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Gases, Consumables, Equipment

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See page 27
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Advanced engineering and design virtually eliminates Carpal Tunnel Syndrome. Proper weight distribution and vented handle make the Q-Gun the industry's most comfortable MIG gun.

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Q-Guns use fewer tips, nozzles and diffusers. Simplify inventory with front-end parts that interchange among Bernard 200 to 600 amp guns...or upgrade other OEM guns.

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Beats Any Other Brand in LESS SMOKE

<table>
<thead>
<tr>
<th>Welding Fume Generation Rate</th>
<th>DW-50</th>
<th>Conventional Flux-cored wire</th>
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<tr>
<td>1200</td>
<td>644</td>
<td>1015</td>
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<tr>
<td>1000</td>
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**Other Features:**
- DW-50 has a fast-freeze slag system which provides excellent weldability in all positions.
- Higher deposition rates can be achieved in all positions.
- Slag can be removed, even in narrow grooves.
- Stable arc produces less spatter than other wires.
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Circle No. 34 on Reader Info-Card
As the economy gets tighter and prices continue to rise, customers want quality, and they want it faster. Companies that can meet the demands obviously have the edge.

Tampa Bay Steel is one of those companies. Tampa Bay Steel Corporation (TBSC) is a good example of a company looking for better ways to keep the edge and sharpen it as demands increase.

Here's how TBSC is solving problems and looking for better ways to keep up with a steadily increasing demand.

Part of Tampa Bays' production involves the cutting of steel plate for OEM's, fabrication shops, and machine shops, a wide variety of customers and requirements. Project specifications can call for cuts to be simple straight line cuts or complicated shapes. Orders come in daily specifying components to be made of plate steel which can vary in thickness from gauge material to 1 inch. The complexity of a project, metal type and thickness determines which cutting machine to use and how the machine configuration should be set up to use different plasma or oxy-fuel torch combinations.

To meet project specifications, TBSC uses plasma cutting machine torches mounted to tables. Three of the cutting tables are equipped with regular plasma machine torches, and two are equipped with high definition torches. Heavier metals up to six inches are usually cut using ATTC oxy-fuel tips. It was determined that by solving two concerns the company could save time and money. Change out time (the time it takes to change torch components) was one concern and low pierce and shield cap life from the existing plasma parts was the other.

To solve these problems, TBSC has experimented with several types of electrodes and shield caps.

Fred Williams, Supervisor of the burning department explained, "After trying several brands of plasma components we decided on ATTC parts. We got a substantial increase in pierces and shield cap life which of course means less change out time."

Mark Stewart, Operations Manager for Tampa Bay Steel explained, "We work together with ATTC to solve technical issues. For example: In one shield cap application, the shield cap used for a 100 amp high definition torch had a very small orifice. We worked in conjunction with ATTC and served as a Beta site to find a solution. We went to a larger orifice and extended the life of the component considerably. They work very closely with us."

Mark noted that when they use ATTC designed nozzles, on the high definition machines, they don't have to stock as many parts. American showed them how their nozzle, would save them a substantial amount by using fewer shields - 10 times fewer when cutting with 100 amp torches. They also showed them how using the same shields, retaining caps and swirl rings for both 70 and 100 amp cutting torches would save them even more money.

Williams points out how they also save money because the ATTC order system can get their orders filled and delivered quickly, usually within 24 hours. "We don't have to leave a table idle for lack of parts," he noted.

"American Torch Tip has filled all our needs in a timely manner, the product quality is excellent and the pricing is great. They definitely have given us a production edge," he concluded.
Defense Contractor Giants to Merge

Northrop Grumman Corp., Los Angeles, Calif., and Newport News Shipbuilding on November 8 announced they have signed a definitive agreement under which Northrop Grumman will acquire Newport News.

Both companies’ boards of directors approved the terms of the transaction. In an exchange offer, Newport News Shipbuilding’s shareholders may elect to receive either $67.50 per share in cash or a number of shares of Northrop Grumman common stock designed to prove a value of $67.50. The acquisition is valued at approximately $2.6 billion, which includes the assumption of approximately $500 million of Newport News Shipbuilding.

Newport News will initially be operated as a Northrop Grumman sector. Later, Northrop Grumman plans to combine its two shipbuilding businesses into one operating sector. Thomas Schievelbein, currently Newport News’ executive vice president and chief operating officer, will become president of the Newport News operating sector. William Fricks, current chairman and chief executive officer of Newport News, plans to retire once the transaction has been finalized.

