base metal. The research discussed here was undertaken to determine the actual physical properties of such joints.

Setup and Procedure

Tests were performed using a 6061 3/4-in.-thick, 750-in.-wide x 6-in.-long aluminum plate. The samples were cleaned, alloyed, brazed, then machined into tensile bars. An approximate 1/4-in. joint clearance was maintained for all 300-plus samples — Fig. 1.

The most common and available braze alloys, BAISi-4 and BAISi-3, were tested. The first alloy was comprised of 11-13% silicon, 0.8% iron, 0.3% copper, 0.15% manganese, 0.1% magnesium, and 0.2% zinc balance aluminum. The second alloy was comprised of 9.3-10.7% silicon, 0.8% iron, 3.3-4.7% copper, 0.15% manganese, 0.15% magnesium, and 0.2% zinc balance aluminum.

The alloy material form and the brazing method play a major role in aluminum brazing and its results, therefore, the following three forms were tested: foil, wire, and paste. The brazing.

CHET WESOLEK (mmp@acd.net) is President of Modern Metal Processing, Inc., Williamston, Mich.
methods used were dip, torch, induction, vacuum, and vacuum partial pressure.

Test samples were prepared by cleaning in acetone or acid etching. The bars were then handled with white gloves. Next, samples were overlapped, then wired together. The foil was placed between the bars and the wire wrapped on the outside.

**Results**

The test results are shown by method and alloy form.

Figure 1 shows dip-brazed results for foil, wire, and paste. Dip brazing lent itself to all forms and yielded good results after heat treatment. Tensile properties of 41,000 to 14,000 ksi were recorded.

Figure 2 shows torch-brazed results for two-alloy form foil and wire. Both forms showed good results in the non-heat-treated and heat-treated conditions. Tensile results of 52,000 to 22,000 ksi for heat treated and 46,900 and 26,700 ksi for nonheat treated were recorded for the alloy.

Figure 3 shows induction-brazed results. The heat-treated foil and 0.060-in.-diameter wire exhibited good strength results of 37,000 to 22,000 ksi, but there were only 6 acceptable samples; 18 of the 60 had voids. The rectangular configuration was the probable cause of the results.

Fig. 3 — Induction-brazed results for foil and wire.

Fig. 4 — Vacuum furnace brazed results using magnesium chips.

Fig. 5 — Vacuum furnace partial pressure brazed results of all four alloy forms.
Figure 4 shows vacuum furnace brazing using magnesium chips (due to the small amount of magnesium in the brace alloy) that yielded results only in foil form, 21,000 to 19,000 ksi. There was no fillet present and BAISi-4 was the only alloy brazed.

Figure 5 shows vacuum furnace partial pressure results from 32,000 to 23,000 ksi in all four alloy forms. All of the more than 60 samples brazed well and were usable from this process.

Figure 6 shows BAISi-3 brazed with the following three methods: torch, induction, and vacuum furnace partial pressure. The strongest results, 50,000 ksi, came from the torch brazing process. The 0.010-in. foil condition was all that was available during the test period.

Conclusions

The torch- and induction-brazed samples showed the highest tensile results, but also the greatest amount of voids and nonbrazed bars. Dip and vacuum partial pressure brazing were lower in strength, but more consistent in adaptability and in producing good braze joints. Pure vacuum brazing was limited to foil with moderate strength results. Dip and vacuum partial pressure also lent themselves to the largest selection of different part configurations. Torch and induction brazing are best suited for round parts.

The highest strength results were from torch- and induction-brazed samples. But those samples also had the largest number of bad brazes.

Dip and vacuum partial pressure yielded lower strength results, but both methods were the most adaptable and had the greatest number of good braze joints.

Foil is the universal alloy form for all brazing methods, especially 0.010 in. Cleanliness and joint fitup are major concerns of aluminum brazing.
In response to this industry demand, AWS has established an accreditation program for companies that use welding as a joining process. The requirements for this program are set forth in an American National Standard, AWS B5.17, Specification for the Qualification of Welding Fabricators.

An appropriate quality system is the foundation of delivering a quality product or service. When designed for the welding fabricator's unique products and suitably committed to paper and practice, the daily manufacturing operations of the fabricator are more consistent and traceable when problems arise. It is an increasing trend that customers want to see that a welding quality assurance system is documented and demonstrated. They are concerned that the fabricator and the fabricator's subcontractors are capable of producing products that meet specifications.

This specification defines the requirement for a company's compliance with welding related functions and assures, through third party assessment, that the Welding Fabricator has the personnel, organization, experience, procedures, knowledge, equipment, capability, and commitment to conduct proper weldments.

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Display knowledge, reduce cost, drive business
Automated metalworking systems maximize product consistency, quality, efficiency and, hence, productivity.

Carpenter Technology, Corp. The Reading, Pa., specialty metals producer has invested more than $42 million in new equipment, which includes a 4500-ton hydraulic forging press that enables the company to focus on production of aerospace components, including rotating quality material for engine discs and shafts. The press, and associated equipment, can also be used to make alloys for the power generation market, stainless steels and other alloys for oil exploration.

“We have talked with forgers and aerospace engine manufacturers, among others, to ascertain what they need now and beyond in critical alloys. And we have established fulfillment of those needs as our goal,” said Tom Zogas, manager of the company's Forge Finish Technical Services.

The forging press was designed to obtain a consistent product with minimal variation from one forged section to the next of similar size, configuration and composition. It is an open-die, two-column pulldown press with dual integrated manipulators. Hydraulics and actuation are below ground level.

The design makes the press more rigid, stable and reliable, and allows for better size control during forging. The system is also safer since oil, moving machinery and pressure seals are below ground. The press’s high level of automation enables tighter control over the microstructure of forged shapes. This is key to variation reduction and can substantially improve production.

Support equipment has also been installed to enhance the capabilities of the press. Ten furnaces are close to the press to help reduce handling time. Four of the furnaces have a reducing atmosphere capability to permit the high-quality levels necessary for certain nickel-based alloys.

An automated stiff-arm crane, capable of lifting 18 tons and traveling up to 800 ft/min, allows fast, consistent transfer of heat sealed stock from the furnace to the press. A large mobile charger, also with an 18-ton lift capacity, has a 46-in. jaw opening to hold large shapes. A control room chair is used to operate all functions of the press.

When in full operation, the press can make large bar and billet for customers, billet for use on the company’s cold rolling mills and wide slab for the production of strip at the company. The press can forge finish pieces, such as oil field drill collars, up to 40 ft long.

Atlas Technologies, Inc. The Fenton, Mich., company produces dual-station die carts that deliver speed and consistency to die-handling operations. The carts enable dies to be changed quickly, cost-effectively reducing batch size and minimizing work in process. Dies can also be pulled for quick quality checks without interrupting production schedules. Dual-station die carts can add hours of stamping productivity per day without adding presses, and controlled die handling can reduce die damage.

The die carts are designed to simultaneously handle and manipulate two dies. Dies can be placed on a cart either lengthwise in a front/rear combination or side by side on the cart. Cart designs are sized to the application, which includes single presses or multiple independent presses or sister tandem lines.

Carts are self-powered and can be automatically controlled or operated with the use of a hand-held pendant. Moving on floor rails at speeds up to 30 ft/min, the carts transport dies of nearly any size to and from presses and die racks.

Precision ball screw-driven, push/pull modules engage die subplates for die
movement. The modules extract outgoing dies and accurately place incoming dies into the press or on or off the cart. Two or more dies can be simultaneously indexed.

Incoming dies can be stationed on die racks next to the cart or dies can be placed directly onto the cart by overhead crane.

For single-press applications, the dual-station die cart can be loaded with incoming die and moved to the press where it then pulls the outgoing die onto the empty station using the push/pull module. It then aligns an incoming die and moves it into the press.

For two-press applications, a dual station die cart with dies placed side by side can be used. An empty cart moves between the presses and extracts both outgoing dies. It then indexes the dies to storage racks. Two incoming dies are loaded on the cart and moved into the presses.

Die carts can be designed for fully automatic, one-button applications allowing for a single operation function. One button executes the entire die change sequence, including indexing of part handling automation.

The company also produces a sheet metal blank destacker for the stamping industry. For continuous flow of blanks and faster stamping, this automated destacking system makes a stack of sheet metal blanks immediately ready for destacking once an existing stack is depleted. A conveyor system stacks blanks to be loaded in the destack station from two opposite sides. Downtime is eliminated as well as the pause between stacks (for stack positioning). The pick-up of the last sheet of the depleted stack is followed by the pick-up of the first sheet of the new stack without interruption. The blank destacker will feed a AA-size transfer press.

Blank stacks are placed on the conveyor on either side of the destack station by fork truck or overhead crane. When blanks are needed, the stacks are conveyed to the destack station and raised into position by a hydraulic, straight-acting lift table. As the number of blanks are reduced, support forks move into place and support the remaining blanks. The lift table lowers to conveyor height and the conveyor queues the next full stack beneath the destack head. When the support forks run out of blanks, the forks retract and the vacuum cups immediately begin destacking from the full stack. Vacuum cups are programmable through the controller to work in any sequence to match blank size. The cups are also accessible from the balcony level where the destack system's electrical control panels are located to adjust their position relative to the blank.

During operation, blanks are separated by an array of fanner magnets, picked up by overhead vacuum cups, and raised to a magnetic belt conveyor. Each blank is then checked for single-blank status. Blanks stack together can be conveyed backwards to a reject tray. The blanks are then conveyed through a washer/polisher and onto a position/load station. The position/load station is programmed for varying blank sizes and double unattached blanks. Quality and surface finish consistency of the sheet metal blanks is increased because automation reduces or eliminates manual handling.

The company designed the software for the destack unit which is interlocked with the press controls. The software allows all functions—position/load station, vacuum cups, part size, cycle rate, etc.—on the destacker to be independently programmed. It also includes system diagnostics and a teach mode. The destack system, however, also features its own independent set of controls.
American Welding Society

AWS Fellows Nominations Invited

Friends and Colleagues:

We’re into the tenth year of the program, and 92 individuals have now entered into the fraternity of Fellows. Again, I encourage you to submit nomination packages for those individuals whom you feel have a history of accomplishments and contributions to our profession consistent with the standards set by the existing Fellows. In particular, I would make a special request that you look to the most senior members of your Section or District in considering members for nomination. In many cases, the colleagues and peers of these individuals who are the most familiar with their contributions, and who would normally nominate the candidate, are no longer with us. I want to be sure that we take the extra effort required to make sure that those truly worthy are not overlooked because no obvious individual was available to start the nomination process.

For specifics on the nomination requirements, please contact Wendy Sue Reeve, at AWS headquarters in Miami, or simply follow the instructions on the Fellows nomination form in this issue of the Welding Journal. Please remember, we all benefit in the honoring of those who have made major contributions to our chosen profession and livelihood. The deadline for submission is January 14, 2002. The Committee looks forward to receiving numerous Fellow nominations for 2003 consideration.

Sincerely,

John W. Moeller
Chairman, AWS Fellows Selection Committee

IMPORTANT NOTICE: Please note that the submission deadline of January 14, 2002, is two weeks earlier than in previous notices. The change was necessary because of newly announced dates for the 2002 AWS Convention.
Nomination of AWS Fellows

I. DEFINITION AND HISTORY
The American Welding Society, in 1990, established the honor of Fellow of the Society to recognize members for distinguished contributions to the field of welding science and technology, and for promoting and sustaining the professional stature of the field. Election as a Fellow of the Society is based on the reputation and outstanding accomplishments of the individual. Such accomplishments will have advanced the science, technology and application of welding in specific areas such as research and development, education, manufacturing, design and other areas the Society may determine, as evidenced by:

* Sustained service and performance in the advancement of welding science and technology
* Publication of papers, articles and books which enhance knowledge of welding
* Innovative development of welding technology

II. RULES
A. Candidates shall have 10 years of membership in AWS
B. Candidates shall be nominated by any five members of the Society
C. Nominations shall be submitted on the official form available from AWS Headquarters
D. Nominations must be submitted to AWS Headquarters no later than February 1 of the year prior to that in which the award is to be presented
E. Nominations shall remain valid for three years
F. All information on nominees will be held in strict confidence
G. No more than two posthumous Fellows may be elected each year

III. NUMBER OF FELLOWS TO BE ELECTED
Maximum of 10 Fellows selected, as determined by the selection committee

Return completed Fellow nomination package to:

Wendy S. Reeve
American Welding Society
550 N.W. LeJeune Road
Miami, FL 33126

Telephone: 800-443-9353, extension 215

SUBMISSION DEADLINE: February 1, 2002
CLASS OF 2003
FELLOW NOMINATION FORM

DATE_ NAME OF CANDIDATE_
AWS MEMBER NO._ YEARS OF AWS MEMBERSHIP_

HOME ADDRESS_
CITY_ STATE_ ZIP CODE_ PHONE_

PRESENT COMPANY/INSTITUTION AFFILIATION_

TITLE/POSITION_

BUSINESS ADDRESS_
CITY_ STATE_ ZIP CODE_ PHONE_

ACADEMIC BACKGROUND, AS APPLICABLE:
INSTITUTION_

MAJOR & MINOR_

DEGREES OR CERTIFICATES/YEAR_

LICENSED PROFESSIONAL ENGINEER: YES_ NO_ STATE_

SIGNIFICANT WORK EXPERIENCE:
COMPANY/CITY/STATE_

POSITION_ YEARS_

COMPANY/CITY/STATE_

POSITION_ YEARS_

SUMMARIZE MAJOR CONTRIBUTIONS IN THESE POSITIONS:

SUGGESTED CITATION (50 TO 100 WORDS, USE SEPARATE SHEET) INDICATING WHY THE NOMINEE SHOULD BE SELECTED AS AN AWS FELLOW. IF NOMINEE IS SELECTED, THIS STATEMENT MAY BE INCORPORATED WITHIN THE CITATION CERTIFICATE.

**MOST IMPORTANT**
The Fellows Committee selection criteria are strongly based on and extracted from the categories identified below. All information and support material provided by the candidate's Fellow Proposer, Nominating Members and peers is considered. Provide as much detailed information as possible regarding:
The candidate's accomplishments under areas identified below (use separate sheet for each category):
A. Research & Development
B. Education
C. Manufacturing
D. Design and Inventions
E. Other (e.g., Standards Development, National and International Liaison)
Evidence of accomplishment should include sustained service and performance in the promotion of joining technology; publication of papers, articles and books; innovative development of joining technology; service to AWS and other technical societies; and list and description of patents, awards and honors.

SUBMITTED BY: PROPOSER_ AWS Member No._
The Proposer will serve as the contact if the Selection Committee requires further information. Signatures on this nominating form, or supporting letters from each nominator, are required from four AWS members in addition to the Proposer. Signatures may be acquired by photocopying the original and transmitting to each nominating member. Once the signatures are secured, the total package should be submitted.

NOMINATING MEMBER:_ AWS Member No._
NOMINATING MEMBER:_ AWS Member No._
NOMINATING MEMBER:_ AWS Member No._

SUBMISSION DEADLINE FEBRUARY 1, 2002
RESERVE YOUR SPACE TODAY!

Stamping, Forming, Joining, Welding, Fabrication, Cutting, Robotics, Lasers, Pipe, Services and Supplies

WELDING SHOW 2002
March 4-7, 2002
Chicago's McCormick Place South

To learn more about how MAX INTERNATIONAL can help your company succeed, and to reserve exhibit space return this card or call AWS WELDING SHOW 1-800-443-9353 ext. 231

combining technology and expertise at
The Navy Joining Center Partners with the Best Manufacturing Practices Center of Excellence

The Navy Joining Center has partnered with the Best Manufacturing Practices Center of Excellence (BMP) and will serve as one of its ten regional extensions and function as a satellite center.

The Office of Naval Research sponsors the Best Manufacturing Practices (BMP) program. The program identifies and shares best manufacturing and business practices being used throughout industry, government, and academia. The BMP, teamed with the U.S. Department of Commerce and the University of Maryland at College Park, form the

Navy's Best Manufacturing Practices Center of Excellence. BMP's mission is to provide the "Best Practices," management tools and technical guidelines that will enable defense and commercial customers to operate at a higher level of competitiveness.

The BMP was created with the goal to overcome wide and costly variances in the quality of goods and services being received by the Navy from contractors throughout the United States. As the Navy went to its suppliers, it found many manufacturing process problems encountered by one contractor were solved by another. The Navy's simple solution to quality, cost, and reliability problems was to have contractors collectively share solutions to problems. Though easily said, this was difficult to accomplish in the world of highly competitive defense contractors.

By fostering a philosophy of sharing knowledge, insight, and experience, a unique data gathering, validation, and application initiative was created to get the Navy's contractors to exchange their process improvement techniques and problem-solving methods. The BMP program is based on participating companies voluntarily sharing information through a unique on-site survey process (not audits). Teams of impartial experts from government, industry, and academia document best practices worthy of sharing. A "Best Practice" is defined as an established documented process, technique, or innovative use of equipment or resources with a proven record of success in providing significant improvement in cost, schedule, quality, performance, safety, environment, or other measurable factors that affect the health of a company.

Today, more than 125 surveys have been conducted, with more than 5000 practices documented, how-to guidelines published, and an Internet site established making BMP's resources easily accessible. The BMP-validated practices encompass a wide range of topics from management, training, procurement, and production, as well as new technology deployment. Of the more than 5000 documented practices, a breakout of topics is shown in the graph below.

BMP is meeting its initial goal and has spread benefits of its goal to a wide range of customers beyond the Navy acquisition community. This has resulted in BMP being a credible "honest broker" for technology transfer. The BMP Center of Excellence and its ten satellite centers around the country serve the entire Department of Defense and all American commercial and government industry.

As a satellite center, The NJC serves the Ohio, Indiana, Michigan, West Virginia, and New York region. For more information on BMP call (800) 789-4BMP, visit its Web site at www.bmp-coe.org, or contact Larry Brown at NJC, (614) 688-5050, or by e-mail: larry_brown@ewi.org. BMP will be at the DMC 2001 conference in Las Vegas, Nev., November 26-29, 2001, booth #507.

NJC to Host Materials Joining Technology Review

The Navy Joining Center (NJC) is hosting a Materials Joining Technology Review on October 4 in Columbus, Ohio. The review will address materials joining technologies being developed by the NJC and manufacturing requirements to support continuous improvement initiatives for enhanced performance and reduced life cycle costs of Navy ships and aircraft.

Speakers from the Navy, industry, and NJC will address future needs for Navy acquisition programs, give perspectives on near term industrial challenges, and highlight the status of NJC projects with demonstrations of key emerging technologies. Participants from the Navy and industry are invited to attend this review. Contact Connie Kotula, NJC, at (614) 688-5156 or e-mail: connie_kotula@ewi.org for more information and a detailed agenda.
Conferences and Exhibitions


Note: A diamond (*) denotes an AWS-sponsored event.
Metal Forming and Fabricating Show and Conference. October 29–31, Expo Center Norte, São Paulo, Brazil. Contact: Monica Carpenter, 55 11 3824-5300, e-mail: mcn@arandanet.com.br; www.arandanet.com.br.


Educational Opportunities


Modern Furnace Brazing. October 24–26, Troy, Mich. Sponsored by Wall Colmonoy Corp. Contact: Marianne Huesing, (248) 585-6400 ext. 248, FAX: (248) 585-7960, e-mail: mnhuesing@wallcolmonoy.com; www wallcolmonoy.com.

Robot and Automation Seminar. November 1, ARC Specialties, Inc., Houston, Tex. Contact: Jeff Koza, ARC Specialties, Inc., 7775 Little York, P.O. Box 35539, Houston, TX 77225, (713) 631-7575, FAX: (713) 631-2555, e-mail: Jeff@arc specialties.com.

2001 Motor Sports Welding School. Classes are scheduled at the Lincoln Electric headquarters in Cleveland, Ohio, and the Alexander Technical Center in Griffin, Ga. For more information and a complete schedule, contact: Lincoln Electric Motorsports Welding School, 22801 St. Clair Ave., Cleveland, OH 44117, (216) 383-2461, FAX: (216) 383-8088; www lincolnelectric.com.


Boiler and Pressure Vessel Inspectors Training Courses and Seminars. 2001 Schedule, National Board of Boiler and Pressure Vessel Inspectors Training and Conference Center, Columbus, Ohio. Conducted by The National Board of Boiler and Pressure Vessel Inspectors. For courses and times, contact: Richard McGuire, Manager of Training, (614) 888-8320, e-mail: rmcquire@nationalboard.org; www nationalboard.org.

Structural Welding: Design and Specification Seminars. Conducted by the Steel Structures Technology Center (SSTC). For 2001 schedule and locations, contact: SSTC, (248) 344-2910, FAX: (248) 344-2911.
Educational Opportunities

AWS Schedule — CWI/CWE Prep Courses and Exams

Exam application must be submitted six weeks before exam date. For exam information and application, contact the AWS Certification Dept., (800) 443-9353 ext. 273. For exam prep course information, contact the AWS Education Dept., (800) 443-9353 ext. 229. For AWS Educational Boot Camp information, contact the AWS Education Dept., (800) 443-9353 ext. 477. Dates are subject to change.

<table>
<thead>
<tr>
<th>Cities</th>
<th>Exam Prep Courses</th>
<th>CWI/CWE Exams</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atlanta, Ga.</td>
<td>Oct. 15–19</td>
<td>Oct. 20</td>
</tr>
<tr>
<td>Birmingham, Ala.</td>
<td>Nov. 5–9</td>
<td>Nov. 10</td>
</tr>
<tr>
<td>Chicago, Ill.</td>
<td>Nov. 12-16</td>
<td>Nov. 17</td>
</tr>
<tr>
<td>Cleveland, Ohio</td>
<td>Dec. 3-7</td>
<td>Dec. 8</td>
</tr>
<tr>
<td>Cleveland, Ohio</td>
<td>Jan. 28-Feb. 1, 2002</td>
<td>Feb. 2, 2002</td>
</tr>
<tr>
<td>Columbus, S.C.</td>
<td>Dec. 10-14</td>
<td>Dec. 15</td>
</tr>
<tr>
<td>Columbus, Ohio</td>
<td>Nov. 5-9</td>
<td>Nov. 10</td>
</tr>
<tr>
<td>Fresno, Calif.</td>
<td>Feb. 4-8, 2002</td>
<td>Feb. 9, 2002</td>
</tr>
<tr>
<td>Long Beach, Calif.</td>
<td>Nov. 12-16</td>
<td>Nov. 17</td>
</tr>
<tr>
<td>Los Angeles, Calif.</td>
<td>Oct. 8-12</td>
<td>Oct. 13</td>
</tr>
<tr>
<td>Louisville, KY</td>
<td>Feb. 25-March 1, 2002</td>
<td>March 2, 2002</td>
</tr>
<tr>
<td>Miami, Fla.</td>
<td>Oct. 15-19</td>
<td>Oct. 20</td>
</tr>
</tbody>
</table>

AWS International Schedule — CWI/CWE Prep Courses and Exams

SAUDI ARABIA
October 20–24, CWI Training (Bahrain)
October 27, CWI Training (Kuwait)
November 1, CWI Examination (Damman)
November 3–7, CWI Training (Damman)
November 8, CWI Examination (Damman)
Nondestructive Technology Testing Center
Contact: Sudhir Phansalkar, 966-3-882-7522, FAX: 966-3-882-8417, e-mail: phs@poweronline.net.

KOREA
October 29–November 2, CWI Training
November 3, CWI Examination
International Welding Technology Research Lab.
Contact: Dr. Chon L. Tae, 866-22-363-3663, FAX: 866-22-363-6257, e-mail: tae@ms13.hinet.net

SINGAPORE
December 3–7, CWI Training
December 10, CWI Examination
Seto Services Pte Ltd.
Contact: 65-556-7777
FAX: 65-556-7718

INDIA
December 5–11, SCWI and CWI Training
December 13 and 14, CWI Examination
Industrial Quality Concepts
Contact: Sundaran Baskaran, 44-499-3826
FAX: 44-499-3826, e-mail: iqc.in.org@vsnl.com
AWS JobFind

The Internet job search site designed exclusively for materials joining industry professionals and the companies that serve them... Worldwide!

Looking for qualified people? For online information, log on to AWS JobFind at: www.aws.org/career

With job categories for welders, engineers, inspectors and over 17 other materials joining industry classifications...

Companies can:
• post, edit and manage your job listings easily and effectively, any day or time
• have immediate access to an entire résumé database of qualified candidates
• look for candidates who match your employment needs: full-time, part-time or contract employees
• receive and respond to résumés, cover letters, etc. via e-mail
• use two efficient job posting options: 30-day or unlimited monthly postings

Individuals can:
• enjoy free access to job listings specific to the materials joining industry
• post a public or confidential résumé in a searchable database
• apply directly online for open positions with prospective employers
• manage your job search any day or time: update your profile, edit your résumé and review all jobs that you applied for
• upload additional résumés for free

NEW ONLINE Career Center

Visit AWS JobFind www.aws.org/career

American Welding Society
ISO 9001 Registered Organization
P.O. Box 440367
Miami, FL 33144-0367
Telephone (800) 443-9353
FAX (305) 443-5647
Visit our website: www.aws.org
Soldering technology has, and will continue to play, an important role in the manufacture of photovoltaic (PV) solar modules. With the solar energy market expanding as overall energy demands grow, a better understanding and control of the soldering process will increase production yields and satisfy stringent field reliability requirements. The wide range of thermal, mechanical, and atmospheric environments that solar energy systems are exposed to can lead to premature solder joint failures that eventually degrade collector durability and performance.

Photovoltaic System Architecture

Photovoltaic systems are used to power a wide variety of applications. From simple hand calculators to larger residential and commercial electrical systems, solar electric power offers a viable, renewable energy alternative. The basic principle behind a photovoltaic system is the conversion of sunlight into electrical energy by a solar cell. The conversion is accomplished through the absorption of photons by a semiconductor material and the release of free electrons that create a direct current in the cell circuit.

Commercial PV systems are based on three primary units — Fig. 1. The simplest unit is the PV cell, which can produce 1–2 W. Individual cells are connected together to form a PV module, which has a typical output range of 30–250 W. For higher power requirements, modules are connected to form a solar array. Several arrays can provide megawatts of power. Mounting hardware, tracking direction controllers, power-conditioning equipment, and storage devices complete the PV system.

Photovoltaic Cell Fundamentals

The basic building block for a PV system is the solar cell — Fig. 2. The cell design is based on semiconductor technology that converts sunlight to electrical energy. Two semiconductor layers, "p" (positive) and "n" (negative), are sandwiched together to form a battery that generates free electrons in the n layer, which are then transferred by an electric field to the cell circuit. The metal grid network and interconnects on the cell surface provide the electrical path to the workload. Copper tabs or strips soldered to the metal grid contacts on one or both sides of the cell electrically connect individual cells. Antireflective coatings are applied over the cell surface to reduce light reflection and increase light absorption, which improves PV conversion efficiency.

Single crystal (c-Si) and poly- or multicrystalline (mc-Si) silicon are the most common and widely used materials for making solar cells. Single crystal silicon is more electrically efficient, but also more costly to fabricate, than the polycrystalline material. The semiconductor junction on the cell is typically formed by diffusing phosphorous (n-type dopant) into the top surface of boron-doped silicon (p-type). Metal contacts and grids on the front and backside of the cell, applied through a variety

F. M. HOSKING (fhoski@sandia.gov) and M. A. QUINTANA are with Sandia National Laboratories, Albuquerque, N.Mex.
of deposition techniques, serve to collect the electrons from the semiconductor and conduct the electrical signal to the workload. The glass and encapsulant provide mechanical integrity, optical transparency, and climatic durability for the cell.

**Conventional PV Solder Joint Design & Processing**

The electrical circuit for each cell is completed by soldering copper strips to contact points along the metal grid system. To facilitate the soldering operation, the copper pieces are precoated with solder. The grid material is generally a silver-based metal applied by vapor deposition, screen printing and firing, ink-jet printing, flame spraying, or photolithography. Chemical flux is used to promote solder wetting and adhesion to the grid contacts. Solder joints are either discrete or continuous in length. The generated electrical signal is conducted along the soldered copper tabs to the output junction box and external workload. An example of a cross-sectioned PV solder joint is shown in Fig. 3.

The conventional PV soldering process uses tin-lead or tin-lead-silver solder alloy and a rosin-based flux. Typical alloy compositions are Sn67Pb37, Sn68Pb40, or Sn62Pb36Ag2 (wt.-%). With growing environmental concerns over the use of lead-containing solders and the handling of hazardous chemicals, there has been greater pressure to introduce more environmentally friendly, lead-free solders and water soluble, low residue (or no clean) organic acid fluxes into the manufacturing cycle. One of the leading lead-free solder alloy candidates is Sn97Ag3.5. These alternative materials will require additional process characterization and qualification to ensure PV industry performance and reliability standards are still satisfied.

Photovoltaic cell strings are soldered by manual (batch) or automated (continuous) techniques. Discrete or spot joints are usually heated with hot air or a hot bar and soldered either by hand or with a machine. Continuous joints are generally made with more automated, controlled heating equipment, such as a solder reflow system with quartz or infrared heat lamps.

The copper interconnects are held in place over the grid contacts with clips, tabs, rollers, or an active vacuum during the soldering operation. The hold-down load can be an important process parameter in the control of solder thickness and run-out. Joint thickness can range from very thin (10 µm) to thick (200 µm). This variability, along with varying geometry, can significantly affect solder joint reliability under thermomechanical fatigue conditions. Ideally, a uniform joint thickness of 50-100 µm is the process target to take advantage of the compliant behavior of most solders. Intermetallic growth and potential failures at the copper and metal grid interfaces should be considered since the solder joints will see elevated temperatures for extended periods of time while in service. There also appears to be a slight difference in the adhesion strength between the front and backside cell joints. Lower backside strengths are attributed to an aluminum addition to the metal grid structure, which can inhibit solder wetting and adhesion.

Soldering temperatures are usually difficult to control, although efforts are being made to replicate recommended heating cycles that properly vaporize the flux carrier, activate the flux, melt the solder, allow adequate time for the solder to react with the base metal(s), and produce a strong metallurgical bond. Photovoltaic soldering times are usually much shorter than those used to solder reflow surface mount devices on a printed circuit board or similar structural applications. For example, it can take a PV cell less than 15 s to reach the soldering temperature since each cell is indexed under a quartz heating lamp. This rapid processing cycle can yield significant process variability unless the materials and processing conditions are tightly controlled. Therefore, it is important when selecting the soldering process to properly balance manufacturing throughput and costs with the ability to make reproducible, reliable solder joints.

**PV Solder Joint Reliability and Characterization**

Photovoltaic manufacturing and field performance codes and certification standards have been developed by the solar industry for a wide variety of service applications. It is important PV systems conform to these standards and are assessed for potential failures prior to field installation and while in service. The objective is to build a cost-effective module with up to a 30-year lifetime. Particular concerns for PV solder joints are long-term exposure to hot, humid environments and diurnal thermal cycling. The chemical compatibility of flux residues and other potentially corrosive media in the packaged module, including the solder alloy, sodium, phosphorous, and titanium ultraviolet catalyst, with entrapped or penetrated moisture from the outdoor environment, could cause circuit shorts or opens that would eventually degrade module performance. Premature thermomechanical fatigue failures, caused by nonisothermal aging, would also reduce service life expectancy. The interaction effects between the different thermal, mechanical, electrical, and atmospheric conditions could further accelerate joint failures.

Recent R&D efforts, sponsored by the U.S. Department of Energy's Photovoltaics Program and coordinated by Sandia National Laboratories in Albuquerque, N.Mex., and the National Renewable Energy Laboratory in Golden, Colo., have focused on developing techniques to better characterize, monitor, and predict solder joint and electrical failures in PV systems. Specific thrust areas include development of reliable nondestructive diagnostic tools for inspecting PV solder joints. Electrical performance, dark current-voltage (I-V), infrared thermal scan, ultraviolet (UV) imaging, and ultrasonic C-scan tests have shown great potential for finding and monitoring joint defects such as entrapped flux residues, voids, cracks, lack of fill, and poorly bonded regions. Coring techniques have been developed to obtain intact samples from specific module and cell locations. The goal is to use and share the resulting information for designing and manufacturing more robust and reliable PV systems.

**Acknowledgments**

Participate in the
83rd Annual AWS Convention
Poster Competition
Chicago, Illinois March 4-7, 2002

Students, educators, researchers, engineers, technical committees, consultants, and anyone else in a welding- or joining-related field are invited to participate in the world’s leading annual welding event by visually displaying their technical accomplishments in a brief graphic presentation, suitable for close, first-hand examination by interested individuals.

Posters provide an ideal format to present results that are best communicated visually, more suited for display than verbal presentation before a large audience; new techniques or procedures that are best discussed in detail individually with interested viewers; brief reports on work in progress; and results that call for the close study of photomicrographs or other illustrative materials.

Two Categories

There are two categories: Student and Commercial.

Professional category is available to display recent advances in welding technology. Blatant advertisement or sales-oriented posters will not be accepted. Prizes will be awarded for first, second, third, and honorable mention where warranted. No prize will be awarded solely because of number (or lack thereof) of entries in a category.

Awards

Judging is based equally on presentation/clarity and technical merit. Awards are made, where warranted, in two categories; Student and Commercial. All first place winners will be recognized at the following year’s AWS Authors’ Breakfast and Awards Luncheon.

<table>
<thead>
<tr>
<th></th>
<th>Student (in each of 3 levels)</th>
<th>Professional</th>
</tr>
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<tbody>
<tr>
<td>First Place</td>
<td>Plaque $200 + Plaque</td>
<td>Plaque</td>
</tr>
<tr>
<td>Second Place</td>
<td>Ribbon $100 + Ribbon</td>
<td>Ribbon</td>
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<tr>
<td>Third Place</td>
<td>Ribbon $50 + Ribbon</td>
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<tr>
<td>Honorable Mention</td>
<td>Ribbon</td>
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</table>

Expenses: Up to a maximum of $1,000 travel expenses will be reimbursed for the top student winner in each level to attend and be recognized at the following year’s AWS Authors’ Breakfast and Awards Luncheon. (NO travel expenses will be paid for the top winner in the Professional Division.)

Rules

1. Complete the Poster Session Application on the back of this page and mail it with a 200-word description (i.e., abstract) of your poster topic by November 1, 2001, to Technical Papers Coordinator, American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126, or electronically to <dorcas@aws.org>. You will be notified in January if your proposed Poster Session topic has been accepted. If so, you should do the following:
   - Mount your material on either 22 x 28-in.-wide or 44 x 28-in.-wide (maximum) poster board, or prepare your material so that it can be mounted for you on one of those sizes of poster board. Laminated digital prints, or digital prints already mounted on backing, may be 40 X 30 in. wide (maximum).
   - Plan to use a flat display format that is large enough to read from 6 to 8 ft away.

2. You will be notified in January if your proposed Poster Session topic has been accepted. If so, you should do the following:
   - Mount your material on either 22 x 28-in.-wide or 44 x 28-in.-wide (maximum) poster board, or prepare your material so that it can be mounted for you on one of those sizes of poster board. Laminated digital prints, or digital prints already mounted on backing, may be 40 X 30 in. wide (maximum).
   - Plan to use a flat display format that is large enough to read from 6 to 8 ft away.
POSTER APPLICATION
83rd Annual AWS Convention
Chicago, Illinois March 4-7, 2001

Complete form and mail with 200-word abstract by November 1, 2001, to Technical Papers Coordinator, American Welding Society, 550 N.W. LeJeune Rd., Miami, FL 33126, or e-mail to <dorcas@aws.org>

DEADLINE: November 1, 2001.

POSTER TITLE OR Topic:

___________________________________________________________

CATEGORY: (Check One) ☐ Professional ☐ A – Certificate or 2-year degree student
☐ B – Undergraduate (4-year) degree student ☐ C – Graduate degree student

School Name_____________________________________________________________
Degree/Certificate you are seeking_____________________________________________
Professor’s name_________________________________________________________
School Mailing Address_____________________________________________________
City_________ State______ Zip_________ Country_______________________________

POSTER AUTHORS

Name_______________________________________________________________
Title or position_________________________ Company or organization___________
Mailing address____________________________ State________ Zip/Postal Code________
City_________ State______ Zip/Postal Code_________ Country_____________________
Area/Country Code__________________________ Telephone_____________________
FAX_________________________________ e-mail address_______________________

For joint authors, give names and FULL MAILING address of other authors (list separately and attach if necessary):

1st Name_________________________ Area/Country Code________________________
Title or position_________________________ Company or Organization___________
Mailing address____________________________ State________ Zip/Postal Code________
City_________ State______ Zip/Postal Code_________ Country_____________________

2nd Name_________________________ Area/Country Code________________________
Title or position_________________________ Company or Organization___________
Mailing address____________________________ State________ Zip/Postal Code________
City_________ State______ Zip/Postal Code_________ Country_____________________

Abstract

The 200-word abstract should include the following:
◆ Overall significance to welding (or, in Category A only, materials science) community.
◆ Newness or originality of poster content
◆ What your illustrations (if any) show
◆ Important points stressed in poster
◆ Where relevant, potential economic impact of the work described by the poster

Poster Presentation

The presence of a personal representative in Chicago is not mandatory.
By Susan Campbell

Welding Instructors Go to School at the AWS Institute

Welding educators participating in the American Welding Society's first-ever Instructors' Institute discovered no matter where in North America they are from, they have plenty of common ground. The 23 instructors who attended the Institute at AWS headquarters in Miami from July 22 to 27 identified a variety of issues they must contend with each school year. Their concerns ranged from recruitment and retention of students to how to obtain funding to professional and curriculum development.

The goals of the program were to "bring together welding instructors from all over the United States, let them learn more about AWS, give them the opportunity to get some hands-on welding practice using the latest and best welding equipment, and provide them with the support and encouragement to be the best instructors they can be," said AWS Deputy Executive Director Jeffrey Hufsey.

"I feel like I've come away with lifelong friends with common interests," instructor Oliver Myers said. "Our colleagues can help us overcome the areas where we're deficient." The end result of instructors' participation in the Institute, Myers said, is that "many students will benefit."

The attendees — secondary and postsecondary welding instructors who directly teach welding — represented each of the 22 domestic AWS districts. They were selected during the District Conferences held in May and June of this year. Attendee Frank Wernet saw the mix of instructional levels as a benefit. "I teach tenth- to twelfth-grade students," he said. "Being able to talk to instructors about what community colleges are looking for can help me better prepare students for the next step." Jerry Sullivan agreed. "Seeing that these 22 individuals are going through the same things you're going through, both good and bad, is a big help," he said. "I talk to other instructors in Tennessee, but this group comes from all over the United States. It gives me a chance to see how things are all over the country."

During the Institute, the instructors split their time between classroom and hands-on activities in the Glenn J. Gibson Welding Laboratory. In the lab, they had opportunities to try out some of the newest welding equipment and learn instructional techniques for processes such as welding aluminum and welding very thin materials. Companies that contributed to the success of the program included ESAB Welding & Cutting Products, Hanover, Pa.; The Lincoln Electric Co., Cleveland, Ohio; Miller Electric Mfg. Co., Appleton, Wis.; Sellstrom Mfg. Co., Palatine, Ill.; Thermal Dynamics, West Lebanon, N.H.; and Welding Engineering Supply Co., Pritchard, Ala.

"I really liked the metallurgical insights," said instructor Frances Guerrero. "I got a few new pointers." She also enjoyed the hands-on time in the welding lab and praised the level of knowledge of all the presenters. "I learned some new techniques I can show my students. I got ideas for things I can use in my classroom. That's what I came here to get."
Participants spent much classroom time identifying welding instruction challenges and coming up with strategies for addressing them. First, they defined the issues, then they broke up into smaller groups to identify the causes of the problems. Next, they outlined the consequences of those issues, made recommendations to solve the problems, and outlined the benefits to the learning institution.

The group working on "Benefits of Community and Industry Support," for example, cited the bond among community, industry, and schools as an important, but fragile, part of young adult education. The efforts of the three groups "can make or break a school's program," the instructors said. "All three groups must support each other to provide a smooth transition for our students from school to the work field and on to a productive life." The group recognized industry and community support comes primarily from volunteers, and time and monetary pressures make it difficult for many people to donate their time. "Don't wait for others; you take the leadership role," they said. "Staying active in the local AWS Section is a wonderful way to meet people willing to take the time to promote welding and to support your program. Recruitment must be active; people rarely come to you."

Some of their suggestions for finding volunteers and getting support from the local community include the following: reminding prospective volunteers that employers look for people who give their time and those that take leadership roles outside the workplace; such people often find their efforts can get them the advancement they are seeking in the workplace. Volunteers can hold events that will expose the general public to welding, or they can get involved in community projects such as caring for the land along a section of highway or using students' welding expertise on a project that helps the community. They also noted welding programs benefit from donations of supplies, providing students with exposure to the professional welding world, and keeping instructors up to date with industry.

The instructors also shared their "best practices" for dealing with issues such as building a successful curriculum, reaching students with special needs, dealing with difficult students and situations, and how to make a program flexible enough to ensure student success.

In addition, the group toured the AWS headquarters building and received information regarding resources the American Welding Society has available for welding educators. — Mary Ruth Johnsen, Features Editor

AWS Technical Papers Committee Meets

Members of the Technical Papers Committee met at Edison Joining Technology Center at The Ohio State University, Columbus, Ohio, on August 28.

Pictured at the meeting are, back row, from left, Dave Farson, Suresh Babu, Stephen Liu, Dennis Harwig, Herschel Smartt, Damlan Kotecki, Fritz Saenger, Ravi Menon, Brian Dammkroger, and John Lippold; front row, from left, John Elmer, Don Tillack, Dorcas Gonzalez, Wangen Lin, Kim Mitchiner, Glen Edwards, John DuPont, and Yoni Adonyi.
Mendoza Elected District 18 Director

John L. Mendoza has been elected to fulfill the remaining term of former District 18 Director John Appledorn, who relocated to the Cleveland area after accepting another position with The Lincoln Electric, Co. His term commenced on June 1 and runs through May 31, 2002.

Mendoza is a 27-year employee of City Public Service, San Antonio’s gas and electric utility. He joined the American Welding Society (AWS) in 1991 and has held several Section offices, including vice-chairman (1995-1997) and chairman (1997-1999). He presently serves as secretary.

Mendoza received a certification in welding technology from San Antonio Trade School in 1973. He joined City Public Service as a welder’s helper, completed a three-year apprenticeship, and attained journeyman welder status in 1979. Mendoza is qualified to ASME Section IX in shielded metal arc tungsten arc welding and has performed power plant maintenance for more than 20 years. In 1992, he earned his AWS Certified Welding Inspector (CWI) credentials and served as weld inspector during construction of the 550-MW Spruce power plant.