“We are very pleased with our strategic acquisition of Newport News,” said Kent Kresa, Northrop Grumman chairman and CEO. “With Newport News, we are creating a $4 billion world-class, fully capable shipbuilding enterprise with expertise in every class of nuclear and nonnuclear naval vessel.”

On April 24, General Dynamics, Falls Church, Va., and Newport News Shipbuilding had announced a plan to merge. That plan was recently terminated following the U.S. Justice Department’s decision not to approve the merger and its filing of an antitrust lawsuit. At that time, the U.S. Department of Defense recommended Justice approve the Northrop Grumman-Newport News merger.

According to the lawsuit, the proposed acquisition of Newport News by General Dynamics, if allowed to proceed, would eliminate competition for nuclear submarines, resulting in a monopoly. Additionally, the Justice Department said the proposed acquisition would harm competition for other military ships — conventionally powered surface combatants — and for the development of electric drive, an emerging technology for powering nuclear submarines and surface ships.

Northrop Grumman Stops Work on Cruise Ships

Northrop Grumman Corp. recently announced it has stopped work on Project America, a program to build two 1900-passenger cruise ships at its Pascagoula, Miss., Ingalls Operations.

American Classic Voyages Co., Miami, Fla., the parent company of Project America, filed for Chapter 11 bankruptcy protection on October 19, following the September 11 terrorist attacks and their impact on the tourism industry. Northrop Grumman’s decision to halt work on the ships followed negotiations with the U.S. Maritime Administration, which decided not to continue the guaranteed funding necessary to complete construction of the ships.

The first cruise ship was 40% complete and 55% erected, and approximately 90% of the production material had been committed. Approximately 1250 employees working on Project America were affected by temporary layoffs. Northrop Grumman said it will make every effort to reassign affected personnel. About 500 employees were to be immediately reassigned to other projects at the Ingalls Operations, while another 200 were to be transferred to the company’s Avondale Operations facility in Gulfport, Miss. Most of the remaining employees will be reassigned to the Avondale Operations facilities in New Orleans, La.

Northrop Grumman had previously announced it would report a charge to operating margin of $60 million in the third quarter 2001 if Project America could not secure guaranteed funding.

“It is with sincere regret and a deep feeling of disappointment that we discontinue work on this contract,” said Phil Dur, corporate vice president and president of Northrop Grumman’s Ship Systems sector.

Daewoo to Build Crazy Horse Hull

BP recently signed a letter of intent with Daewoo Shipbuilding & Marine Engineering Co., Ltd., South Korea, to design, fabricate, and transport a semisubmersible unit for the Crazy Horse oil project in the Gulf of Mexico. The $380-million contract calls for delivery in the first quarter of 2004, in time for module integration and production startup in early 2005.

Daewoo will build the unit at its fabrication yard in Okpo, Korea. The company will construct the lower hull, deck box, some process and utilities equipment, quarters for 188 people, and a complete, dual-hoist, 2-million-pound-capacity drilling system. The platform is expected to be the largest semisubmersible production/drilling unit in the world. The lower hull will measure approximately 350 x 350 ft and the upper deck box will measure approximately 350 x 450 ft.

The Crazy Horse complex has reserves estimated to be at least 1.5-billion barrels equivalent. At its peak, the platform could produce 250,000 barrels of oil and 200 million standard cubic feet of gas per day.

Primary topside modules for the platform will be built in Morgan City, La.
The AWS and DVS (German Welding Society) will present their second conference and exposition on plastic welding March 4-6, 2002 in New Orleans, LA. The program will include one day of basic plastic welder education with "hands on plastic welding" available for participants. There will be two days of presentations that include Success stories, Failure cost and solutions and Standards and new developments. Papers will be provided by North American and European thermoplastic industry experts. Exhibits will include plastic welding equipment, plastic welding testing facilities and plastic suppliers. If you are involved in plastic welding as an end user or fabrication shop this conference is an event you cannot afford to miss. Exhibit space is on a first come first serve basis, call now to reserve your space.

**CONFERECE COST:**
AWS Members .........................$610
Nonmembers ...........................$685

Non-members receive a one-year complimentary membership to AWS. Registration includes conference sessions, conference handout material, lunches, reception, and refreshment breaks. The registration fee does not include hotel accommodations. Hotel accommodations are subject to hotel regulations and are the responsibility of the attendee.

**Exhibitor Registration Information:**
A $750 exhibitor fee includes one 8 x 10 space, one draped 6' table, one chair, an identification sign, and one complete conference registration, which includes all conference handout materials, lunchee, reception and refreshments breaks. All breaks and reception will occur in the exhibit area.

For more information please contact the American Welding Society Conference Business Unit at 800-443-0350, x 449 or via E-mail at conf@aws.org

American Welding Society
Right-to-Know Laws Under Scrutiny

As a result of the September 11 terrorist attacks, Congress is focusing on the security of U.S. infrastructure. In so doing, questions have been raised regarding the viability of right-to-know laws, designed to keep citizens informed. For example, the Clean Air Act and EPA regulations require chemical plants to file “risk management plans” that include details about the potential impact of a catastrophic accidental chemical release. After September 11, the EPA removed such disclosures from its Web site, although the information otherwise remains publicly available.

In addition, legislation has been introduced in Congress designed to restrict public access to safety information regarding pipelines, dams, refineries, power plants, and transmission lines. Specifically, the legislation would make it a crime for a federal employee to disclose any information that would reveal a specific weakness or vulnerability to attack such facilities may have. Critics charge the legislation would allow companies to conceal routine safety dangers from the public, such as those arising from corrosion, inadequate maintenance, etc.

The Future of H1-B Visas

The September terrorist attacks has placed renewed focus on immigration issues, particularly student visas, and the H1-B visa, designed for foreign workers with special expertise in areas such as engineering. In recent years, Congress has responded to the business community’s pleas to increase the number of H1-B visas that enable qualified professionals from overseas to come to the United States.

In the short term, however, the September attacks have further weakened the economy, compelling companies to decrease hiring in general, including foreign workers with H1-B status. Individuals holding H1-B visas may soon be hearing the brunt of a legislative reaction as well. A bill has been introduced in the U.S. Senate that would require employers to inform immigration officials within 14 days of an H1-B employee resigning or being dismissed.

NAFTA Dispute Process At Issue

Like many trade agreements, the North American Free Trade Agreement (NAFTA) includes a dispute resolution process designed to address and resolve complaints quickly and at a relatively low cost. In addition, the agreement allows dispute resolution to be carried out without reporting to the courts of the United States, Mexico, or Canada, all of which could be perceived as biased against foreign companies.

While the goal of keeping disputes out of the courts has been attained, speed and economy in expediting the process have not. Under NAFTA, independent panels deliberate in secret and, presumably, without political influence. In practice, however, numerous complaints have become bogged down in lengthy proceedings that resemble traditional, inefficient litigation.

Antitrust Enforcement to Remain Consistent

There was a time when a change in administrations meant a change in antitrust enforcement by federal regulators. During the late 1970s, for example, the Carter administration was extremely active, while the successor Reagan administration was equally extreme in its restraint. In 1988, however, the Bush administration adopted a more moderate approach. This was continued by the Clinton administration for 8 years, and now the new Bush administration has agreed to do the same. Regulators appointed by President Bush have committed to pursue the centrist approach to enforcement that business has come to expect over the past 12 years, making antitrust one of the few areas of regulatory consistency.

Miscellaneous Developments

- Ergonomics. The U.S. Department of Labor (DOL) has delayed announcement of a plan of action on ergonomics issues in the workplace. Following legislative repeal of DOL’s massive regulation earlier this year, the Department has been actively working on an alternative approach. Several public forums have solicited testimony and produced written comments on the subject.

- Research and Development Tax Credit. Efforts to make the research and development tax credit permanent appear to be failing. An amendment was offered in early 2001 to an unrelated piece of legislation, but was defeated on procedural grounds. Surprisingly, the economic stimulus legislation did not include an extension.

- Science/Technology Council. President Bush signed an Executive Order on October 1 extending the President’s Council of Advisors on Science and Technology. The Council, comprised of 24 presidential appointees, is designed to solicit advice and counsel from the business and academic communities.

- Internet Taxes. Congress is expected to renew and extend the moratorium on taxes on sales over the Internet. The original moratorium, adopted in 1998, expired earlier this year. Congress has been under intense pressure from state and local governments to allow the imposition of sales taxes, but the effect of such a move on the already-weakened economy is seen as too risky to allow.

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.
Editorial

A Salute to Certified Welders

I would like to dedicate this editorial to the men and women who perform their duties and responsibilities as welders, for I believe they are the backbone of industry. Although most people know little about the person behind the welding helmet, these individuals are skilled craftsmen responsible for producing the products we use everyday. Whether you are traveling on the International Space Station, crossing the seas on an aircraft carrier, working in a high-rise office building, driving an automobile, or receiving energy from a nuclear power plant, you are relying on the skills of certified/qualified welding personnel.