In 1994, Mendoza was promoted to maintenance trainer, responsible for the training and performance qualification of power plant welders. He is proficient in course design and was instrumental in the creation of the Skills Training Evaluation Program (STEP) used by City Public Service for employee development.

Mendoza pursued his interest in welder education and earned his AWS Certified Welding Educator (CWE) credentials in 1996. That same year, he received Craft Instructor certification from the National Center for Construction Education and Research and was hired as an adjunct welding instructor for the Texas A&M University System. This year, Mendoza attained credentials as a Certified Training Manager/Director by Langgevin Learning Services. He is currently pursuing a Master Trainer certification.

Since 1996, Mendoza has generated and distributed the newsletter for the San Antonio Section. He organizes and coordinates AWS District Conferences, serves as test supervisor for CWI/CWE exams, created and maintains the Section’s Web site, organizes Step Night activities, and obtains welding proclamations from city and state officials.

Mendoza presently serves as cochairman of the welding advisory committee for St. Philip’s College, judges SkillsUSA/VICA welding competitions, is a member of the City Public Service Speaker’s Bureau, and is a 26-year member of the International Brotherhood of Electrical Workers, Local 500.

In 2000, Mendoza attended the AWS Nine-Year CWI Recertification Course and was the recipient of the Dalton E. Hamilton Memorial CWI of the Year Award for District 18.

NEW SUPPORTING COMPANIES

New Supporting Companies

Miracle Steel Corp.
600 Oakwood Rd.
P.O. Box 1266
Watertown, SD 57201

New Educational Institutions

Arizona Welding Institute, Inc.
P.O. Box 3577
530 Haul Rd.
Page, AZ 86040

Grand River Technical School
1200 Fair St.
Chillicothe, MO 64601

Morrison R. Waite High School
(Toledo Public Schools)
301 Morrison Dr.
Toledo, OH 43605

Western Iowa Tech Community College
4647 Stone Ave.
Sioux City, IA 51106

Basic Requirements for Welding Inspectors Outlined

A new standard for the minimum recommended job requirements of welding inspectors, the Specification for the Qualification for Welding Inspector Specialists and Welding Inspector Assistants, has been published by AWS.

A first edition, this standard helps employers evaluate an inspector’s education and experience, while considering company objectives. Recommended processes and procedures for the qualification of welding inspectors are outlined in the text. Topics such as destructive testing, safety practices, and comprehensive symbols and reports are included to provide a better understanding of the inspector guidelines.

The AWS Specification for the Qualification for Welding Inspector Specialists and Welding Inspector Assistants (B5.2:2001) is 8½ x 11 in., softbound, and three-hole drilled. The cost is $18 for AWS members and $24 for others.

This 12-page, ANSI-approved document is available by calling (800) 854-7179 or by visiting the AWS Web site at www.aws.org.
Middlesex Gases & Technologies, Inc., is a family-owned, independent, third-generation distributor of gases, welding-related products, and safety equipment. It offers customers the latest technology associated with its products, as well as an expert staff, the majority of which has more than 25 years of experience in the industry.

The company has the technical ability to address specific applications. It fills, tests, and delivers the purities and consistent products required in industrial, specialty, high-purity grades, and mixtures. Cryogenic liquids and gases with the latest cylinder technology, manifolding, and regulation requirements are the company's specialty.

For the latest in welding technology, Middlesex Gases & Technologies is a distributor and authorized service center for all of the major equipment manufacturers. The company's technical sales staff and certified service technicians have the resources and knowledge to train and support customers in all phases of the welding processes, including gas metal arc, gas tungsten arc, flux cored arc, and shielded metal arc welding; plasma welding and cutting; oxygen cutting; and welding and brazing.

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DALUS, Monterrey, Mexico, became the first AWS Accredited Test Facility in Mexico on July 19. DALUS is now offering certifications to both companies and individuals for Certified Welder, Certified Welding Inspector (CWI), Certified Welding Educator, and Certified Welding Engineer. DALUS's first group of CWIs passed the exam on July 21.

DALUS opened its doors to its first training class in November 2000. In May, after 390 hours of instruction, the group of students became the first to complete DALUS's entry-level welder diploma program.

DALUS's goal is to be available for any person who wants to train as a welder. Fernando Méndez, training director and, along with Rogelio de los Santos, one of the founders of DALUS, said, "We do not want to be exclusive, we want to be inclusive."
During the AWS Annual Executive Board Meeting in August, the board of directors moved to honor the loss of David S. Berger, a past director-at-large and District director, and Robert D. Alm, a Life Member, by placing a memorial resolution for each in the permanent records of the Society. Their contributions and dedication to the Society shall be missed.

David S. Berger

The Board of Directors observes, with great regret, the death of Past Director-at-Large and District Director David S. Berger on July 20, 2001.

Mr. Berger joined the American Welding Society in 1975. He served the Society in many ways, at both the local and national levels. From 1983 to 1989, Mr. Berger served as District 21 Director and from 1989 to 1991 as Director-at-Large.

Mr. Berger received his bachelor’s degree in mechanical engineering from Oregon State University. His career included working for the Bridge Design Section of the Oregon State Department of Highways, Pittsburgh Testing Laboratory, Mitsubishi International, and Mitsubishi Shipbuilding and Engineering Ltd. Mr. Berger also served as President of the Matsuo Bridge America Corporation.

At the time of his death, Mr. Berger was retired and residing in Salem, Oreg.

In recognition of the many contributions of David S. Berger to the welding industry and the Society, the Board of Directors wish to record the following:

WHEREAS, the American Welding Society has sustained an irreplaceable loss with the death of one of its Past Directors-at-Large and District Directors, and

WHEREAS, David S. Berger served the Society and the welding industry honorably and with great distinction,

BE IT RESOLVED that the Executive Committee, on behalf of the Board of Directors of the American Welding Society in the meeting assembled on August 12, 2001, in Mystic, Connecticut, records its sorrow at the loss of a valued associate and expresses its appreciation for the many contributions of David S. Berger, and

BE IT FURTHER RESOLVED that these resolutions be placed in the permanent records of the Society and that copies be forwarded to his wife, Kay.

Robert D. Alm

The Board of Directors observes, with great regret, the death of Life Member, Robert D. Alm on June 20, 2001.

Mr. Alm joined the American Welding Society in 1956 and was a member of the AWS San Francisco Section. He served as a consultant for the American Welding Society from 1994 through 1998.

Mr. Alm received his engineering degree at California State Polytechnic College. He was a registered professional engineer with the state of California. Mr. Alm worked at the Mare Island Naval Shipyard for 35 years. Prior to retirement in 1988, he held the position of head of the Shipyard’s Welding Engineering Division.

Mr. Alm was a member of Vallejo Elks Lodge, NARFE, AARP, and a lifetime member of the American Welding Society. At the time of his death, Mr. Alm resided in Vallejo, Calif.

In recognition of the many contributions of Robert Alm to the welding industry and the Society, the Board of Directors wish to record the following:

WHEREAS, the American Welding Society has sustained an irreplaceable loss with the death of one of its Life Members, and

WHEREAS, Robert Alm served the Society and the welding industry honorably and with great distinction,

BE IT RESOLVED that the Executive Committee, on behalf of Board of Directors of the American Welding Society in the meeting assembled on August 12, 2001, in Mystic, Connecticut, records its sorrow at the loss of a valued associate and expresses its appreciation for the many contributions of Robert Alm, and

BE IT FURTHER RESOLVED that these resolutions be placed in the permanent records of the Society and that copies be forwarded to his wife, Beverly, son, Gregory Dalessi, and daughter, Sharon Antonen.
Leadership Symposium Held at AWS Headquarters

To foster the exchange of ideas between Sections and Districts, AWS held the Third Leadership Symposium on July 28-31. This event is designed to strengthen leadership skills, give tips on planning activities, provide an opportunity to meet AWS staff, and provide a chance for participants to learn about helpful resources available from the Society.

Past AWS President Lee Kvidahl, who is currently AWS National Membership Committee chairman, worked with Member Services Associate Executive Director Cassie Burrell on the Symposium itinerary.

Representatives from all 22 Districts and 25 Sections attended the event. Representing their District at the Symposium were: District 1, Troy Grieco, Boston; District 2, Alfred Farland, Long Island; District 3, Mike Wiswesser, Lehigh Valley; District 4, Daniel Hatter, Southwest Virginia; District 5, Carl Matricardi, Atlanta; District 6, Neal Chapman and Ken Phy, Syracuse; District 7, Monte Swigart, Dayton; District 8, Jim Sears, Memphis; District 9, Tony DeMarco, New Orleans; District 10, Lisa Ryan, Cleveland, and Chuck Moore, Mahoning Valley; District 11, Phil Schiffer, West Michigan, and Donald DeCorte, Detroit; District 12, Dan Roland, Milwaukee; District 13, Paul Burys; District 14, Robert Richwine and Michael Anderson, Indiana; District 15, Dwight Affeldt, Northwest; District 16, Jeff Pelster, Southeast Nebraska; District 17, Patrick Fagerquist, North Texas; District 18, John Mendoza, San Antonio; District 19, Bruce Weisman, Alaska, and Ron McKeowo, British Columbia; District 20, Bill Komlos, Utah; District 21, Bert Callender, San Fernando Valley; District 22, Leddee Montebon and Mike Murphy, Santa Clara Valley.

Leadership Symposium attendees pose for a photo at AWS headquarters in Miami.

A group of attendees as they set sail on Biscayne Bay for a sightseeing cruise of Miami.

Attendees participating in a workshop during the Symposium.

AWS National Membership Committee Chairman Lee Kvidahl presenting Lisa Ryan of the Cleveland Section with her Leadership Excellence Award Certificate.
Tri-State Section members Tim Turley, left, and Jeff Crockett, right, with West Virginia University Welding Department Chairman Carl Smith after receiving their degrees.

District 1 Director Geoffrey Putnam, seated in race car, with Jim Gagnon, operations manager of the Skip Barber Racing School.

District 1
Director: Geoffrey H. Putnam
Phone: (802) 439-5916

CONNECTICUT
JUNE 30
Speaker: Jim Gagnon, operations manager.
Affiliation: Skip Barber Racing School.
Activity: Section members toured the Skip Barber Racing School's main facility for maintenance, repair and fabrication of its fleet of wheeled formula Dodge race cars. This was followed by an afternoon of racing at the Lime Rock Park.

DISTRICT 7
Director: Robert J. Taberaiik
Phone: (614) 488-7913

TRI-STATE
May 22
Activity: Section members Tim Turley and Jeff Crockett graduated with honors from West Virginia University. Turley, who is chief welding inspector for Kanawha Mfg. Co., and Crockett, who is plant manager for Edlon PSI, both received degrees in welding technology.

DISTRICT 8
Director: Wallace E. Hooey
Phone: (256) 332-3366

WEST TENNESSEE
March 8
Speaker: Phillip Cranford regional coordinator.

WEST TENNESSEE
March 8
Affiliation: Skills USA/VICA.
Activity: The Section held the Regional VICA high school contest.
Dave Hamilton of Chattanooga attended as the state VICA coordinator. Ten students participated in the contest. Ashley LeCompte was presented with a section scholarship by instructor Rodney Russell.

WEST TENNESSEE
March 8
Speaker: Phillip Cranford, regional coordinator.

NORTHEAST MISSISSIPPI
May 10
Activities: The Section held Ladies' Night. Steve Latham gave
Ashley Lecompte, right, accepting a West Tennessee Section scholarship from welding instructor Rodney Russell.

Pictured with Bob Peroutka, the Lakeshore Section's winner of the District 12 Educator of the Year Award are, from left, past Section Chairman Lee Dahlen, Peroutka, Jim Hoffman, and Dalton Pierce.

District 10 Director Vic Matthews, right, accepting a speaker's gift from Mahoning Valley Section Chairman Kenny Jones.

Ill-Mo team members, from left, Jim Brown, Mike Stark, Tom Tazer, and Joe Berry admiring the hole-in-one prize at the Sangamon Valley Section's annual golf outing. Unfortunately, the prize went unclaimed.

DISTRICT 10
Director: Victor Y. Matthews
Phone: (216) 383-2638

MAHONING VALLEY
April 19
Speaker: Victor Matthews, District 10 director

a presentation on the history of the American Welding Society and conducted the installation of officers for the 2001-2002 term. Elected to office were Jimmy Agerton, chairman; John T. Berry, first vice chairman; Gary Gammill, second vice chairman; and Sam Gray, treasurer.

DISTRICT 10
Director: Victor Y. Matthews
Phone: (216) 383-2638

MAHONING VALLEY
April 19
Speaker: Victor Matthews, District 10 director

Topic: How to get and keep AWS members active at the local and District levels.

DISTRICT 10
Director: Victor Y. Matthews
Phone: (216) 383-2638

MAHONING VALLEY
April 19
Speaker: Victor Matthews, District 10 director

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DISTRICT 10
Director: Victor Y. Matthews
Phone: (216) 383-2638

MAHONING VALLEY
April 19
Speaker: Victor Matthews, District 10 director

DISTRICT 12
Director: Michael D. Kersey
Phone: (262) 650-9364

LAKESHORE
Activity: Bob Peroutka was presented with the District Educator of the Year Award. Peroutka is a welding instructor for Manitowoc Cranes Group, which operates its welding school year-round, instructing new welders and certifying experienced welders.
Emirates Welding Section officers, from left, Treasurer G. Sivakrishnan, Secretary R. Bashkar, Chairman Bernard D'Silva, and committee member Narinder Pal, at the annual general meeting in June.

Treasurer: G. Sivakrishnan
Secretary: R. Bashkar
Chairman: Bernard D'Silva
Committee Member: Narinder Pal

Affiliation: Thermal Technology
Topic: High-frequency welding of tubular products.

DISTRICT 18
Director: John Mendoza
Phone: (210) 353-3679

SAN ANTONIO
August 14
Speaker: Edgar Lozano, construction specialist
Affiliation: City of San Antonio
Topic: Building permits and inspections.

INTERNATIONAL SECTIONS

DISTRICT 14
Director: Hill Bax
Phone: (314) 644-3300, ext. 105

SANGAMON VALLEY
June 15
Activity: The Section held its Annual Golf Outing at the Elks Country Club in Lincoln, Ill. The event benefitted the Section’s scholarship fund.

DISTRICT 17
Director: Oren P. Reich
Phone: (254) 867-2203

EAST TEXAS
January 18
Speaker: Robert Nichols, director of thermal technology
Affiliation: Lone Star Steel, Co., Lone Star, Tex.
Topic: High-frequency welding of tubular products.

DISTRICT 3
Director: Claudia Bottenfield
Phone: (717) 397-1312

EAST TEXAS
January 18
Speaker: Robert Nichols, director of thermal technology
Affiliation: Lone Star Steel, Co., Lone Star, Tex.
Topic: High-frequency welding of tubular products.

DISTRICT CONFERENCE

DISTRICT 14
Director: Hill Bax
Phone: (314) 644-3300, ext. 105

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Director: John Mendoza
Phone: (210) 353-3679

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DISTRICT 18
Director: John Mendoza
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INTERNATIONAL SECTIONS

DISTRICT 18
Director: John Mendoza
Phone: (210) 353-3679

SAN ANTONIO
August 14
Speaker: Edgar Lozano, construction specialist
Affiliation: City of San Antonio
Topic: Building permits and inspections.
Know Your District Director

**District 1**
Geoffrey H. Putnam
Plasma Torch Designer
Thermal Dynamics
Industrial Park #2
West Lebanon, NH 03784
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FAX: (603) 298-6461
e-mail: viputnam@sover.net

**District 2**
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FAX: (732) 868-0768
e-mail: alnpat@cninet.com

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**District 4**
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Pitt Community College
P.O. Drawer 7007, Hwy. 11 South
Greenville, NC 27835-7007
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FAX: (252) 321-4611
e-mail: rlanier@pcc.pitt.cc.nc.us

**District 5**
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e-mail: eas1corp@aol.com

**District 6**
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**District 7**
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**District 8**
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**District 9**
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**District 10**
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**District 11**
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FAX: (734) 241-7511
e-mail: scott.chapple@midwayproducts.com

**District 12**
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Waukesha, WI 53186
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FAX: (262) 650-9370
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**District 13**
Jesse L. Hunter
Senior Staff Engineer-Quality Control
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202 W. Cleveland, P.O. Box 79
Heyworth, IL 61745
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FAX: (309) 888-8991
e-mail: jahntr@msn.com

**District 14**
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5835 Manchester Ave.
St. Louis, MO 63110
Phone: (314) 644-3500, ext. 105
FAX: (314) 644-4336
e-mail: hilb@mail.cookay.com

**District 15**
Jack D. Heikkinen, President
Spartan Sauna Heaters, Inc.
7484 Malta Rd.
Evelyn, MN 55734
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e-mail: spartans@cpinternet.com

**District 16**
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FAX: (515) 294-0568
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**District 17**
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FAX: (254) 867-3550
e-mail: oreich@tstc.edu

**District 18**
John L. Mendoza, Technical Trainer
City Public Service
3319 Kashmuir
San Antonio, TX 78223-11612
Phone: (210) 860-2592
e-mail: jmendoza@att.net
— continued on next page
The Sierra Nevada Section, District 22, has been awarded the Henry C. Neitzel National Membership Award for the greatest net numerical increase for the year 2000-2001. The winner of the Henry C. Neitzel National Membership Award for the greatest net percentage increase for 2000-2001 is the Mid-Ohio Valley Section, District 7. Following are the Sections in each district that showed an increase in membership.

<table>
<thead>
<tr>
<th>District</th>
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<tr>
<td>1</td>
<td>Green &amp; White Mountains</td>
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<td>San Fernando Valley</td>
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<tr>
<td>22</td>
<td>Sierra Nevada</td>
</tr>
</tbody>
</table>

* No Section within the District had an increase in its membership.

ISO/TC44 Committee Meets in Slovenia

Members of the ISO/TC44 Welding and Allied Processes Committee met at the Slovenian Welding Institute in Ljubljana, Slovenia, on July 13 and 14. Pictured in front of the Institute are, from left, International Standards Activities Committee (ISAC) Vice Chairman and AWS Director-at-Large Damian Kotecki, ISAC Chairman Walter Sperko, and ISAC Secretary Andrew Davis.

District 19
Philip F Zammit
Quality Assurance Manager
Brooklyn Iron Works Inc.
2401 E. Brooklyn
Spokane, WA 99207
Phone: (509) 468-2310, ext. 120
FAX: (509) 468-0284
e-mail: pzammit@brooklynindustrial.com

District 20
Jesse A. Grantham
WJMG West
7100 N. Broadway, Ste. 1C
Denver, CO 80221
Phone: (303) 451-6759
FAX: (303) 280-4747
e-mail: jesse_a_grantham@prodigy.net

District 21
E.R. "Bob" Schneider, Chief Consultant
Bob Schneider Consultant Services
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San Diego, CA 92126
Phone: (858) 693-1657
FAX: (619) 693-4552
e-mail: bschs@pacbell.net

District 22
Mark D. Bell, Principal Consultant
Preventive Metallurgy
14114 Sargent Ave.
Galt, CA 95632
Phone: (209) 367-1398
FAX: (209) 367-1399
e-mail: acemet@softcom.net

Visit AWS on the Web

The world of AWS is as close as a click of your mouse. While visiting the American Welding Society's Web site, you can renew your membership, buy books and standards and even look for a new job. To see what's on the Web site for you, just visit http://www.aws.org.
Development work has begun on the following new or revised standards. Directly and materially affected individuals are invited to contribute to the development of such standards. Those wanting to participate may contact the staff engineer listed with the document.

Participation on AWS Technical Committees and Subcommittees is open to all persons.

AWS B2.1-1-011:200X, Standard Welding Procedure Specification (WPS) for Shielded Metal Arc Welding of Galvanized Steel, 10 Gauge through 18 Gauge, in the As-Welded Condition, With or Without Backing. This standard contains the essential welding variables for welding galvanized steel in the thickness range of 10 through 18 gauge, using manual shielded metal arc welding. It cites the base metals and operating conditions necessary to make the weldment, the filler metal specifications, and the allowable joint designs for fillet and groove welds. Engineer: Len Connor, (305) 443-9353 ext. 302.

AWS B2.1-1-012:200X, Standard Welding Procedure Specification (WPS) for Shielded Metal Arc Welding of Carbon Steel, 10 Gauge through 18 Gauge, in the As-Welded Condition, With or Without Backing. This standard contains the essential welding variables for welding carbon steel in the thickness range of 10 through 18 gauge, using manual shielded metal arc welding. It cites the base metals and operating conditions necessary to make the weldment, the filler metal specifications, and the allowable joint designs for fillet and groove welds. Engineer: Len Connor, (305) 443-9353 ext. 302.

AWS B2.1-1-013:200X, Standard Welding Procedure Specification (WPS) for Shielded Metal Arc Welding of Austenitic Stainless Steel (M-8/P-8/S-8, Group 1), 10 Gauge through 18 Gauge, in the As-Welded Condition, With or Without Backing. This standard contains the essential welding variables for welding austenitic stainless steel in the thickness range of 10 through 18 gauge, using manual shielded metal arc welding. It cites the base metals and operating conditions necessary to make the weldment, the filler metal specifications, and the allowable joint designs for fillet and groove welds. Engineer: Len Connor, (305) 443-9353 ext. 302.

AWS B2.1-1-014:200X, Standard Welding Procedure Specification (WPS) for Shielded Metal Arc Welding of Carbon Steel to Austenitic Stainless Steel (M-1 to M-8/P-8/S-8, Group 1), 10 Gauge through 18 Gauge, in the As-Welded Condition, with or without Backing. This standard contains the essential welding variables for welding carbon steel to austenitic stainless steel in the thickness range of 10 through 18 gauge, using manual shielded metal arc welding. It cites the base metals and operating conditions necessary to make the weldment, the filler metal specifications, and the allowable joint designs for fillet and groove welds. Engineer: Len Connor, (305) 443-9353 ext. 302.

AWS B2.1-22-015:200X, Standard Welding Procedure Specification (WPS) for Gas Tungsten Arc Welding of Aluminum (M/P/S-22 to M/P/S-22), 18 Gauge through 10 Gauge, in the As-Welded Condition, With or Without Backing. This standard contains the essential welding variables for aluminum in the thickness range of 10 through 18 gauge, using manual gas tungsten arc welding. It cites the base metals and operating conditions necessary to make the weldment, the filler metal specifications, and the allowable joint designs for fillet and groove welds. Engineer: Len Connor, (305) 443-9353 ext. 302.

Standards for Public Review

The American Welding Society (AWS) was approved as an accredited standards-preparing organization by the American National Standards Institute (ANSI) in 1979. AWS rules, as approved by ANSI, require all standards be open to public review for comment during the approval process. This column also advises of ANSI approval of documents. The following standards are submitted for public review. A copy may be obtained by contacting Rosalinda O'Neill, American Welding Society, Technical Dept., 550 NW LeJeune Rd., Miami, FL 33126, or by calling (800) 443-9353 ext. 451, e-mail: roneill@aws.org.

B2.1-1-003:200X, Standard Welding Procedure Specification (WPS) for Gas Metal Arc Welding (Short Circuiting Transfer Mode) of Galvanized Steel (M-1), 18 Gauge through 10 Gauge, in the As-Welded Condition, With or Without Backing. Revised standard. $5.00. [ANSI Public Review expires October 23, 2001.]

B2.1-1-004:200X, Standard Welding Procedure Specification (WPS) for Gas Metal Arc Welding (Short Circuiting Transfer Mode) of Carbon Steel (M-1, Group 1), 18 Gauge through 10 Gauge, in the As-Welded Condition, with or without Backing. Revised standard. $5.00. [ANSI Public Review expires October 23, 2001.]

B2.1-8-005:200X, Standard Welding Procedure Specification (WPS) for Gas Metal Arc Welding (Short Circuiting Transfer Mode) of Austenitic Stainless Steel (M-8, P-8, or S-8), 18 Gauge through 10 Gauge, in the As-Welded Condition, With or Without Backing. Revised standard. $5.00. [ANSI Public Review expires October 23, 2001.]
Standard Notices


New Standards Approved by ANSI


♦ D14A Subcommittee Seeks Members

The D14A Subcommittee on Industrial and Mill Cranes is seeking new members. The subcommittee is responsible for collecting, reviewing, and promulgating minimum requirements considered necessary for the control of welding in the fabrication of industrial machinery and equipment. This includes weld design, data, welding process selection, materials control, fabrication practices, quality standards inspection, and tests.

For more information on becoming a D14A Subcommittee member, contact Antony Oseitutu, AWS staff engineer and secretary to the the D14 Committee and Subcommittees, 550 NW 1st Avenue Rd., Miami, FL 33126, (800) 443-9353 ext. 544 or, outside the U.S., (305) 443-9353 ext. 314, or via e-mail to aoseitut@aws.org.

♦ Order Your AWS Publications

AWS publications are now being distributed by Global Engineering Documents. To order publications, call Global at (800) 851-7179. Publications can also be ordered from the e-store on the AWS Web site, www.aws.org.

WELDING JOURNAL | 75
2001-2002 Member-Get-A-Member Campaign

Listed below are the people participating in the 2001-2002 Member-Get-A-Member Campaign. For campaign rules and a prize list, please see page 67 of this Welding Journal.

If you have any questions regarding your member proposer points, please call the Membership Department at (800) 443-3933 ext. 480.

Winner's Circle

( AWS Members sponsoring 20 or more new Individual Members, per year, since June 1, 1999.)

J. Compton, San Fernando Valley**
E. H. Ezell, Mobile**
J. Merzthal, Peru*
B. A. Mikeska, Houston*
W. L. Shreve, Fox Valley*
G. Taylor, Pascagoula*
T. Weaver, Johnstown/Altoona*
G. Woomer, Johnstown/Altoona*
R. Wray, Nebraska*

*Denotes the number of times an Individual Member has achieved Winner's Circle status. Status will be awarded at the close of each membership campaign year.

President's Guild

( AWS Members sponsoring 20 or more new Individual Members between June 1, 2001, and May 31, 2002.)

J. Merzthal, Peru — 22
R. L. Peaslee, Detroit — 21

President's Roundtable

( AWS Members sponsoring 11-19 new Individual Members between June 1, 2001, and May 31, 2002.)

T. A. Ferri, Boston — 14

President's Club

( AWS members sponsoring 6-10 new Individual Members between June 1, 2001, and May 31, 2002.)

S. R. Bollhorst, Indiana — 9
D. W. Peters, Chicago — 7
M. Hyzny, North Central Florida — 6
D. J. Schultz, Siouxland — 6
G. W. Taylor, Pascagoula — 6

President's Honor Roll

( AWS members sponsoring 1-5 new Individual Members between June 1, 2001, and May 31, 2002.)

Only those sponsoring 2 or more AWS Individual Members are listed.

J. Compton, San Fernando Valley — 3
H. M. Hunt, Tulsa — 3
J. S. Armstrong, East Texas — 2
C. Crompton, Jr, Florida West Coast — 2
R. A. Graf, Arrowhead — 2
J. S. Stiles, Florida West Coast — 2
R. Wiese, New Jersey — 2

Student Sponsors

( AWS members sponsoring 3 or more new AWS Student Members between June 1, 2001, and May 31, 2002.)

T. Huston, Pittsburgh — 25
S. E. Hower, Reading — 25
R. A. Large, Manchester — 23
B. Huff, Sangamon Valley — 12
P. Baldwin, Peoria — 11
S. Green, North Texas — 7
R. Grays, K ern — 4
L. D. Davis, New Orleans — 3
R. Felix, Long Bch./Orange City — 3
A. Honegger, LA/Inland Empire — 3
W. P. Miller, Jr., New Jersey — 3

International Welding/Joining Conference — Korea 2002

The Korean Welding Society has issued a call for papers for the International Welding/Joining Conference — Korea 2002, to be held in Kyongju, Korea, from October 28 to October 30, 2002. Topics of interest include, but are not limited to, metallurgy, high-density energy process, low-temperature joining, welding education, automation, design, welding processes, and welding fabrication.

The deadline for abstracts is February 15, 2002. Authors will be notified of acceptance by March 15, and final manuscripts are due on June 15. Abstracts and manuscripts should be written in Microsoft® Word 97 or newer format. Abstracts should not exceed 500 words.

For further information or to submit an abstract, contact Program Committee, IWG-Korea 2002, Yusong P.O. Box 104, Taejon. 305-710 Korea,FAX: 82 42 828 6513, e-mail: koweld@kws.or.kr, www.kws.or.kr/eng.html.
### 2001 District and Section Awards

#### Meritorious Awards

#### 2001 District Meritorious

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<tr>
<th>Dist.</th>
<th>Name</th>
<th>Section</th>
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<td>Shannon Fanning</td>
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<td>20</td>
<td>Kelly Niswender</td>
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#### 2001 Section Meritorious

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<tr>
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<td>Joseph Kane</td>
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<td>Alan Zibitt</td>
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<td>Jay Goyert</td>
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#### Educator Awards

#### 2001 Private Sector Educator District Awards

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<td>James Danaher</td>
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<td>Tom Heppner</td>
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<td>Jim McCarrick</td>
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#### 2001 District Educator Awards

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<td>Herbert Brown</td>
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<td>Steven Gore</td>
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<td>Russell Wahrman</td>
<td>Triangle</td>
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### 2001 District Educator Awards

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<th>Dist.</th>
<th>Name</th>
<th>Section</th>
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<td>Michael J. Bannester</td>
<td>North Central Florida</td>
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<td>Martha Vann</td>
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<td>Thomas Matecki</td>
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<td>Tina Buchanan</td>
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<td>Carl Spitzer</td>
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<td>John T. Berry</td>
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<td>Joe Smith</td>
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<td>Larry Morey</td>
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<td>Reed Nielsen</td>
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### 2001 Section Educator Awards

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<td>Bobbie Perkins</td>
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<td>Randy Owens</td>
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<td>20</td>
<td>Bob Shook</td>
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<td>20</td>
<td>Ed Golding</td>
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### CWI of the Year Awards

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<td>Kenneth Stockton</td>
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<td>Greg Shields</td>
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<td>Walter Sperko</td>
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<td>Gale Mole</td>
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<td>7</td>
<td>Tom Katzman</td>
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<td>Howard Bochmig</td>
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<td>Jim Thompson</td>
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<td>Jerry Sullivan</td>
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<td>10</td>
<td>Larry Stelhins</td>
<td>Cleveland</td>
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<td>Bob Zimny</td>
<td>Chicago</td>
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<td>Paul Burys</td>
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<td>Dan McCarty</td>
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<td>13</td>
<td>Mike Kruse</td>
<td>St. Louis</td>
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<td>13</td>
<td>Alan Mattox</td>
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<td>13</td>
<td>Mike Hanson</td>
<td>Northwest</td>
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<td>16</td>
<td>John Newhouse II</td>
<td>Kansas City</td>
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<td>17</td>
<td>Phil Walker</td>
<td>Ozark</td>
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<td>17</td>
<td>Duane McLaughlin</td>
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<td>18</td>
<td>James Veillon</td>
<td>Lake Charles</td>
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<td>18</td>
<td>Leonard Becker, Jr.</td>
<td>Sabine</td>
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<td>19</td>
<td>Sid Capouillez</td>
<td>Puget Sound</td>
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<td>20</td>
<td>Jesse Grantham</td>
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<td>Bill Komlos</td>
<td>Utah</td>
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### 2001 Section CWI of the Year Awards

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<tr>
<th>Dist.</th>
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<tr>
<td>2</td>
<td>Alfred Farland</td>
<td>Long Island</td>
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<td>4</td>
<td>Sam Glass</td>
<td>Carolina</td>
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<td>4</td>
<td>Daniel Hatter</td>
<td>Southwest Virginia</td>
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<td>4</td>
<td>Bill Jackson</td>
<td>West Tennessee</td>
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<td>8</td>
<td>Robert Thomas, Sr.</td>
<td>Holston Valley</td>
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<td>8</td>
<td>Gary Gammill</td>
<td>Northeast Mississippi</td>
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<td>9</td>
<td>Jim Casey</td>
<td>Birmingham</td>
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<td>9</td>
<td>Kevin Ryan</td>
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<td>9</td>
<td>Paul Gros</td>
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<td>Henry Cochran</td>
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<td>Norm King</td>
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<td>13</td>
<td>Zach Awad</td>
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<td>13</td>
<td>Mearle Longpecker</td>
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<td>14</td>
<td>Tim Turner</td>
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<td>14</td>
<td>Michael Kamp</td>
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<td>Steven Fults</td>
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<td>14</td>
<td>Bill Donovan</td>
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<td>17</td>
<td>Joe Dawson</td>
<td>Oklahoma City</td>
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<td>18</td>
<td>John Forney</td>
<td>Houston</td>
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<tr>
<td>20</td>
<td>Wendy Burlington</td>
<td>Eastern Idaho/Montana</td>
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<td>20</td>
<td>Ed Knowlden</td>
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<td>Reed Robbins</td>
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<td>Andrew Lutas</td>
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<tr>
<td>20</td>
<td>Terry Taylor</td>
<td>Colorado</td>
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</tbody>
</table>
GUIDE TO AWS SERVICES

550 NW LeJeune Rd., Miami, FL 33126
Phone (800) 443-9355; Telex 51-9245; (888) WELDING
Fax (305) 443-7559; Internet: www.aws.org
Phone extensions appear in parentheses.

AWS PRESIDENT
Richard L. Arn
Teletherm Technologies, Inc.
37104 Laughlin Rd.
Lisbon, OH 44432

ADMINISTRATION
Executive Director
Frank G. DeLanrier, CAE (210)
Deputy Executive Directors
Richard D. French (218)
Jeffrey R. Halsey (264)
John J. McCaughlin (235)
Assistant Executive Director
Debbie A. Gadavidi (222)
Corporate Director of Quality Management Systems
Linda K. Henderson (298)
Chief Financial Officer
Frank R. Tarafi (252)

INFORMATION SERVICES
Corporate Director
Joe Gilli (258)

HUMAN RESOURCES
Director
Luis Hernandez (266)

INTERNATIONAL INSTITUTE OF WELDING
Information (294)
Provides liaison activities involving other professional societies and standards organizations, nationally and internationally.

GOVERNMENT LIASON SERVICES
Hugh K. Webster
Webster Chambers & Bean
Washington, D.C.
(202) 466-2976
Fax (202) 855-0216
Identifies sources of funding for welding education and research & development. Monitors legislative and regulatory issues important to the industry.

WELDING EQUIPMENT MANUFACTURERS COMMITTEE
Associate Executive Director
Richard L. Alley (217)

Welding Industry Network (WIN)
Associate Executive Director
Charles R. Fassinger (297)

COMMUNICATIONS
Corporate Director, Communications
Nanette M. Zapata (308)

Corporate Director of Administrative Services
Jim Landford (214)

CONVENTION & EXPOSITIONS
Exhibiting Information (242, 250, 295)
Managing Director of Exposition Sales
Tom L. Davis (231)
Director
John Osprea (462)
Organizes the week-long annual AWS International Welding and Fabricating Exposition and Convention. Regulates space assignments, registration materials, and other Expo activities.

PUBLICATION SERVICES
Division Information (348)
Managing Director
Jeff Weber (246)
WELDING JOURNAL
Publisher
Jeff Weber (246)
Editor
Andrew Callison (249)
National Sales Director
Rob Saltzstein (274)
WELDING HANDBOOK
Welding Handbook Editor
Annette O'Brien (303)
Publishes AWS's monthly magazine, the Welding Journal, which provides information on the state of the welding industry, its technology, and society activities. Publishes the Welding Handbook and books on general welding subjects.

MEMBER SERVICES
Department Information (480)
Associate Executive Director
Cassie R. Burrell (253)
Director
Rhonda A. Mayo (260)
Serves as a liaison between Section members and AWS headquarters informs members about AWS benefits and other activities of interest.

For customized certification and educational programs to industry and government.

EDUCATION AND CONFERENCE SERVICES
Managing Director
Debrah C. Weir (219)
Information on education products, projects, and programs, CWI, SCWI, and other seminars designed for preparation for certification. Responsible for the S.E.N.S.E. program for welding education, and dissemination of training and education information on the Web.

CONFERENCE SERVICES
Director
Giselle L. Rodriguez (278)
Responsible for national and local conferences and seminars on industry topics ranging from the basics to the leading edge of technology.

Product Development
Managing Director
Debrah C. Weir (219)

CERTIFICATION OPERATIONS
Information and application materials on certifying welders, welding inspectors, and educators.

Managing Director
Wendy S. Reeve (215)
Director
Terry Perez (470)

Awards & Fellows
Managing Director
Wendy S. Reeve (215)

INTERNATIONAL BUSINESS DEVELOPMENT
Director of Intl Business Development
Walter Herrera (375)

TELEWELD
Fax: (305) 443-5951
For information about AWS technical publications, contact the technical services personnel listed below.

TECHNICAL SERVICES
Department Information (340)
Managing Director
Leonard P. Connor (302)
Qualification, Friction Welding, Food Processing Equipment
Andrew R. Davis (466) International Standards Program Manager, Welding in Marine Construction, Inspection
Stephen P. Hendrick (305) Safety and Health Manager, Metallic Processes, Mechanical Testing Engineers
Hardy H. Campbell III (300) Structural
Rakesh Gupta (301) Filler Metals
Christopher B. Pollock (304) Brazing, Soldering, Railroads, Computerization, Instrumentation, Robotics
John L. Gayler (472) Sheet Metal, Plastics and Composites, Personnel Qualification, Metals & Alloys
Ed Mitchell (254) Thermal Spray, High-Energy Beam Welding and Cutting, Resistance Welding, Automotive, Aerospace
Anthony Y. Oseintu (314) Oxutel Gas Welding & Cutting, Arc Welding and Cutting, Machinery and Equipment, Welding Iron Castings, Piping & Tubing

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AWS MISSION STATEMENT

The mission of the American Welding Society is to provide quality products and services to our members and the industry which will advance the science, technology and application of materials joining throughout the world.

AWS FOUNDATION, INC.
550 NW LeJeune Rd.
Miami, FL 33126
(305) 445-6628
(800) 443-9353, ext. 293
Or e-mail: bobw@aws.org
General Information
(800) 443-9353, ext. 689

Chairman, Board of Trustees
Ronald C. Pierce
Executive Director
Frank G. DeLaurier, CAE
Director of Development
Robert B. Witherell

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

Nominees for National Office

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

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

To be considered a candidate for positions of President, Vice President, Treasurer or Director-at-Large, the following qualifications and conditions apply:

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

Vice President: To be eligible to hold the office of Vice President, an individual must have served at least one year as a Director, other than Executive Director and Secretary.

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

Director-at-Large: To be eligible for election as a Director-at-Large, an individual shall previously have held office as Chairman of a Section, as Chairman or Vice Chairman of a standing, technical or special committee of the Society, or as District Director.

Interested parties are to send a letter stating which particular office they are seeking, including a statement of qualifications, their willingness and ability to serve if nominated and elected, and 20 copies of their biographical sketch.

This material should be sent to L. William Myers, Chairman, National Nominating Committee, American Welding Society, 550 NW LeJeune Rd., Miami, FL 33126.

The next meeting of the National Nominating Committee is currently scheduled for March 2002, in Chicago, IL. The terms of office for candidates nominated at this meeting will commence June 1, 2003.

Honorary-Meritorious Awards

The Honorary-Meritorious Awards Committee has the duty to make recommendations regarding nominees presented for Honorary Membership, National Meritorious Certificate, William Irrgang Memorial, and the George E. Willis Awards. These awards are presented in conjunction with the AWS Exposition and Convention held each spring. The description of these awards follow, and the submission deadline for consideration is July 1 prior to the year of presentation. All candidate material should be sent to the attention of John J. McLaughlin, Secretary, Honorary-Meritorious Awards Committee, 550 NW LeJeune Rd., Miami, FL 33126.

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

William Irrgang Memorial Award: This award is administered by the American Welding Society and sponsored by The Lincoln Electric Co. to honor the late William Irrgang. It is awarded each year to the individual who has done the most to enhance the American Welding Society's goal of advancing the science and technology of welding over the past five-year period.

George E. Willis Award: This award is administered by the American Welding Society and sponsored by The Lincoln Electric Co. to honor George E. Willis. It is awarded each year to an individual for promoting the advancement of welding internationally by fostering cooperative participation in areas such as technology transfer, standards rationalization, and promotion of industrial goodwill.

International Meritorious Certificate Award: This award is given in recognition of the candidate's significant contributions to the worldwide welding industry. This award shall reflect "service to the International Welding Community" in the broadest terms. The awardee is not required to be a member of the American Welding Society. Multiple awards can be given per year as the situation dictates. The award consists of a certificate to be presented at the award's luncheon or at another time as appropriate in conjunction with the AWS President's travel itinerary, and, if appropriate, a one-year membership to AWS.

Honorary Membership Award: An Honorary Member shall be a person of acknowledged eminence in the welding profession, or who is accredited with exceptional accomplishments in the development of the welding art, upon whom the American Welding Society sees fit to confer in honorary distinction. An Honorary Member shall have full rights of membership.
Bulletin Describes Oxygen Analyzer

A technical bulletin describing the DF310 process oxygen analyzer is available. The analyzer can be separated into components for mounting throughout an OEM system, or it can be housed in a single, small enclosure. It is not affected by temperature and is available in ranges from 0-500 parts per billion to 0-25%. The analyzer includes the company's nondepleting coulometric sensor that never requires rebuilding or replacing. Calibration is traceable to NIST standards.

Delta F Corp.
4 Constitution Way, Woburn, MA 01801

Industrial Catalog Features Grinding Wheels

The company's 2001 industrial catalog features grinding wheels for all MROP applications. Blank stock for fast turnaround on Creepfeed applications, rubber wheels, segments, and superabrasives are listed. The catalog also includes reference information about industry standards for grinding wheel safety, wheel shapes and faces, Rockwell hardness guide, and conversion charts.

Radiac Abrasives, Inc. 110
1015 S. College Ave., Salem, IL 62881-1410

Video Illustrates Benefits of Orbital Welding

In response to the growing use of orbital welding in a variety of industries, the company has created a video illustrating the benefits of orbital welding of tubing, fittings, valves, and other components. The six-minute video provides an overview of equipment, technology, and techniques used in the process. Demonstrations of the company's M100 power supply, standard and microweld heads and fixtures, arc gap gauge, and tube facing tool are also included.