During a recent career day presentation, a parent came to me and said, "How dare you talk to my son about being a welder!" I asked this gentleman what career he wanted his son to pursue and he said he wanted him to become a surgeon. "What are the differences between a surgeon and a certified/qualified welder?" I asked, then provided him with my comparison of the two careers. Surgeons are skilled professionals; welders are also skilled and proud professionals. Surgeons can make a six-figure salary; so can experienced, top-quality welders. (One of my personal friends made $145,000 as a welder last year.) Surgeons must have good eye and hand coordination; welders must have good eye, hand, and feet coordination. Surgeons handle life and death situations for patients; skilled welders impart craftsmanship to products such as jet engines, pacemakers, and automobiles that can have life or death consequences for consumers. I told the father, "If you're traveling at 17,500 mph at 250 nautical miles above the earth on the International Space Station, you don't want the welder who built it to have had a 'bad weld day.'" He smiled and said, "Now I understand that welders are skilled professionals."

Many industries require welders to be qualified to the requirements of codes and standards such as those written by the American Welding Society. In addition, the Society's Certified Welder program is designed to provide transferable credentials to professional welders who have demonstrated a skill level desired by industry. These credentials are not limited to a specific job, employer, or location because the welders have satisfactorily performed to a standard that has national and international acceptance. Performance-based tests such as these separate top-quality welders from those who think they are welders but whose skills have not been documented. I recommend completion of the AWS Certified Welder program to all welders. When applying for jobs, AWS Certified Welders have an advantage over other candidates who do not have the same credentials.

The American Welding Society is proud to support welders, a world-class group of professionals. The AWS Certified Welder program is an important step in the welding certification process. In today's society, companies that take pride in the quality of their products will pay their welders well. Remember, quality is not inspected into products; it comes from individuals with excellent welding skills who take pride in their work. Continue to work hard and don't expect anything less than the best from yourself. Be proud of your hard work and the years of experience that have made you a top-quality welder. Let's keep our welding industries proud: Become a card-carrying AWS Certified Welder.

Ernest Levert
AWS Vice President

American Welding Society
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14 | DECEMBER 2001
Relief for MIG welder indigestion.

MIG welding indigestion doesn't come from jalapeño peppers. It comes from poor arc stability, inconsistent feedability, and clogged liners and tips. You get jam-ups and burnbacks. Welding stops. And then you get indigestion.

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Stand Up and Be Counted

Suddenly, it’s okay to be patriotic again, and thank God for that. We Americans are far too ready to apologize for our shortcomings, real or imagined, and to hide deep feelings for our country lest others chide us for being too sentimental. Now, because of shared pain and shock, it seems important to declare ourselves a part of something greater that tries, with varying degrees of success, to do good in the world. And so there has been a great outpouring of feeling and contributions to help with the recovery from the awful events of September 11.

But the country is still in a state of shock and anxiety is high. Our leaders have urged us to return to our normal lives, but that is happening slowly. Travel is down, confidence is down, and there is a feeling of malaise. There are some who are pleased to see Americans hesitant and uneasy. It gives them hope that our country is crumbling from within. It’s important to show the world that we aren’t cowering under our beds, fearful of every shadow.

That is why your American Welding Society is making a statement by determining to go ahead with the 2002 Welding Show in Chicago on March 4–7. We have not wavered in our plans for this important event. The Society and the exhibitors are steadfast in their belief that the show must go on. But we need you to make it a success. Now is the time for each member to declare his or her support for the Society and our industry by attending and urging others to attend. Even in the best of times, only about 20% of show attendees identify themselves as AWS members in spite of the fact this is the largest and most definitive show for the welding industry in North America. Other shows claim to represent welding, but they are only pale imitations of the AWS Welding Show. No doubt there were good reasons for not attending in the past, but these times call for extra effort. After all, if members can’t be bothered to support the show, who will?

McCormick Place and the city of Chicago have already strengthened security for trade shows. There is no need to fear being a part of a large gathering. The exhibitors will be there with all the latest equipment and will be eager to help you with answers to your manufacturing problems. Our technical sessions and conferences will be packed with information you can use to improve the way you do business. Networking opportunities will abound. This is where you can find out how to meet your customers’ demands for bigger, better, faster. By attending, you can do something for your country, for your Society, and for yourself.