Swagelok Co. 111
31400 Aurora Rd., Solon, Ohio 44139-2764

New Literature

For more information, circle number on Reader Information Card.

Safety Matting Featured in Catalog

More than 140 varieties of industrial matting are featured in the company's catalog.
catalog. The mats are ergonomically designed to alleviate worker fatigue and enhance safety. Products for workers in manufacturing plants who weld or work with punch presses, drill presses/lathes, band saws, paint booths, and more are presented in the catalog with color photos and full descriptions. A chemical resistance chart and product list are included in the catalog for reference.

Tennessee Mat Company, Inc.
1414 Fourth Ave. S., Nashville, TN 37210-4123

Updated Robotics Video Released

The Robotic Industries Association (RIA) has updated its free video, Introduction to Successful Robotic Solutions. The video provides a quick overview of the benefits of robotizing and industrial applications. The nine-minute video highlights several companies that have used robotic technology to reduce costs, increase productivity, and improve workplace safety. The video is available from RIA by calling (734) 994-6088.

The Robotic Industries Association
900 Victors Way, Ste. 140, Ann Arbor, MI 48108

Brochure Highlights High-Purity, Low Vapor Pressure Alloys

High Purity Alloy, a brochure explaining the scope and uses of the company’s product line, a product specification chart, and information about technical support is available. This family of alloys are vacuum melted and cast to ensure the cleanliness of the filler metal. After casting and processing, the alloys are fabricated to several standard sizes, but custom fabrication can include wire drawing, strip rolling/slitting, and blanking/ring forming.

Handy & Harman PMFG, a Lucas-Milhaupt, Inc. company
5606 S. Pennsylvania Ave., Cudahy, WI 53110

ISO 9000 Handbook Revised


Canadian Standards Association
114
178, Blvd. Rexdale, Toronto, Ontario, M9W 1R3, Canada
Mittler Supply Names CEO

Mittler Supply, Inc., South Bend, Ind., has named Dennis G. Hulth [AWS], president and chief operating officer, as chief executive officer. Mittler will retain the title of president.

Motoman Names Vice President

Glenn Jackson has joined Motoman, Inc., Dayton, Ohio, as vice president of the Advanced Systems Group. He has spent the past 16 years at FANUC Robotics, where he rose to the position of general manager of the Advanced Systems Group.

Genesis Systems Expands Sales Force

Genesis Systems Group (GSG), Davenport, Iowa, has hired John Perusek as automotive account manager for the company’s regional office in Michigan.

He is charged with account management for automotive Tier supplies.

US Inspection Names Sales Manager

US Inspection Services, Dayton, Ohio, has announced the promotion of Mike Fitzpatrick to district sales manager, Midwest. He will oversee all aspects of sales and marketing for the company’s Indianapolis and Chicago facilities.

Obituaries

David Steiner Berger

David Steiner Berger died on Friday, July 20, of heart disease. Berger was an AWS member since 1975 and served the Society as a director-at-large.

Berger was president of the Matsoo Bridge America Corp., Arleta, Calif., and was licensed by the state of Oregon as a mechanical engineer.

Berger graduated from Oregon State University with a degree in mechanical engineering. In 1952, he joined the Bridge Division of the Oregon Highway Dept. From 1970 to 1971, and again in 1973, he was with the Pittsburgh Testing Laboratory. From 1971 to 1973, he was with Mitsubishi International, and, from 1974 to 1975, with Mitsubishi Shipbuilding and Engineering, Ltd. He also served as president of the Matsoo Bridge America Corp.

An active member of the American Welding Society, Berger served as San Fernando Valley Section chairman for the 1977-1978 term. His other activities include helping with the Section’s welding inspector examination preparation courses and assisting with the AWS Qualification and Certification examinations for welding inspectors held in Tokyo (1981) and Osaka (1982), Japan.

He was a member of the U.S. Marine Corps and served in World War II and Korea. Following an honorable discharge from active service, Berger continued his military career in the Marine Corps Reserves, retiring in 1975 as a Lieutenant Colonel.

Survivors include his wife, Kathryn; daughters and sons-in-law, Judy and Jay Westinghouse and Sally and Jon Beilstein; stepsons, Michael and Jeffrey Arnot; granddaughter and grandson-in-law, Kelly and Brend Running; grandsons, Steven and Matthew Beilstein; great-grandsons, Travis and Robby Running; step-grandson, Samuel Arnot; great aunt, Virginia Spiers; and sister, Ann Smith.
AWS Counselor Nominations Invited

Friends and Colleagues:

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

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

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

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

For specifics on the nomination requirements, please contact Wendy Sue Reeve at AWS headquarters in Miami, or simply follow the instructions on the Counselor nomination form in this issue of the Welding Journal. The deadline for submission is January 14, 2002. The Committee looks forward to receiving these nominations for 2003 consideration.

Sincerely,

L. W. Myers
Chairman, Counselor Selection Committee

IMPORTANT NOTICE: Please note that the submission deadline of January 14, 2002, is two weeks earlier than in previous notices. The change was necessary because of newly announced dates for the 2002 AWS Convention.
CLASS OF 2003
COUNSELOR NOMINATION FORM

DATE______________________NAME OF CANDIDATE__________________________
AWS MEMBER NO.______________________YEARS OF AWS MEMBERSHIP______________________
HOME ADDRESS__________________________
CITY_____________________________STATE______ZIP CODE_______PHONE____________________
PRESENT COMPANY/INSTITUTION AFFILIATION__________________________
TITLE/POSITION__________________________
BUSINESS ADDRESS__________________________
CITY_____________________________STATE______ZIP CODE_______PHONE____________________
ACADEMIC BACKGROUND, AS APPLICABLE:
INSTITUTION__________________________________________________________
MAJOR & MINOR__________________________________________________________
DEGREES OR CERTIFICATES/YEAR__________________________________________________________
LICENSED PROFESSIONAL ENGINEER: YES__________NO__________STATE__________
SIGNIFICANT WORK EXPERIENCE:
COMPANY/CITY/STATE______________________________
POSITION______________________________YEARS______________________________
COMPANY/CITY/STATE______________________________
POSITION______________________________YEARS______________________________
SUMMARIZE MAJOR CONTRIBUTIONS IN THESE POSITIONS:

SUGGESTED CITATION (50 TO 100 WORDS, USE SEPARATE SHEET) INDICATING WHY THE NOMINEE SHOULD BE SELECTED AS AN AWS COUNSELOR. IF NOMINEE IS SELECTED, THIS STATEMENT MAY BE INCORPORATED WITHIN THE CITATION CERTIFICATE.

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

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

NOMINATING MEMBER:__________________________
AWS Member No.______________________
NOMINATING MEMBER:__________________________
AWS Member No.______________________
NOMINATING MEMBER:__________________________
AWS Member No.______________________
NOMINATING MEMBER:__________________________
AWS Member No.______________________

SUBMISSION DEADLINE FEBRUARY 1, 2002
Nomination of AWS Counselor

I. HISTORY AND BACKGROUND

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

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

- Leadership of or within an organization that has made a substantial contribution to the welding industry. (The individual’s organization shall have shown an ongoing commitment to the industry, as evidenced by support of participation of its employees in industry activities such as AWS, IIW, WRC, VICA, NEMA, NSRP SP7 or other similar groups.)
- Leadership of or within an organization that has made substantial contribution to training and vocational education in the welding industry. (The individual’s organization shall have shown an ongoing commitment to the industry, as evidenced by support of participation of its employees in industry activities such as AWS, IIW, WRC, VICA, NEMA, NSRP SP7 or other similar groups.)

II. RULES

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

III. NUMBER OF COUNSELORS TO BE SELECTED

2001 Class of Counselors:
Year one, maximum of 20 Counselors selected, as determined by the committee
2002 Class of Counselors:
Year two, maximum of 20 Counselors selected, as determined by the committee
2003 Class of Counselors:
Year three, maximum of 15 Counselors selected, as determined by the committee
2004 Class of Counselors:
Year four, and thereafter: maximum of 10 Counselors selected, as determined by the committee

Return completed Counselor nomination package to:

Wendy S. Reeve
American Welding Society
550 N.W. LeJeune Road
Miami, FL 33126
Telephone: 800-443-9353, extension 215

SUBMISSION DEADLINE: February 1, 2002
Q: We are using BNi-5 to braze nozzles made of AISI 316L. The application in pharmaceutical processing requires a smooth surface to ensure a complete cleaning between nozzles. Is there a brazing procedure utilizing this base-material/filler-metal combination that will result in smooth fillets?

A: Your question about surface quality of fillets is frequently asked. Because penetrant bleeds out along the fillet line when the part sets, penetrant inspectors often classify the porosity as a crack.

First, a little history on the subject. When the American Welding Society (AWS) brazing specifications were written, the subject of porosity and penetrant inspection was discussed at length. As a final decision, the qualifying sentence, "These inspection techniques are not suitable for inspection of brazed fillets because they routinely give false results," was added to AWS C3.6, Specification for Furnace Brazing, paragraph 5.4.3.1.

Some of the variables that affect fillet porosity and surface contour include:

1) Fillet size vs. porosity. In general, the larger the fillet size, the more porosity there is. Conversely, the smaller the fillet, the less porosity.

2) Brazing temperature vs. porosity. The higher the brazing temperature, in general, the more porosity there is. This is caused by the brazing filler metal dissolving more base metal, thus resulting in the liquid filler metal, at the brazing temperature, having a wider melting range. To obtain less porosity, the brazing temperature should be as low as possible.

3) Time at heat vs. porosity. The longer the time at heat, the more base metal dissolved into the filler metal. This results in more porosity.

4) Location of the filler metal vs. porosity. Applying the filler metal to the bottom of a tubular joint or the back side of a joint will generally keep the excess filler metal (larger fillets) away from the critical fillet side. Also, the fillet on the opposite side of the joint from the filler metal placement is generally smaller and smoother.

5) Atmosphere vs. porosity. BNi-5 is...
one of the more sensitive to atmosphere quality filler metals. But, vacuum pressure is only one of many things that makes up atmosphere quality. Therefore, a good vacuum reading does not necessarily ensure good atmosphere quality. A residual gas analyzer (RGA) on the vacuum furnace will certainly help because it is very sensitive. But, the RGA may not solve all atmosphere problems because it analyzes the cold gases and does not pick up materials that condense in the heat shielding as the temperature drops. A very simple T-specimen with a large glob of BNi-5 on one side, on one end, put in the furnace with the load will have a story to tell. The atmosphere quality is very good for BNi-5 if the filler metal all flows away from the point of application and leaves only a stain. If there is a substantial pile of filler metal remaining at the point of application, the silicon and chromium in the filler metal were oxidized during heating, in the range of 540 to 925°C (1000 to 1700°F). This can add to porosity and, in particular, the fillet roughness problem.

6) Filler metal solidus to liquidus range vs. porosity. In general, the wider the range between the solidus and liquidus, the more porosity can be expected. For this reason, it is best to have a filler metal with the narrowest melting range.

7) Solubility of base metal in filler metal vs. porosity. In general, the more the base metal is dissolved by the filler metal, the wider the melting range and the more porosity present.

8) Cooling rate vs. porosity. Slow cooling allows dendrites, the first material to solidify, to form in the fillet. As cooling progresses, the liquid portion of the filler metal shrinks back into the joint, thus pulling back into the fillet. This exposes the dendrites, resulting in more porosity and a rougher fillet. Torch brazing, with its short time at heat and fast cooling when the torch is pulled away, gives fewer problems with porosity. Furnace-brazed parts have a much longer time above the solidus of the filler metal and cool much slower. Therefore, they have more porosity.

9) Eutectic alloys vs. porosity. Eutectic alloys with a single melting point are much better than BNi-5 and have less porosity, assuming they do not have any of the aforementioned problems. Unfortunately, it is essential to have a chemistry range when manufacturing filler metals. This indicates eutectic filler metal can be expected to have at least some melting range. If the phase diagram indicates a very steep valley to the eutectic composition, the melting range would be expected to increase.

10) Pure metals vs. porosity. A pure metal with a single-melting point, such as copper or silver, should result in no porosity. Unfortunately, pure metal also undersea cable and remain corrosion-free for the next 50 years. Unfortunately, salt spray testing showed copper corrosion products along the gold-plated fillet. The boxes had been copper brazed at the normal temperature of 1150°C (2000°F) and, at that temperature, enough iron was dissolved to form dendrites on cooling, thus causing porosity. The thin gold plating covered the fillet surface but failed to close the very small porosity, allowing the salt spray fog to penetrate the pores and form copper corrosion salts on the surface of the fillet. At that time, we did not think of all of the above variables and resorted to brazing with a gold copper filler metal with suitable corrosion resistance.

11) BNi-5 vs. porosity and smoothest fillet. As is apparent, many variables affect the porosity and roughness of the fillet. The best chance of reducing the porosity and roughness, or eliminating them, is the following:

- Make the smallest fillets possible.
- Reduce the brazing temperature to the lowest possible temperature that will produce a sound joint.
- Hold the time at heat as short as possible.
- Place the filler metal at the bottom of a tubular joint or the opposite side of the joint from the critical fillet.
- Be sure to have the best quality atmosphere, vacuum, or hydrogen.
- Cool as fast as practical.

While it should not be necessary, gas tungsten arc and electron beam welding have been used to smooth fillets when necessary.

Since the brazing filler metal and base metal are specified, items 6 and 7 cannot be changed. Note that for each of the above items, there are consequences. Space limitations, however, do not allow us to address them at this time.

I hope this will shed some light on the complex porosity problem and solutions for BNi-5. We would appreciate hearing from anyone about their experiences dealing with the fillet porosity problem.

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OCTOBER 2001
Jim Turner's Dream Becomes A Reality at Central Piedmont Community College

In 1941, with only $500 cash and the promise of several suppliers to let him sell merchandise on consignment, James Austin Turner, Jr., founded National Welders Supply Company, selling merchandise from the trunk of his car. From this humble beginning, Turner built National Welders Supply into one of the largest independently owned industrial gas manufacturers/welding supply distributors in the United States, as well as the largest privately owned company of any type in the state of North Carolina.

Turner always understood the importance of educating welders. During World War II, he set up a school to train welders for work in the shipyards on the East Coast. One of his lifelong passions was to elevate the position of welder to that of a recognized, degreed professional.

Turner's dream is about to become a reality. In November, Central Piedmont Community College's (CPCC) Southwestern Campus, Charlotte, N.C., will dedicate the Jim Turner Center for Welding Technology. To honor the memory of Jim Turner and his dedication to welding education, his daughter, Judith T. Carpenter, chair of the board for National Welders Supply, arranged a $1 million donation from the Turner Family Foundation, along with the Foundation of the Carolinas, to fund the Turner Center. The Center will provide state-of-the-art equipment, materials, processes, and support services to the welding program at CPCC. The goal of the Center is to offer "welders a way in which to achieve professional status in their field."

According to Turner Center Director Anver Classens, the Center consists of "30 welding stations and 10 flexible stations, which can be modified for use depending of the processes being taught each semester" (some classes are offered only on alternate semesters). The Center is outfitted with an industrial robotic welding machine, a cutting machine, and ultrasonic and X-ray testing equipment. Also at the lab are ten gas tungsten arc welding machines donated by The Lincoln Electric Co., and a newly arrived metal shear machine custom fabricated in Spain to fit the lab.

Central Piedmont's welding program began in 1963. Last year, the program was moved to the college's new Southwestern Campus and expanded to 7685 sq ft. It has been growing and currently has approximately 100 full-time students.

The college's welding technology curriculum provides students with a sound understanding of the science, technology, and applications essential for successful employment in the welding and metal industries. Required courses in math, blueprint reading, metallurgy, welding inspection, and destructive and nondestructive examination provide students with industry-standard skills.

Students can graduate with an associate's degree in applied science-welding technology and receive a diploma, or they may opt to earn one or more of the state-approved certificates the college offers including Welding Technology with a Specialization in Shielded Metal Arc Welding of Pipe, Welding Technology with a Specialization in Inert Gas Welding, or Welding Technology with a Specialization in Entry Level Welding (advanced and expert level welding certificates are also available). American Welding Society certification as QC-10 Entry Level Welder, QC-11 Advanced Level Welder, and QC-12 Expert Level Welder is available at the school, which is an AWS Accredited Test Facility.

In addition to the traditional means of financial aid, CPCC offers a "Jumpstart" scholarship. This scholarship, funded through private donations, is for students to receive technical training. It pays for tuition, fees, books, and supplies for short-term technical programs designated as Jumpstart. These programs currently include web development, Novell networking, HEATT diesel, printing and graphics, and welding. By the end of a 16-week term, students can earn their Entry Level Welder certification, making them eligible to be hired by companies and to earn a good living. Most students in the Jumpstart program return to CPCC for additional training (often paid for by their employers) through the school's evening classes.

Classens said, "The Turner Family Foundation pushed for the Jim Turner Center for Welding Technology to be a high-tech facility." And it is. Already highly rated throughout North Carolina, with the opening of the Turner Center, CPCC has become "a leader of North Carolina [welding] schools," Classens said. -- Susan Campbell, Associate Editor
Relief for robotic indigestion.

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Manual Torch Brazing

Manual torch brazing involves broad heating of the assembly by a flame. The torch or workpiece are moved to achieve uniform heating of both surfaces to be joined.

Flux is normally required with the process. An exception is the joining of pure copper base metal with phosphorus-bearing filler metal. The phosphorus joins with the oxides on the surface to provide wetting of the filler metal.

Torch brazing is widely used because of its relatively low cost and portability. The flame is generated by the combustion of a combination of oxygen and a fuel gas. The same equipment can be used as with oxyfuel gas welding. The process lends itself to the use of low-melting filler metals, which have excellent flow characteristics.

Torches

The components of a manual torch are body, mixer, and tip. The torch body consists of a handle and valves to control the flow of oxygen and fuel gas. The mixer provides the chamber for mixing the fuel gas and oxygen for proper combustion. There are a variety of torch tips, each designed to provide a certain flame profile and size.

Torches come in a variety of sizes from small ones that allow a 30 ft³/h flow of acetylene to very large ones with a 400 ft³/h acetylene flow.

Tips

Torch tips are normally made of copper alloys, which possess high thermal conductivity, minimizing overheating potential. Tips used with acetylene or hydrogen have a flat face across the orifice, while those used with propane or other fuel gases have recessed faces at the orifice. Orifice diameters vary. The manufacturer's recommendations should be followed for a specific application because torch size and mixer design can affect tip performance.

Fuel Gases

The fuel gases commonly used for torch brazing are acetylene, natural gas, propane, propylene, and certain proprietary mixes. These gases are mixed with oxygen or air. The maximum heat obtained is with the oxygen-fuel gas mixture. Flame temperature and cost are major factors in selecting a fuel gas.

Acetylene gas is high on the preference list because its flame reaches a temperature as high as 5660°F. It is supplied in cylinders and dissolved in acetone, a solvent capable of absorbing 25 times its own volume. This method of supply is the best known way to ensure safe delivery of this highly explosive gas. When not absorbed in acetone, acetylene is unstable and may explode at temperatures of 1435°F or higher, or at pressures more than 30 psig. The accepted safe practice for acetylene is never to use it at pressures in excess of 15 psig.

Flame Characteristics

As the ratio of oxygen to fuel gas changes, the nature of the flame changes. The most common flame conditions used are reducing and neutral. Oxidizing flames are not recommended.

Carburizing Flame. As oxygen is added to the fuel gas, the flame becomes luminous and sooting disappears. As the oxygen content is increased, the luminous part of the flame becomes smaller and is centered near the torch tip. A blue zone, consisting of an excess of fuel gas, forms around the outside edge of the flame. This flame can be used for brazing.

Reducing Flame. As the oxygen content is increased further, the luminous area becomes smaller and consists of an inner cone with a feathery trail extended outward from the flame end. This condition indicates a slight excess of fuel gas and is an excellent flame for brazing.

Neutral Flame. When the oxygen addition reaches the ratio necessary for the fuel gas to be completely combusted, the feather that extended out from the bright inner cone disappears. This flame is used in brazing when an excess of carbon in the reducing flame is detrimental to the base metals or when maximum flame temperature is required.

Oxidizing Flame. When the oxygen-to-fuel gas ratio exceeds that needed for complete combustion, the flame becomes oxidizing. The flame produces a hissing sound. The inner cone in the flame will appear to be constricted. Oxidizing flames are not recommended for brazing.

Fuel Gas Flame. When hydrocarbon fuel gases are burned without oxygen or added through the torch, they typically produce a yellowish flame. Soot particles are usually present because the oxygen in the air is not sufficient to support complete combustion. This flame is not useful in brazing.
Safety with Oxyfuel Gas Brazing

Hazards associated with oxyfuel gas brazing include injury from improper selection and use of equipment and consumable materials, inhalation of toxic fumes and gases emitted during the brazing process, exposure to heat rays from the flame or hot metal, and fire from the contact of the flame or metal spatter with combustible materials. Electric shock is also a potential hazard if the operation is automated.

Torching

All welding and cutting torches should be of an approved type. They should be kept in good working order and serviced at regular intervals by the manufacturer or qualified technicians. A torch must be used only with the fuel gas for which it is designated. The fuel gas and oxygen pressures should be those recommended by the torch manufacturer.

The procedure recommended by the manufacturer should be followed when lighting and extinguishing the torch. The torch should be lighted only with a friction lighter, pilot light, or similar ignition source. Do not use matches or cigarette lighters.

Hoses

Hoses should be only those specified for oxyfuel gas brazing systems. Generally, these hoses are manufactured in accordance with RMA/CGA publication IP-7. The fuel gas hose is usually red with left-hand threaded fittings. A green hose with right-hand fittings is generally used for oxygen. Hoses should be free of any greases and in good condition. When parallel lengths are taped together for convenience, no more than 4 in. of any 12-in. section of hose should be covered.

Only proper ferrules and clamps should be used to secure the hose to fittings. Long runs of hose should be avoided. Excess hose should be coiled to prevent kinks and tangles, but it should not be wrapped around cylinders or cylinder carts while in use.

Backfire

A backfire during brazing is a momentary retrogression of the flame back into the tip. It usually results in a momentary flame-out followed by reignition of the tip flame and is accompanied by a pop or bang, depending on the size of the tip.

In severe cases, however, hot products of combustion within the tip may be forced back into the torch and even the hose. Occasionally, such backfires ignite the inner liner of hoses (especially oxygen), resulting in the hoses burning through. Such backfires can cause injury.

Flashback

A flashback is an occurrence initiated by a backfire where the flame continues to burn inside the equipment instead of being re-established at the tip. Flashbacks result in very rapid internal heating of the equipment and can destroy equipment quickly.

Usually a flashback is recognized by a whistling or squeal-
Without a doubt, aluminum is increasingly being used within the welding fabrication industry. There has been a major increase in usage by the automotive industry, and by industries such as furniture, recreation and sporting equipment, shipbuilding, transportation and containers, military, and aerospace. Developments in aluminum usage continue with a view toward using it as a replacement for steel.

As more aluminum components are produced, the need for reliable repair work on aluminum weldments has also increased. Repair work to aluminum structures is regularly carried out on such items as truck bodies and boat hulls needing repair after damage from collision or after wear and tear resulting from severe service conditions — Fig. 1.

This article will examine some common considerations associated with the repair of aluminum alloys that can help prevent problems associated with such work, thus ensuring successful repairs.

**Identification of Alloy Type**

Probably the most important consideration encountered during a repair operation is identification of the aluminum base alloy. If the base material type of the component requiring repair is not available through a reliable source, it can be difficult to select a suitable welding procedure. There are guides that list the most probable type of aluminum used in different applications, such as most extruded aluminum (typically 6-series Al-Mg-Si). Air conditioning systems and heat exchangers manufactured by the automotive industry are typically made from 3003 or 5052 plate and 6061 tubing — Fig. 2. Car wheels are often made from 5454 and are suitable for temperature applications because of its controlled magnesium (less than 3% Mg). Ship hulls are often made with 5083 (5% Mg).

However, if the base material type is not known or is unavailable, chemical analysis is the only reliable way of establishing the exact type of aluminum alloy present. A small sample of the base material must be sent to a reliable aluminum testing laboratory, and a chemical analysis must be performed. The substance's chemistry can then be evaluated and a determination made as to the most suitable filler alloy and welding procedure to use. This is an important step to undertake because incorrect assumptions about the chemistry of an aluminum
alloy can result in very serious effects on the welding results.

There are seven major types of aluminum alloys with a wide range of mechanical properties and, consequently, a wide range of performance and applications. Some have very good weldability while others do not and are unsuitable if welded, for structural applications. Some can be properly welded with one type of filler alloy while others cannot, making welds with poor mechanical properties. Filler alloy and base alloy chemistry mixture are main considerations relating to welded joint suitability, crack sensitivity, and joint performance. Without knowing the base material type, it is difficult to assess the correct filler and base alloy mixture.

If an aluminum component is to be repair welded and later used in a structural application, welding should not commence until a thorough understanding of the alloy type and the correct welding procedure to be followed is established, particularly if a later weld failure could result in property damage and/or injury.

High-Performance Aluminum Alloy Repair

Another problem associated with the repair of small aluminum structures is the temptation to repair high-performance, high-replacement price components made from exotic aluminum alloys. These materials are usually not welded onto original components and are often found on aircraft, hang gliders, sporting equipment, and other types of high-performance, safety-critical equipment.

There are a small number of high-performance aluminum alloys that are unweldable. Performing welding on such components and then returning them to service can be dangerous. Probably the two most commonly found aluminum alloys within this category are 2024, an aluminum, copper, magnesium alloy and 7075, an aluminum, zinc, copper, and magnesium alloy.

Both materials can be susceptible to stress corrosion cracking after welding, which is particularly dangerous because it is generally a type of delayed failure, not detectable immediately after welding, that develops after the component has been in service for some time. The completed weld joint may appear to be of excellent quality immediately after welding. X-rays and ultrasonic inspection shortly after welding typically will find no indication of a welding problem. However, changes that occur within the base material adjacent to the weld during the welding process can produce a metallurgical condition within these materials that can result in intergranular microcracking that may be susceptible to propagation and eventual failure of the welded component. The probability of failure can be high and the time to failure unpredictable and dependent on variables such as tensile stress applied to the joint, environmental conditions, and the period of time that the component is subjected to these variables.

Care should be taken when considering the repair of components made from these materials. As stated before, if there is any possibility of a weld failure becoming the cause of damage to property or injury to persons, repair work by welding on these alloys should not be performed and the component should not be returned to service.

Base Material Strength Reduction after Repair Welding

There are considerations relating to the effect heating has on base material during the repair-welding process. Aluminum alloys are divided into heat-treatable and nonheat-treatable alloys. Each has a different effect on the repair process.

Since they do not respond to heat treatment, nonheat-treatable alloys are used in a strain-hardened condition to improve the alloy’s mechanical properties. During the welding process, heat introduced to the aluminum base will generally return the base material, adjacent to the weld, to its annealed condition. This will typically produce a localized reduction in strength within this area and may or may not be of any design/performance significance.

Heat-treatable alloys are almost always used in one heat-treated form or another. Often, they are used in the T4 or T6 condition (solution heat-treated and naturally aged or solution heat-treated and artificially aged). Base materials in these heat-treated tempers are in optimum mechanical condition. Heat introduced to these base materials during the repair welding process can change mechanical properties within the repair area. Unlike nonheat-treatable alloys, which are annealed and returned to this condition when subjected briefly to a specific temperature, heat-treatable alloys are affected by time and temperature.

The effect from heating during welding repair on a heat-treatable alloy is generally a partial anneal and an overaging effect. Because the amount of reduction in strength is largely determined by overall heat input during the welding process, there are guidelines as to how this reduction can be minimized. Generally, minimum amounts of preheating and low interpass temperatures should be used to control this effect. However,
even with the best-designed welding procedures, considerable loss in tensile strength is always experienced within the heat-affected zone when arc welding these types of materials.

Unfortunately, it is usually either cost restrictive or, more often, impractical to perform postweld-solution heat treatment because of the high temperatures required and distortion associated with the process.

Cleaning and Material Preparation Prior to Welding

Even when welding on new components made from new material, cleanliness of the part to be welded is important. Aluminum has a great attraction for hydrogen; hydrogen’s presence in the weld area is often related to the cleanliness of the plate being welded. When working with this type of material, one must be aware of the potential problems associated with used components that may have been subjected to contamination through exposure to oil, paint, grease, or lubricants. Such contaminants can provide hydrocarbons that can cause porosity in the weld during the welding operation.

The other source of hydrogen that should be considered is moisture, often introduced through the presence of hydrated aluminum oxide. For these reasons, it is important to completely clean the area to be repaired prior to welding. This is typically achieved by using a degreasing solvent to remove hydrocarbons followed by stainless steel wire brushing to remove any hydrated aluminum oxide. More aggressive chemical cleaning may be required for certain applications.

In cases that require removal of an existing weld or base material to conduct a repair, one should consider the methods available to perform this operation and the affect it will have on the finished weld. If a crack in the surface of a weld prior to rewelding needs to be removed, a method that will not contaminate the base material to be welded should be used. Care should be taken when using grinding discs; some have been found to contaminate the base material by depositing particles onto the surface of the aluminum. Routing and chipping with carbide tools is often the most successful method for material removal. Care must be exercised if using plasma arc cutting or gouging, particularly on heat-treatable aluminum alloys. This can produce microcracking of the material surface after cutting, which is typically removed mechanically prior to welding.

Conclusion

There are many considerations associated with the repair of aluminum alloys. Perhaps the most important point to understand is there are many different aluminum alloys that require individual consideration. The majority of the base materials used for general structural applications can be readily repaired using the correct welding procedure. The majority of aluminum structures are designed to be welded in the as-welded condition and, therefore, with the correct consideration, repair work of previously welded components can and should be conducted satisfactorily.
Prevention and Control of Weld Distortion

Distortion can be troublesome, but there are a variety of ways to control it

Beginning welders, and even those that are more experienced, commonly struggle with the problem of weld distortion (warping of the base plate caused by heat from the welding arc). Distortion is troublesome for a number of reasons, but one of the most critical is the potential to create a weld that is not structurally sound. This article will help define what weld distortion is, then provide a practical understanding of the causes of distortion, describe effects of shrinkage in various types of welded assemblies and how to control it, and, finally, look at methods for distortion control.

What is Weld Distortion?

Distortion in a weld results from the expansion and contraction of the weld metal and adjacent base metal during the heating and cooling cycle of the welding process. Welding done entirely on one side of a part will cause much more distortion than if the welds are alternated from one side to the other. During this heating and cooling cycle, many factors affect shrinkage of the metal and lead to distortion, such as physical and mechanical properties that change as heat is applied. For example, as the temperature of the weld area increases, yield strength, elasticity, and thermal conductivity of the steel plate decrease, while thermal expansion and specific heat increase — Fig. 1. These changes, in turn, affect heat flow and uniformity of heat distribution.

Reasons for Distortion

To understand how and why distortion occurs during heating and cooling of a metal, consider the bar of steel shown in Fig. 2. As the bar is uniformly heated, it expands in all directions, as shown in Fig. 2A. As the metal cools to room temperature, it contracts uniformly to its original dimensions.

But if the steel bar is restrained (as in a vise) while it is heated, as shown in Fig. 2B, lateral expansion cannot take place. Since volume expansion must occur during heating, the bar expands in a vertical direction (in thickness) and becomes thicker. As the deformed bar returns to room temperature, it will still tend to contract uniformly in all directions, as in Fig. 2C. The bar is now higher and thinner. It has been permanently deformed, or distorted.

In a welded joint, these same expansion and contraction forces act on both the weld and the base metal. As the weld metal solidifies and fuses with the base metal, it is in its maximum expanded form. On cooling, it attempts to contract to the volume it would normally occupy at the lower temperature, but is restrained from doing so by the adjacent base metal. Because of this, stresses develop within the weld and the adjacent base metal. At this point, the weld stretches (or yields) and thins out, thus adjusting to the volume requirements of the lower temperature. But only those stresses that exceed the yield strength of the weld metal are relieved by this straining. By the time the weld reaches room temperature — assuming complete restraint of the base metal so that it cannot move — the weld will contain locked-in tensile stresses approximately equal to the yield strength of the metal. If the restraints (clamps that hold the workpiece, or an opposing shrinkage force) are removed, the residual stresses are partially relieved as they cause the base metal to move, thus distorting the weldment.

Shrinkage Control — What You Can Do to Minimize Distortion

To prevent or minimize weld distortion, methods must be used both in design and during welding to overcome the effects of the heating and cooling cycle. Shrinkage cannot be prevented, but it can be controlled. There are several ways to minimize distortion caused by shrinkage.

Do not overweld. The more metal placed in a joint, the greater the shrinkage forces — Fig. 3A. Correctly sizing a weld for the requirements of the joint not only minimizes distortion, but also saves weld metal and time. The amount of weld metal in a filler weld can be minimized by the use of a flat or slightly

Based on information from The Lincoln Electric Co., Cleveland, Ohio, (216) 481-8100.
convex bead, and in a butt joint by proper edge preparation and fitup — Fig. 3B. The excess weld metal in a highly convex bead does not increase the allowable strength in code work, but it does increase shrinkage forces.

When welding heavy plate (over 1-in. thick), bevelling or even double bevelling can save a substantial amount of weld metal, which automatically translates into much less distortion.

In general, if distortion is not a problem, select the most economical joint. If distortion is a problem, select either a joint in which the weld stresses balance each other or a joint requiring the least amount of weld metal.

Use intermittent welding. Another way to minimize weld metal is to use intermittent rather than continuous welds where possible, as in Fig. 3C. When attaching stiffeners to plate, for example, intermittent welds can reduce the weld metal by as much as 75%, yet provide the needed strength.

Use as few weld passes as possible. Fewer passes with large electrodes (Fig. 3D) are preferable to a greater number of passes with small electrodes if transverse distortion poses a problem. Shrinkage caused by each pass tends to be cumulative, thereby increasing total shrinkage when many passes are used.

Place welds near the neutral axis. Distortion is minimized by providing a smaller leverage for the shrinkage forces to pull the plates out of alignment. Figure 3E illustrates this. Both design of the weldment and welding sequence can be effectively used to control distortion.

Balance welds around the neutral axis. This practice, shown in Fig. 3F, offsets one shrinkage force with another to effectively minimize distortion of the weldment. Here, too, design of the assembly and proper sequence of welding are important factors.

Use backstep welding. In the backstep technique, the general progression of welding may be, say, from left to right, but each bead segment is deposited from right to left, as in Fig. 3G. As each bead segment is placed, the heated edges expand, temporarily separating the plates at B. But as the heat moves out across the plate to C, expansion along outer edges C-D brings the plates back together. This separation is most pronounced as
the first head is laid. With successive heads, the plates expand less and less because of the restraint of prior welds. Backstepping may not be effective in all applications, and the technique cannot be used economically in automatic welding.

**Anticipate shrinkage forces.** Presetting parts (at first glance, it was thought this referred to overhead or vertical welding positions, which is not the case) before welding can make shrinkage perform constructive work. Several assemblies, preset in this manner, are shown in Fig. 3H. The required amount of preset for shrinkage to pull the plates into alignment can be determined from a few trial welds.

Prebending, presetting, or prespringing the parts to be welded (Fig. 3J) is a simple example of the use of opposing mechanical forces to counteract distortion due to welding. The top of the weld groove, which will contain the bulk of the weld metal, is lengthened when the plates are preset. Thus, the completed weld is slightly longer than it would be if it had been made on the flat plate. When the clamps are released after welding, the plates return to the flat shape, allowing the weld to relieve its longitudinal shrinkage stresses by shortening to a straight line. The two actions coincide, and the welded plates assume the desired flatness.

Another common practice for balancing shrinkage forces is to position identical weldments back to back (Fig. 3L), clamping them tightly together. The welds are completed on both assemblies and allowed to cool before the clamps are released. Prebending can be combined with this method by inserting wedges at suitable positions between parts before clamping.

In heavy weldments particularly, the rigidity of the members and their arrangement relative to each other may provide the balancing forces needed. If these natural balancing forces are not present, it is necessary to use other means to counteract the shrinkage forces in the weld metal. This can be accomplished by balancing one shrinkage force against another or by creating an opposing force through fixturing. Opposing forces may be other shrinkage forces; restraining forces imposed by clamps, jigs, or fixtures; restraining forces arising from the arrangement of members or components. It was mentioned earlier in this section that the restraining force provided by clamps increases internal stresses in the weldment until the yield point of the weld metal is reached. For typical welds on low-carbon plate, this stress level would approximate 45,000 lb/ft². One might expect this stress to cause considerable movement or distortion after the welded part is removed from the jig or clamps. This does not occur, however, since the strain (unit contraction) from this stress is very low compared to the amount of movement that would occur if no restraint were used during welding.

**Remove shrinkage forces after welding.** Peening is one way to counteract the shrinkage forces of a weld head as it cools. Essentially, peening the bead stretches it and makes it thinner, thus relieving (by plastic deformation) the stresses induced by contraction as the metal cools. But this method must be used with care. For example, a root bead should never be peened, because of the danger of either concealing a crack or causing one. Generally, peening is not permitted on the final pass because of the possibility of covering a crack and interfering with inspection and because of the undesirable work-hardening effect. Thus, the utility of the technique is limited, even though there have been instances where between-pass peening proved to be the only solution for a distortion or cracking problem. Before peening is used on a job, engineering approval should be obtained.

Another method for removing shrinkage forces is by thermal stress relieving, which is controlled heating of the weldment to an elevated temperature, followed by controlled cooling. Sometimes two identical weldments are clamped back to back, welded, and then stress-relieved while being held in this straight condition. The residual stresses that would tend to distort the weldments are thus minimized.

**Minimize welding time.** Since complex cycles of heating and cooling take place during welding and since time is required for heat transmission, the time factor affects distortion. In general, it is desirable to finish the weld quickly, before a large volume of surrounding metal heats up and expands. The welding process used, type and size of electrode, welding current, and speed of travel affect the degree of shrinkage and distortion of a weldment. The use of mechanized
welding equipment reduces welding time and the amount of metal affected by heat and, consequently, distortion. For example, depositing a given-size weld on thick plate with a process operating at 175 A, 25 V, and 3 in./min requires 87,500 J of energy per linear inch of weld (also known as heat input). A weld with approximately the same size produced with a process operating at 310 A, 35 V, and 8 in./min requires 81,400 J per linear inch. The weld made with the higher heat input generally results in a greater amount of distortion (the words “excessive” and “more than necessary” are not used because the weld size is, in fact, tied to the heat input). In general, the filler weld size (in inches) is equal to the square root of the quantity of the heat input (kJ/in.) divided by 500. Thus, these two welds are most likely not the same size.

### Other Techniques for Distortion Control

#### Water-Cooled Jig

Various techniques have been developed to control distortion on specific weldments. In sheet-metal welding, for example, a water-cooled jig (Fig. 4) is useful to carry heat away from the welded components. Copper tubes are brazed or soldered to copper holding clamps and the water is circulated through the tubes during welding. The restraint of the clamps also helps minimize distortion.

#### Strongback

The strongback is another useful technique for distortion control during butt joint welding of plates, as shown in Fig. 5. Clips are welded to the edge of one plate and wedges are driven under the clips to force the edges into alignment and to hold them during welding.

#### Thermal Stress Relieving

Except in special situations, stress relief by heating is not used for correcting distortion. There are occasions, however, when stress relief is necessary to prevent further distortion from occurring before the weldment is finished.

### Summary

#### A Checklist to Minimize Distortion

In summary, follow the checklist below in order to minimize distortion in the design and fabrication of weldments.

- Do not overweld.
- Control fitup.
- Use intermittent welds where possible that are consistent with design requirements.
- Use the smallest leg size permissible when fillet welding.
- For groove welds, use joints that will minimize the volume of weld metal. Consider double-sided joints instead of single-sided joints.
- Weld alternately on either side of the joint when possible with multiple-pass welds.
- Use a minimal number of weld passes.
- Use low heat-input procedures. This generally means high deposition rates and higher travel speeds.
- Use welding positioners to achieve the maximum amount of flat-position welding. The flat position permits the use of large-diameter electrodes and high-deposition-rate welding procedures.
- Balance welds about the neutral axis of the member.
- Distribute welding heat as evenly as possible through a planned welding sequence and weldment positioning.
- Weld toward the unrestrained part of the member.
- Use clamps, fixtures, and strongbacks to maintain fitup and alignment.
- Prebend members or preset joints to let shrinkage pull both back into alignment.
- Sequence subassemblies and final assemblies so the welds being made will continually balance each other around the neutral axis of the section.

Following these techniques will help minimize the effects of distortion and residual stresses.
Test Your Knowledge

1. Which of the following is not always an essential element of a FCAW system?
   a. constant voltage power supply
   b. tubular electrode
   c. wire feeder
   d. shielding gas
   e. none of the above

2. Shielding for the GTAW and PAW processes is accomplished through the use of
   a. granular flux
   b. slag
   c. inert gas
   d. reactive gas
   e. none of the above

3. A green stripe on a tungsten electrode designates
   a. pure tungsten
   b. 1% thoriated tungsten
   c. 2% thoriated tungsten
   d. zirconated tungsten
   e. none of the above

4. When welding aluminum with the GTAW process, what type of welding current is commonly used?
   a. DCEP
   b. DCEN
   c. AC
   d. both a and b above
   e. both a and c above

5. SAW and ESW are similar in that
   a. both are arc welding processes
   b. both use shielding gas
   c. both use a granular flux
   d. both a and b above
   e. both b and c above

6. A welding process done essentially in the flat position with welding progressing from bottom to top of the weld joint positioned vertically identifies
   a. GMAW
   b. SAW
   c. ESW
   d. both a and b above
   e. both b and c above

7. Which are not common to both GTAW and PAW?
   a. nonconsumable tungsten electrode
   b. copper constricting nozzle
   c. shielding gas nozzle
   d. externally applied filler metal
   e. none of the above

8. What technique is employed with PAW to produce full-penetration welds?
   a. stringer beads
   b. weave beads
   c. keyhole
   d. backstep
   e. none of the above

9. Brazing differs from welding in that
   a. no filler metal is used
   b. an oxyfuel flame is used
   c. the base metal is not melted
   d. all of the above
   e. none of the above

10. For satisfactory results, a braze joint should have
    a. a large surface area
    b. a small clearance between pieces to be joined
    c. a precise bevel
    d. both a and b above
    e. both b and c above

11. Of the following metals, which cannot be effectively cut using OFC
    a. high-carbon steel
    b. low-carbon steel
    c. medium-carbon steel
    d. stainless steel
    e. none of the above

12. The diagram below depicts what welding process?
    a. SMAW
    b. ESW
    c. FCAW
    d. SAW
    e. PAW

Diagram:

Answer: 1. c, 2. b, 3. c, 4. d, 5. c, 6. c, 7. a, 8. a, 9. c, 10. c, 11. d, 12. c
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JIC = Inside Front Cover
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Simulation of Dynamic Behavior in a GMAW System

A model is developed to predict variations in welding parameters due to surface tension and electromagnetic force

BY J. H. Choi, J. Y. Lee, AND C. D. Yoo

ABSTRACT. The dynamic behavior of a GMAW system is simulated using a short circuiting transfer model incorporated with characteristic equations for the power supply, welding wire, and arc. The wire equation, which relates the variation of the wire extension to the wire feed and melting rates, is modified to include the effect of a molten drop attached at the wire tip. With this modification, the behavior of the GMAW system is described more precisely, and information about the initial bridge volume is provided to simulate the short circuit transfer.

A short circuit model is proposed to predict the variation of short circuit parameters considering the effects of surface tension and electromagnetic force due to current. Variation of welding parameters are continuously simulated during short circuit as well as free-flight transfer modes, and the calculated results are in broad agreement with the experimental results that occur with argon shielding.

Introduction

Although determining the proper welding condition is an important task in the gas metal arc welding (GMAW) process, it is time consuming and requires considerable trial and error. In order to estimate the operating range of welding parameters and process stability, the behavior of the GMAW system needs to be predicted in cases of free-flight and short circuiting transfer modes. In this work, the characteristic equations for the GMAW system are solved using a simplified short circuiting transfer model to predict the dynamic behavior of the system. The simulation results are verified by comparing with the experimental results. Since the GMAW system consists of several subsystems including the power supply, welding arc, and wire, as illustrated in Fig. 1, its characteristics depend on the dynamic behavior of each subsystem, which has been described using the characteristic equation.

The power supply was converted into an equivalent RL circuit, and the wire equation was used to describe the rate change of the wire extension with respect to welding parameters. The welding arc characteristics were expressed using Ayrton's equation modified for the gas metal arc welding globular and spray transfer modes (Refs. 1, 2). The constants for Ayrton's equation and wire melting rate were experimentally determined, and these values are used in this work for simulation.

Richardson, et al. (Ref. 3), considered the dynamic effects of the power source on wire melting rate in pulsed GMAW. Quinn, et al. (Ref. 4), proposed the electrode extension model based on heat transfer to predict the variation of wire extension and to determine the welding conditions under which short circuiting transfer takes place.

In order to simulate the GMAW process continuously, it is necessary to consider the metal transfer mode. In the case of free-flight modes, such as globular and spray, the static force balance model and pinch instability theory have been most widely utilized to predict drop detaching conditions (Refs. 5, 6). However, few models were reported for the short circuit mode compared with the free-flight mode. Ishichenko (Ref. 7) proposed the simple analytic short circuit model to predict the short circuit time due to surface tension, but the effect of the electromagnetic force was ignored. Although numerical technique was recently employed to analyze the short circuit as well as the free-flight modes (Refs. 8, 9), this approach is not adequate to simulate the entire GMAW system because of its complexity and computing time. It appears that simulation of the short circuiting transfer combined with the free-flight mode has not been attempted, mainly due to lack of a proper short circuit model.

Continuous simulation of the GMAW process is of interest in this work, especially when the short circuit mode is involved, because process stability was reported to be dependent on short circuit frequency, current, and voltage signals (Refs. 10, 11). The conventional welding

KEY WORDS

GMAW
Gas Metal Arc
Short Circuiting Transfer Model
Surface Tension
Electromagnetic Force
Transfer Model
wire equation is modified to predict the system behavior more precisely and to provide the initial bridge volume for short circuiting transfer. A short circuit model is proposed to predict the variation of short circuit parameters considering the effects of surface tension and electromagnetic force. With the characteristic equations and short circuit model, it becomes possible to simulate the dynamic behavior of the GMAW system. The predicted results are compared with the experimental results for argon shielding.

**Modeling of the GMAW System**

**Characteristic Equations**

The dynamic behavior of the welding power supply, welding arc, and wire as shown in Fig. 1 is described using the corresponding characteristic equations. The power supply is converted into the equivalent RL circuit as

\[ L \frac{dI}{dt} + RI = U_o - U_a \]  

where \( L \) and \( R \) represent the inductance and resistance of the welding system, \( I \) the welding current, \( U_o \) the equivalent open-circuit voltage, and \( U_a \) the arc voltage. The welding arc characteristics are described using Ayrton's equation (Refs. 1, 2)

\[ U_a = k_1 + k_2 I + (k_3 + k_4 I)^2 \]  

where \( \ell_a \) denotes the arc length and the \( k \) denotes the constants depending on the welding wire and shielding gas. The conventional wire equation has been used to describe the relationship between the rate change of the extension, wire feed, and melting rate

\[ \frac{d\ell_e}{dt} = v_f - v_m \]  

where \( \ell_e \) represents the extension, \( v_f \) the wire-feed rate, \( v_m \) the wire-melting rate, and \( a \) and \( b \) the constants for arc and joule heating, respectively.

The conventional wire equation assumes the molten portion at the wire tip is detached or removed as soon as it melts. This assumption appears to be valid in the spray mode, where small droplets are ejected at high frequency. However, in the globular mode, the molten drop grows at the wire tip for a relatively long period so that it affects the arc length and, subsequently, welding current and voltage. To predict the dynamic behavior of GMAW more precisely, the conventional wire equation needs to be modified to include the effect of a hanging droplet at the wire tip. The wire extension is described in this work as the sum of the solid extension length and molten drop length hanging at the wire tip as illustrated in Fig. 1 (i.e., \( \ell_e = \ell_{es} + \ell_{ed} \)) so that the effect of the molten drop is considered until its detachment. In this case, the rate change of the solid wire extension depends on the wire-feed and melting rates, and the drop growth rate is proportional to the wire-melting rate until its detachment

\[ \frac{d\ell_{es}}{dt} = v_f - v_m \]  

\[ \frac{dV_d}{dt} = \left( \frac{\pi D_d^2}{4} \right) v_m \]

where \( \ell_{es} \) represents solid wire extension, \( V_d \) the attached drop volume, and \( D_d \) the wire diameter. The drop length, \( \ell_{od} \), is calculated from the drop volume by assuming a spherical shape.

Drop detachment is determined using the force balance model and pinch instability theory for the globular and spray modes, respectively (Refs. 5, 6, 12). When the drop detaches, the entire drop volume is assumed to be ejected from the wire tip (i.e., \( \ell_{ed} = 0 \)). The short circuit transfer takes place as soon as the extension becomes equal to the contact tip to workpiece distance (CTWD). Since the arc is extinct during the short circuit period, the arc voltage in equation 1 and the constant \( a \) for arc heating in equation 3 become 0. The modified wire equation provides information about the initial bridge volume for the short circuiting transfer, as well as the effects of the hanging drop on welding parameters for the free-flight mode.

**Modeling of the Short Circuiting Transfer**

A short circuit model that includes the effects of surface tension and electromagnetic force is proposed and used to
predict variations of the welding parameters during short circuiting transfer. The following assumptions are made to simplify the complex behavior of short circuiting transfer:

1) The initial bridge shape is spherical and the contact diameter within the weld pool surface is equal to the wire diameter.
2) Flow velocity within the bridge and pressure within the weld pool are neglected.
3) The bridge shape is described by two principal radii, as illustrated in Fig. 2.
4) The pool surface remains flat and metal transfer is stable.

Once the bridge is formed, molten metal flows into the weld pool due to surface tension and electromagnetic force, and the bridge shape varies continuously as in Fig. 2A. The bridge shape is described using the principal radii of \( R_1 \) and \( R_2 \) in Fig. 2B, and \( R_2 \) is determined from the bridge volume and height, which vary continuously during a short circuit period. Given the principal radii, the average pressure on the cross section of the bridge center is derived (Ref. 12) as follows:

\[
P_{\text{avg}} = \frac{\mu_0 I^2}{8 \pi R_2^2} + \gamma \left( \frac{1}{R_1} + \frac{1}{R_2} \right) \tag{6}
\]

where \( \mu_0 \) represents the permeability and \( \gamma \) the surface tension. Applying the Bernoulli equation with assumption 2, the flow velocity at the contact between the bridge and pool surface can be calculated using the average pressure and bridge height as

\[
v = \frac{2}{\rho} \left( P_{\text{avg}} + \rho gh \right) \tag{7}
\]

where \( \rho \) denotes the mass density of molten metal and \( h \) the distance between the pool surface and bridge center. The volume to be transferred from the bridge to molten pool is calculated by multiplying the flow velocity, contact area, and discrete time interval \( \Delta t \). The bridge volume and height are used to calculate the principal radii, and the short circuit time is the sum of the discrete time intervals until bridge breakup. It is noted that the Bernoulli equation was utilized to estimate the plasma jet velocity in the arc welding, and it predicted the experimental results within the order of magnitude (Ref. 12). Therefore, similar accuracy is expected for the flow velocity and short circuit time predicted using this short circuit model.

**Calculation Procedure**

When the wire-feed rate, CTWD, and equivalent open circuit voltage (OCV) are given as the inputs, variations of welding parameters such as the extension, drop volume, current, and voltage are calculated by solving the characteristic equations numerically using the Runge-Kutta method. The drop-detaching condition for the free-flight mode is determined using the force balance model and pinch instability theory. To simulate the free-flight mode, the open circuit voltage is selected to be equal to the experimental welding voltage because of the constant voltage characteristics of the GMAW power source.

When the extension becomes equal to the CTWD, the short circuit model is applied. Since the arc is extinct during the short circuit time, the effect of the arc is eliminated such that arc voltage and the constant \( a \) for arc heating in equations 1 and 3 become 0. The initial bridge volume is given from the results of characteristic equations in the free-flight mode. The pressure and flow velocity are computed using the principal radii, equations 6 and 7. Assuming constant flow velocity during the small time interval, \( \Delta t \), the remaining bridge volume and corresponding principal radii are calculated for the next time step. For each time step, current and voltage are computed iteratively using equations 1 and 3, and this procedure is repeated until bridge breakup. When the arc is regenerated, effects of the arc are restored in equations 1 and 3, and half of the final bridge volume is given as the initial drop volume attached at the wire tip, as in Fig. 2A.
The constants and parameters used for computation are listed in Table 1 (Refs. 1, 2). It is noted that constants a, b, and each k are valid only for steel welding wire with a 1.2-mm diameter and 100% argon shielding condition. Bead-on-plate welds were made and welding parameters such as the wire-feed rate, welding current, and voltage were measured. The welding conditions were selected as CTWD of 15–25 mm, welding current of 150–350 A, and voltage of 18–34 V so that short circuit and free-flight transfer modes were produced.

Figure 3 shows the experimental results of current and voltage waveform in the spray mode under the condition of a wire-feed rate of 156.1 mm/s and CTWD of 19 mm. Average current and voltage of the experimental results are 343.2 A and 32.7 V, respectively.

The simulated results using the conventional and modified wire equations are compared in Fig. 4 where the current and voltage waveforms are calculated using the same experimental parameters and open circuit voltage (OVC) of 32.7 V. When the modified wire equation is used, small ripples caused by droplet growth and detachment are calculated in the waveform. In the case of the conventional wire equation, constant current and voltage of 340 A and 30.3 V are calculated without ripples, which correspond to the average current and voltage for the modified wire equation. In both cases, welding voltage is maintained constant with small fluctuation, which demonstrates the self-regulation effect of GMAW in the steady state. Comparing with the experimental results, the current and voltage are predicted quite accurately using the characteristic equations. The droplet at the wire tip appears to have negligible effects because small droplets are ejected at high frequency in the spray mode.

Measured current and voltage waveforms in the globular mode are shown in Fig. 5 with a wire-feed rate of 104.3 mm/s and CTWD of 25 mm. The average current and voltage of the experimental results are 207.3 A and 27 V. The calculated results using the same experimental parameters are illustrated in Fig. 6. Since the drop grows larger in the globular mode, the magnitude of the ripple increases for the modified wire equation. Similar to the spray mode, the current and voltage with the conventional wire equation are constant at 214 A and 25.9 V, respectively, which correspond to the average values with the modified wire equation. Although the effect of the attached drop increases in the globular mode, it appears to have only minor effects on welding parameters.

Results and Discussions

Globular and Spray Transfer Modes

The constants and parameters used for computation are listed in Table 1 (Refs. 1, 2). It is noted that constants a, b, and each k are valid only for steel welding wire with a 1.2-mm diameter and 100% argon shielding condition. Bead-on-plate welds were made and welding parameters such as the wire-feed rate, welding current, and voltage were measured. The welding conditions were selected as CTWD of 15–25 mm, welding current of 150–350 A, and voltage of 18–34 V so that short circuit and free-flight transfer modes were produced.

Table 1 — Constants Used for Calculation (Refs. 1, 2)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass density, ρ</td>
<td>7800 kg/m³</td>
</tr>
<tr>
<td>Kinematic viscosity, ν</td>
<td>2.8 x 10⁻⁷ m²/s</td>
</tr>
<tr>
<td>Surface tension</td>
<td>1.2 N/m</td>
</tr>
<tr>
<td>Coefficient, γ</td>
<td>4π x 10⁻² m²/s (globular)</td>
</tr>
<tr>
<td>Permeability, μ</td>
<td>0.02383 mm²/As (spray)</td>
</tr>
<tr>
<td>Constant for arc heating, a</td>
<td>4.6061 x 10⁻³ A⁻²⁻¹</td>
</tr>
<tr>
<td>Constant for joule heating, b</td>
<td>6.27 x 10⁻⁵ A⁻²⁻¹ (short circuit)</td>
</tr>
<tr>
<td>System resistance, R</td>
<td>5.0 mΩ/A</td>
</tr>
<tr>
<td>System inductance, L</td>
<td>0.35 mH</td>
</tr>
<tr>
<td>k₁</td>
<td>16.24 V</td>
</tr>
<tr>
<td>k₂</td>
<td>0.02376</td>
</tr>
<tr>
<td>k₃</td>
<td>0.553 V/mm</td>
</tr>
<tr>
<td>k₄</td>
<td>6.395 x 10⁻² V/Amm</td>
</tr>
</tbody>
</table>

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Short Circuiting Transfer Mode

Effects of the initial bridge volume and current on the principal radius and short
circuit time as predicted using the proposed short circuit model are shown in Figs. 7 and 8. The principal radius \( R_1 \) varies during the short circuit period because the bridge volume decreases continuously until bridge breakup. Variations of the principal radius \( R_1 \) during the short circuit period are illustrated in Fig. 7. When the current is kept constant at 300 A during short circuiting transfer and imposed on the bridge with the initial bridge radius of 0.75, 1, and 1.25 mm, the short circuit time increases with larger bridge radius in Fig. 7A. When the constant currents of 150, 300, and 450 A are applied to a bridge with an initial radius of 1 mm, the short circuit time decreases with the higher current in Fig. 7B. The principal radius decreases linearly up to the wire radius of 0.6 mm, and it decays rapidly afterward because the pinch force increases due to reduction of the current-conducting area.

The effects of the initial bridge radius and current on short circuit time are illustrated in Fig. 8 where constant current is used during the short circuit period. While the short circuit time decreases with the higher current and smaller initial bridge radius, the initial bridge radius appears to have more influence on the short circuit time than the current. In practice, the relationships between the bridge volume, current, and short circuit time are coupled so that larger bridge volume induces longer short circuit time and higher current, which acts to accelerate bridge breakup. During continuous simulation, the initial bridge volume is given by solving the characteristic equations.

Figure 9 shows the experimental current and voltage waveforms in the short circuit mode with a wire-feed rate of 82.1 mm/s, welding voltage of 21.2 V and CTWD of 19 mm. Average current and voltage are 184.6 A and 18.9 V, and the short circuit frequency becomes 65.8 Hz with a short circuit and arcing time of 2.3 and 12.9 ms, respectively. The calculated results using the same experimental parameters with OCV of 21.2 V are illustrated in Fig. 10. Average current and voltage are 174 A and 20.3 V, and the short circuit frequency becomes 55 Hz with short circuit and arcing time of 1.1 and 16.9 ms. Compared with the experimental results, there exists significant discrepancy in short circuit time (2.3 vs. 1.1 ms). However, arcing time and short circuit frequency are predicted with reasonable accuracy (12.9 vs. 16.9 ms, 66 vs. 55 Hz). Since the arcing time is much longer than short circuit time, the discrepancy in short circuit time has minor effects on the frequency. While experimental peak current is higher than calculated peak current by 50 A due to longer short circuit time, the predicted average current and voltage show reasonably good agreement with the experimental results.

Since the behavior in the free-flight mode is accurately predicted, the larger discrepancy in the short circuit time appears to stem from the short circuit model. Among several reasons, assumption 2 appears to be the major cause of error because it may oversimplify the complex behavior of metal flow within the bridge and pool. Another assumption of the spherical bridge shape and
Prediction of Metal Transfer Mode

A mixed metal transfer mode is calculated using the parameters at the boundary between short circuit and free-flight modes. Figure 11 shows the experimental results with the wire-feed rate of 82.1 mm/s, welding voltage of 22 V and CTWD of 19 mm. It is noted welding voltage is increased slightly higher than that in Fig. 9 (21.2 vs. 22 V). Average current and voltage are 175.7 A and 22 V, the short circuit frequency and time are 11 Hz and 4.9 ms, respectively. The simulated waveforms using the same experimental parameters with OCV of 22 V are illustrated in Fig. 12 where the average contact condition may not be appropriate, especially when the initial bridge volume becomes smaller. Oversimplification of the proposed short circuit model includes the simple bridge shape during the short circuit period and remaining bridge volume at the bridge breakup. Further development of the short circuit model is needed for accurate prediction of the short circuit time.
current and voltage are 180 A and 21.1 V, and short circuit frequency and time are 13 Hz and 6.1 ms, respectively. The predicted results show reasonably good agreements with the experimental results. In addition to the short circuit model, the drop is calculated to be detached in the free-flight mode just after bridge breakup, which demonstrates that both free-flight and short circuit modes take place in a mixed way under this welding condition.

Figure 13 shows the metal transfer modes identified using the fixed CTWD of 19 mm. The metal transfer mode including the mixed mode is predicted using the welding parameters equal to the experimental condition, and the narrow region of the mixed mode exists between the free-flight and short circuit modes. The predicted mixed and short circuit modes are in broad agreement with the experimental results. It appears the metal transfer mode as well as the variation of welding parameters can be predicted through simulation when the wire-feed rate, CTWD, and equivalent open circuit voltage are given as the inputs.

Conclusions

The dynamic behavior of the GMAW system is continuously simulated using the modified wire equation and short circuit model. Although the system behavior is predicted more precisely using the modified wire equation, it has only minor effects in the free-flight mode. The importance of the modified wire equation is to provide the initial bridge volume for the short circuit model. The short circuit model needs further improvement to yield more accurate short circuit time predictions. Combining the characteristic equations with the short circuit model, the welding current, voltage, and metal transfer mode, including the mixed mode, are predicted with reasonable accuracy for argon shielding.

Acknowledgment

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References


Call For Papers

The two-day international conference, Supermartensitic Stainless Steels 2002, organized by the Belgian Welding Institute, is now soliciting abstracts of papers for oral presentation. The conference will be held October 3-4, 2002, in Brussels, Belgium.

The supermartensitic stainless steels are also known as the weldable martensitic stainless steels or super 13 Cr steels with low carbon content. Paper topics can include overviews, research, case histories, applications, new technology, failure reports, service experience, or anything relevant to the subject. Sales pitches promoting particular products or services will not be accepted. Main topic areas include, but are not limited to, service and applications, metallurgy, welding, fabrication, manufacturing, toughness requirements, and corrosion. The conference language will be English.

Abstracts of 300-500 words on a single A4 page should be submitted by mail, fax, or e-mail before November 1, 2001, to the Conference Secretariat. The submission should be single-line spaced, headed by the title, name(s), and affiliation(s) of all authors, along with the full address, telephone, fax, and/or e-mail of the corresponding author. Papers are accepted on the understanding the author(s) will attend the conference.

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Heat Generation in the Inertia Welding of Dissimilar Tubes

A reduced thermal model is developed that accurately captures joint temperatures and provides guidance in weld parameter development

BY V. R. DAVÉ, M. J. COLA, AND G. N. A. HUSSEN

ABSTRACT. The transient thermal response in inertia welding is difficult to capture analytically. Heat is generally dissipated over time scales of less than one second, an order of magnitude faster than direct-drive friction welding. The present work critically examines the nature of the heat generation term through an analysis of experimental data. The method presented here determines the heat generation term for the inertia welding of dissimilar tubes (tube thickness small in comparison to radius so that radial effects are neglected) solely based on machine-generated data, namely the curve of angular speed vs. time and the magnitude of material burnoff. A simple approach to determining the heat allocation to both sides of the dissimilar joint is proposed, and the resulting thermal problem is solved using an analytical method. The predictions are compared to actual thermocouple data from welds conducted under identical conditions, and are shown to be in good agreement. Although the method proposed in this work does not replace more detailed numerical analyses of the inertia welding process, it does provide guidance in weld parameter development. This is demonstrated through the model-based scaling of weld parameters for dissimilar tube welds over a range of tube diameters.

Introduction

Previous Thermal Models of Friction and Inertia Welding

In industrial friction and inertia welding production situations, it is not always possible to conduct extensive instrumented testing during which temperature data are gathered. Peak joint temperature and the temperature profile in the region near the weld can have a significant impact on flash formation, heat-affected zones, and joint strength. Cooling rates are closely related to joint temperature profiles and they directly influence the residual stress state developed in the joint. The issue of residual stress becomes more significant in dissimilar material joints. It is therefore desirable to have a means of rapidly and accurately estimating peak joint temperatures and cooling rates based on input parameters and routinely gathered inertia welding machine performance data.

The present model offers such estimates based on an analytical solution and two proposed parametric representations of the heat generation term. The model presented here is specifically for tubular cross sections, and the analytical models assume constant, but temperature-averaged, material properties. The only required inputs are the measured decay of the rotational speed, the moment of inertia of the flywheel, the total burnoff or reduction in length due to flash, and an assessment (or assumption) of how the burnoff is divided between the two tubes.

It is not the intent of this work to supplant more detailed numerical analyses of the inertia welding process, which are important in determining such mechanical aspects of the process as residual stress and flash formation. The present model is, however, sufficiently accurate to be used as a reduced-order thermal model for process optimization and parameter development in the inertia welding of tubes. A more accurate "truth" model, such as a finite element model, can then be used to further examine a more limited set of interesting parameters and quantify flash evolution and residual stress formation.

The first published analytical solution to the transient thermal history during friction welding is generally attributed to Rykalin, et al. (Ref. 1), although several of the same era researchers from the former Soviet Union also discussed heat input during friction welding (Refs. 2-4). The mathematics upon which this analytical solution is based appears, among other places, in the work of Carlslaw and Jaeger (Ref. 5). The model assumptions are semi-infinite solid; constant flux at the free surface for time $t_0$, then flux is "turned off"; zero initial temperature; and constant material properties. The solution is given by the following equation (Refs. 1, 5):

For $0 \leq t \leq t_0$:

$$T = \left( \frac{2\alpha t}{k} \right) \left[ -\frac{x}{2} \text{erfc} \left( \frac{x}{2\sqrt{\alpha t}} \right) \right]$$

For $x > t_0$:

$$T = \left[ \sqrt{\alpha t} \cdot \text{erfc} \left( \frac{x}{2\sqrt{\alpha t}} \right) \right]$$

where $k$ is the thermal conductivity, $\alpha$ is the thermal diffusivity, $x$ is the distance.
from the weld interface, and \( q_o \) is the magnitude of the surface heat flux.

The next significant contribution was made by Cheng (Refs. 6, 7), who analyzed both similar and dissimilar tubular joint configurations. Cheng numerically solved the differential equation of heat conduction (see Equation 2, which follows) with appropriate boundary conditions, and also allowed the material properties to vary with temperature (Ref. 6):

\[
\frac{\partial T}{\partial t} + U(t) \frac{\partial T}{\partial x} = \frac{1}{\rho c_p} \left( k \frac{\partial^2 T}{\partial x^2} \right) - \frac{\sigma e P}{\rho c_p A} (T^4 - T_0^4) - \frac{hP}{\rho c_p A} (T - T_0)
\]

(2)

where \( A \) is the cross-sectional area, \( T_0 \) is the ambient temperature surrounding the tube, \( \rho \) is the density, \( \sigma \) is the film coefficient of heat transfer (convective cooling), \( U(t) \) is the velocity of the melt front, \( e \) is the emissivity, and \( \sigma \) is the Stefan-Boltzmann constant. Cheng allowed for the existence of a melt layer by incorporating a moving boundary term. Several experimental studies have refuted the notion of melting during friction welding, such as the work of Weiss and Hazlett (Ref. 8), and this topic will be revisited later in the present work. As Wang (Ref. 9) pointed out, it is quite likely that softened material at temperatures near the melting point will be expelled as flash before melting can occur.

Wang and Nagappan (Ref. 10) performed a thermal analysis similar to that of Cheng but for the inertia welding of steel bars. Their predictions showed the peak temperature to be less than the melting point and that for inertia welding, the peak temperatures are achieved very quickly as compared to conventional friction welding. Additionally, they noted a strong dependence of the predicted temperature distribution on the total welding time. This total welding time is a function of all the main process variables: initial rotational speed, thrust pressure, moment of inertia, etc. Their model has good qualitative agreement with measured temperature values.

Johnson, et al. (Ref. 11), have also noted the power dissipation curve for inertia welding is very different than that for friction welding. They have suggested a two-part curve: Stage I, corresponding to a more concentrated initial contact and Stage II, a slower (relatively slower) decay. They proposed the following functional forms:

Stage I: \( q(t) = q_{\text{max}} \sin(\omega t) \)

Stage II: \( q(t) = \frac{q_{\text{max}}}{\pi} \frac{\sqrt{k \rho c_p}}{\pi} \)

(3)

where \( q_{\text{max}} \) is the maximum power dissipation and \( T_{\text{max}} \) is the maximum interface temperature attained — Fig. 1. A more recent multistage thermal model for direct-drive friction welding was developed by Midling and Grong (Ref. 12), who proposed various analytical forms for the heating stage, steady-state condition, and cooling stage based on continuous planar disc sources at the weld interface.

There are numerous finite element analyses and finite difference models on both conventional friction and inertia welding. These modeling efforts account for the heat generation term by examining the coupled thermomechanical problem together with an interfacial friction law. This interfacial friction law or constitutive relation must account for frictional heating. Sluzalec (Refs. 13, 14) was one of the first to use the finite element analysis (FEA) approach for friction welding, and Moal, et al. (Refs. 15, 16), have developed an FEA model specifically for inertia welding. Sahin, et al. (Refs. 17, 18), have produced a series of finite difference models, Weiss (Ref. 19) has also investigated the residual stresses after welding using the FEA approach. Fu and Doan (Ref. 20) have more recently used the FEA approach to model the axial pressure distribution in addition to the temperature field.

As mentioned earlier, this work is a reduced order model of the inertia welding process. It is motivated by the need to have simple, yet realistic, models that can be used for in-situ process monitoring and control and for rapid parameter development and validation. It differs from previous works in that it attempts to more accurately capture heat generation during welding as a function of time by using data routinely gathered by the inertia welding machine. This data is directly used as an input to the thermal simulation, which in this case is a reduced-order analytical model of heat conduction. As such, this approach could also be used with more sophisticated models for heat transfer, and would provide a reasonable estimate of heat generation without having to explicitly model the combined thermomechanical problem. Also, this approach is amenable to an on-line monitoring strategy that flags potentially defective welds in critical components and has the potential to alleviate the inspection burden by reducing it to “inspection for cause” as opposed to inspecting every component.

Equipment and Experimental Procedure

The commercially pure niobium and 316L stainless steel utilized in this study were in the form of 1 in.-diameter tubes. The Nb tube wall thickness was slightly thicker (0.125 in.) than the 316L tube wall (0.08 in.) to provide for greater forging action during the upset stage. Prior to
Inertia welding, the tubes were sectioned into 3-in.-lengths and the faying surfaces were machined while flood cooled in isopropyl alcohol.

Inertia welds were produced using an MTI Model 90B inertia welding system. Initial emphasis was placed on determining parameters capable of producing joints that could sustain bending through 90 deg. Once suitable starting parameters were developed, welds were made at a surface velocity of 393 ft/min and axial force of 8330 Ibf while maintaining a constant moment of inertia of 5.19 Ibm-ft²; P = 8330 Ibf. The nonlinear, least-squares-fit parameters are m = 2.931 and n = 1.718. The heat input is then assumed to have the following form:

\[ Q(t) = A_0 \cdot \omega(t) \]  

where \( Q \) is the total heat input in watts, \( \omega \) is the speed curve as represented by Equation 7, and \( A_0 \) is a constant. The constant is evaluated based on conservation of energy. Before this can be done, it is recognized that some of the energy available to the joint from the flywheel will be used to heat and expel flash. Therefore,
the effective energy conducted into the workpiece will be less than the initial energy of the flywheel. The approach taken in this work was to examine the joint after the weld and make a determination as to the amount of material expelled from each side. For example, in the case of dissimilar welds between Nb and 316L stainless, the flash was expelled almost entirely in the Nb. The inertia welding machine tracks the reduction in length during the weld, and, therefore, it is possible to know the burnoff directly from machine measurements. Then it is assumed the flash carries off an amount of energy equal to

$$E_{\text{flash}} = B \cdot A_c \cdot p \cdot C \cdot \Delta T_{\text{MAX}}$$  

(9)

where $B$ is the total reduction in length, or burnoff; $A_c$ is the cross-sectional area of the tube; $p$ is the density; $C$ is the average specific heat over the temperature range $\Delta T_{\text{MAX}}$ and $\Delta T_{\text{MAX}}$ is the maximum temperature rise.

Since the maximum temperature attained is not known a priori, an iterative procedure must be used. The peak joint temperature is first estimated, the energy lost to flash is then evaluated, the resulting thermal profile is calculated, and the process is repeated until the maximum predicted temperature matches the estimate. The constant $A_3$, can now be evaluated:

$$Q(t) = A_0 \cdot \omega(t)$$

$$\int_0^t Q(t') dt' = (E_0 - E_{\text{flash}})$$

so

$$A_0 = \frac{(E_0 - E_{\text{flash}})}{\int_0^t \omega(t') dt'}$$

where $E_0 = \frac{1}{2} I_0 \omega_0^2$  

(10)

The second method of determining the heat flux involves direct consideration of the dissipation of rotational kinetic energy by the weld. For any given time during the weld, it can be generally said the following expression relates the energy dissipated by the weld to the loss in kinetic energy of the flywheel:

$$E_{\text{weld}}(t) = \frac{1}{2} I_0 \omega_0^2 - \frac{1}{2} I_0 \left[\omega(t)\right]^2$$  

(11)

Therefore, it is immediately observed that the power dissipation in the weld is given by the following:

$$Q(t) = -I_0 \omega(t) \cdot \frac{d\omega}{dt}$$  

(12)

This ignores stored elastic energy in the tooling or inertia welding machine and also ignores other energy losses such as machine friction and grip "slippage," i.e., energy loss at the workpiece/tool interface. It turns out this method was independently discovered by Dr. H. A. Nied, Sr., of General Electric Co., and was brought to the authors' attention through Ref. 22. Using the same model for the rotational speed as shown in Equation 7, the total power dissipation in the weld is assumed to be the following:

$$Q(t) = C_0 \cdot m \cdot n \cdot \frac{1}{1 + \frac{k_2 \cdot P_2 \cdot C_2}{k_1 \cdot P_1 \cdot C_1}}$$  

(13)

The thermal profiles can now be evaluated with the aid of Duhamel's theorem, as applied to the case of 1-D heat conduction in a semi-infinite solid with a time-varying flux at the free surface, as follows:

$$T(x, t) = \frac{1}{k} \cdot \int_0^t q(t') dt'$$

$$\exp \left(\frac{-x^2}{4 \alpha^2 t} \right)$$  

(15)

where $q(t)$ is the time-varying surface flux.

The heat flux $q$ is easily derived from the expressions for total power shown in Equations 8 and 13 by considering the cross-sectional area and the fraction of energy entering into a particular side of the joint, as follows:

$$q(t) = \frac{Q_{\text{total}}(t)}{A_c} \cdot \frac{1}{1 + \frac{k_2 \cdot P_2 \cdot C_2}{k_1 \cdot P_1 \cdot C_1}}$$  

(16)

For the two proposed heat inputs, the thermal profiles will now be compared for a stainless steel-to-niobium weld. The weld parameter data and assumed thermal properties of the materials are shown in Table 1. The resulting thermal profiles are shown in Figure 5 and are compared to the actual data at the position of the weld interface, i.e., x = 0. Model 1 refers to the heat flux as specified by Equation 8, whereas Model 2 refers to the heat flux as given by Equation 13.

A measure of how well the two models represent the data can be deduced by considering the error as a function of time:

$$\text{Error}(t) = M(t) - Y(t)$$  

(17)

where $M(t)$ is the predicted temperature at $t$ and $Y(t)$ is the measured temperature at $t$. 

Fig. 6 — Error as defined by Equation 14 shown as a function of time for Models 1 and 2.

Fig. 7 — The effect of variations in thermomechanical properties on model predictions.
Table 1 — Weld Parameter Data and Assumed Thermal Properties

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Rotational Speed</td>
<td>1407 rpm (1500 nominal)</td>
</tr>
<tr>
<td>Moment of Inertia</td>
<td>5.19 lb-ft²</td>
</tr>
<tr>
<td>Axial Welding Force</td>
<td>8310 lb</td>
</tr>
<tr>
<td>Average Specific Heat for Nb over 273–1273 K</td>
<td>0.29 J/g-K</td>
</tr>
<tr>
<td>Average Thermal Conductivity for Nb over 273–1273 K</td>
<td>0.59 W/cm-K</td>
</tr>
<tr>
<td>Average Specific Heat for 316 SS over 273–1273 K</td>
<td>0.56 J/g-K</td>
</tr>
<tr>
<td>Average Thermal Conductivity for 316 SS over temperature range 273–1200 K</td>
<td>0.21 W/cm-K</td>
</tr>
<tr>
<td>Fraction of total power going to Nb side</td>
<td>0.445</td>
</tr>
<tr>
<td>Fraction of total power going to 316 SS side</td>
<td>0.555</td>
</tr>
</tbody>
</table>

The nominal bond pressure is usually not altered as the size is increased, although the bond force is adjusted to make the bond pressure constant. In the present treatment, the effect of pressure is considered and modifications to the bond pressure with size are proposed. The effect of increasing pressure is tracked by a close examination of the power dissipation curves, and joints made in components of different sizes are considered “equivalent” when their respective power dissipation curves resemble one another.

The behavior of the hot, highly worked interfacial layer that forms during the inertia weld can generally be modeled using the following phenomenological form (Ref. 15):

$$\tau = (\text{const.}) (\Delta v)^p$$  \hspace{1cm} (19)

where $\tau$ is the shear stress, $\Delta v$ is the relative slip velocity, and $P$ is the interfacial bond pressure.

The slip velocity for thin-walled tubes is given by $v = \alpha r$, where $r$ is the average radius. The expression for the tangential shear (radial shear effects ignored) stress then becomes the following:

$$\tau(t) = (\text{const.}) [\alpha(t) r(t)]^p$$ \hspace{1cm} (18)

or

$$\frac{\tau(t)}{[\alpha(t)]^p} = (\text{const.}) r(t)^p$$ \hspace{1cm} (20)

The quantities on the left-hand side of Equation 20 are directly related to the heat input and power dissipation during the weld. Therefore, if it is assumed the power dissipation is to be held constant as the part size changes, then this suggests an additional scaling law (in addition to Equation 18):

$$r^p = (\text{const.})$$ \hspace{1cm} (21)

In the present work, it was assumed that $p = q = 1$ in Equation 21 for purposes of testing the newly proposed scaling law. First, welds were produced between titanium and niobium using only Equation 18, i.e., keeping the initial bond energy per unit area a constant. The interfacial bond pressure was also held constant. The subscale tube diameter was 0.75 in., and the full scale was 1 in. The bond parameters for both bonds based purely on Equation 18 and constant interfacial bond pressure are shown in Table 2.

The full-scale bonds made under these conditions easily passed a destructive bond test (samples were bent after flash was removed and a bend angle of greater than 45 deg was achieved before failure at the joint), whereas the subscale samples failed immediately upon being subjected to bonding loads (essentially zero bend angle). Clearly the assumed scaling law based purely on Equation 18 did not work. The bond pressure was then modified based on Equation 21 with exponents $p$ and $q$ equal to 1. The original bond pressure based on constant bond pressure was 5978 lbf. The bond pressure predicted by Equation 21 with $p = q = 1$ is 7963 lbf. The full-scale bond was conducted at a bond pressure of 5978 lbf. Based on the data in Fig. 8, as the subscale and full-scale power curves start to resemble one another, the resulting bonds are expected to have comparable bond quality. The sample bend tests also suggest this is the case. This means the power dissipation curve can provide valuable guidance in the selection of bond parameters as the size of the joint changes. The assumption of $p = q = 1$ is somewhat arbitrary, but importance should not be attached to the specific

Fig. 8 — A comparison between the power dissipation during the bond for the full-scale bond and the subscale bond conducted at various bond forces.

The evolution of the error is shown in Fig. 6 for the two models under consideration. It is clear Model 2 better represents the data at short times, whereas Model 1 seems to be more suitable at long times. Another important factor that has been ignored in the treatment thus far is the effect of temperature-dependent material properties. This effect is shown in Fig. 7 by changing the assumed material properties for conduction through the stainless steel.

Heat Input Model as a Basis for Selection of Weld Parameters

It will now be shown that the proposed heat generation term can be used to select weld parameters as part size is changed, i.e., the parameter-scaling problem. The basic assumption in inertia welding is that the energy per unit area of the joint must be kept constant as the weld parameters are scaled for larger or smaller diameters. This means the following, with $E$ specified by the initial flywheel kinetic energy:

$$\frac{E_1}{A_1} = \frac{E_2}{A_2}$$ \hspace{1cm} (18)
values of these parameters. The central message of this study is that the power dissipation characteristic as a function of time is a good means of transferring weld parameters from one part size to a smaller or larger size.

Inertia Welding Heat Generation and the Possible Existence of a Liquid Interlayer

There has been and continues to be some debate about the possible existence of a liquid layer during inertia or friction welding. Cheng (Refs. 6, 7) allowed for the existence of such a molten layer in his modeling work. Several experimental studies by Squires (Ref. 23), Weiss, and Hazlett (Ref. 8), and Hasui, et al. (Ref. 24), did not find evidence of melting. Wang and Nagappan (Ref. 10) predicted the peak temperatures would be below the melting point based on their modeling work of inertia-welded steel bars. Wang (Ref. 9) points out available metallurgical investigation does not support the existence of a liquid film at the interface, and torque measurements do not show a disruption or sudden drop that may be expected on account of a liquid interlayer.

To further analyze the possibility of melting during the inertia bonds made in this work, the possibility of a fluid layer subjected to shear is considered. A predicted melt layer thickness will now be derived for such a layer by invoking simple hydrodynamic reasoning. The laminar boundary layer thickness is specified by the following:

\[
\delta = \frac{v \cdot x}{U_\infty}
\]  

where \( x \) is the position along the wall in the direction of flow, \( v \) is the kinematic viscosity, and \( U_\infty \) is the free-stream velocity.

The average velocity during the speed curve decay is obtained by finding the average value of the speed curve shown in Equation 7 using fit parameters as described in Fig. 4. This results in an average velocity of 0.93 m/s. The dynamic viscosity of molten iron ranges from 1 to 10 centipoise (a centipoise, cP, is equal to 10^{-1} kg-m^{-1}s^{-1}) over a range of temperatures (Ref. 25), and this equates to a kinematic viscosity of 6 \times 10^{-2} \text{ m}^2/\text{s}. The distance \( x \) is the maximum distance the part may rotate during the inertia weld, which in this case is the total circumferential travel during the decay in rotational velocity. Again using Equation 7 for the conditions described in Fig. 3, the part makes a total of 2.5 rotations, so the maximum possible travel distance is 0.2 m. Therefore, the Reynolds Number of this flow is the following:

\[
Re = \frac{U_\infty x}{v} = \frac{(0.93 \text{ m/s}) \cdot (0.2 \text{ m})}{(1 \times 10^{-6} \text{ m}^2/\text{s})} = 1.86 \times 10^5
\]  

which is within the laminar regime. The corresponding film thickness then becomes

\[
\delta = \frac{v \cdot x}{U_\infty} = \frac{(1 \times 10^{-6} \text{ m}^2/\text{s}) \cdot (0.2 \text{ m})}{(0.93 \text{ m/s})} = 464 \mu\text{m}
\]  

From microstructural investigation, there is no evidence of a 400+ micron-wide melt layer that, if it did exist, would be most conspicuous and easily detectable. Furthermore, even on submicron-length scales, no evidence of melting was detected. At the interface, there was an intermetallic reaction layer consisting of a Nb-Fe-Cr intermetallic compound that was approximately 200 nm thick. If we assume this layer was formed by liquid-phase reaction, we can approximate the thickness of the laminar boundary layer to be the width of this reaction zone. In that case, using Equation 22, the equivalent metal viscosity would have been approximately \( 2 \times 10^{-10} \text{ cP} \), which is a physically unrealistic number for molten metals. It is, therefore, reasonable to assume there was no melting during the welding process.

Conclusions and Future Work

In this study of the heat generation term during inertia welding of dissimilar metals, the following was demonstrated:

1) The temperature profile during inertia welding can be well represented by simple analytical solutions that directly use machine-generated data.

2) The proposed forms of the heat generation term can be used to provide guidance for parameter development when attempting to transfer successful weld parameters to varying part diameters.

3) It is unlikely a fluid layer was generated during the inertia welds discussed in this work.

The heat generation terms represented by Equations 8 and 13 could also be used as part of an in-situ process monitoring methodology. If the heat generation term, the effective bond time (time required for angular speed to drop to 10% of its initial value), the material burnoff, and the burnoff rate are all monitored, it may be possible to establish a process window based solely on in-situ measurements, which would be the first step toward a 100% quality-assured methodology for inertia welding (no postprocess inspection required). Accounting for temperature-dependent material properties can enhance the thermal predictions in this work, and such simulations are in progress.

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