Why would you not come? It’s time to stand up and be counted.

Tom L. Davis
Managing Director, Exposition Sales
Web Sites Promote Local Metalforming Activities

Twenty Web sites were recently launched to promote local activities and membership in the Precision Metalforming Association's (PMA's) local districts, or chapters. The sites highlight the volunteer officers, program schedules, and members in each of PMA's districts. The sites can be accessed by visiting www.metalfoming.com, then clicking on Districts & Divisions/Districts/Local District Information.

PMA partnered with ViewAsUDo to develop the easy-to-use Web sites. Member companies can utilize the sites to promote activities, services, and products. Cities represented in the 20 districts include Minneapolis and St. Paul, Minn.; Milwaukee and Menomonee Falls, Wis.; Dayton, Cincinnati, and Toledo, Ohio; Indianapolis, Ind.; Lancaster and York, Pa.; Dallas/Ft. Worth, Tex.; Chicago, Ill.; Waterbury, Conn.; Nashville, Tenn.; Pontiac, Mich.; Ontario, Canada; and San Jose, Calif.

PMA is a full-service trade association representing the $41 billion metalforming industry of North America. Its 1600 member companies include metal stampers, fabricators, spinners, slide formers, and roll formers. Members are located in 30 countries, with the majority in North America in 41 U.S. states as well as Canada and Mexico.

Site Offers GMAW Solutions

Ed Craig's WeldReality.Com. This site is the place where visitors will “find practical welding solutions for manual/robot welding issues.” It includes an “Applications” section that describes real-world welding situations, detailed sections on weld cost analysis and gas metal arc and flux cored arc welding, and a bulletin board where visitors can post and receive answers to questions. It also offers information on Craig’s training materials and consulting services.

The Steels and Weld Consumables section features information on more than 1000 steels. The section also includes an extensive discussion of aluminum alloys, such as filler metal selection and problems that can occur. According to the site: “A prime cause of black oxide soot on an aluminum MIG weld is a weak or misdirected arc. The problem is typically caused by a) insufficient arc energy (increase current/wire feed); b) an arc length that is too long (reduce the arc length, lower the welding voltage); c) ensure the forehand technique is used to direct the arc to the aluminum oxide skin in front of the weld; d) weld speed too fast.”

http://www.weldreality.com

Site Highlights Air Pollution Control Systems

Nederman, Inc. The company, a Westland, Mich.-based manufacturer of air pollution control systems such as fume extraction arms and high vacuum systems, recently redesigned its Web site. The redesigned site features new pages and documents with upgraded graphics. The site contains product specifications, brochures, engineering data, case studies, spare parts lists, and assembly instructions that can be downloaded in PDF format.

The site also includes a company history, contact information including distributor locations worldwide, trade show information, and press releases.

http://www.nedermanusa.com

Stamping Lubricants and Chemicals Featured

Metal Mates, Inc. The company, based in Waterford, Mich, produces stamping lubricants and specialty chemicals for the metalforming and related industries. Products, services, and support are all detailed on the Web site. The site’s News section includes product releases, case studies, and other new items. Visitors can contact the company via e-mail.

http://www.metalmates.net
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Call toll-free: 877-WELD-GEAR (877-935-3432)
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Hobart Institute Protects Copyright

The Hobart Institute of Welding Technology, through its attorneys, recently issued a "cease and desist" letter to an individual who had been selling welding training manuals over a popular Internet auction site, stating they were Hobart Institute manuals. Upon receiving the manuals, purchasers found the publications were photocopies of Hobart Institute manuals.

Doug Rogers of Vorys, Sater, Seymour & Pease, a law firm in Columbus, Ohio, issued the letter, which stated the Internet advertisement provided false or misleading information. The advertisement stated "purchasers will receive original manuals" when in fact they received copies. The advertisement also mentioned "state-of-the-art text," which was true when the manuals were originally published, but is now a false claim because updated versions of many of the manuals have since been issued.

United States copyright law gives the copyright holder the exclusive right to make copies of copyrighted works. In this case, the Hobart Institute had not approved making any copies of the manuals. The individual to whom the letter was sent has agreed to remove all advertising regarding the training manuals, to no longer copy any Hobart Institute manuals, and to cease selling any existing copies of the manuals.

Georgia Adopts International Codes


International Code Council codes represent the world's first set of fully consistent, coordinated codes for the built environment. They address essential building, structural, fire prevention and suppression, plumbing, mechanical, gas and electrical requirements necessary for establishing a reasonable level of safety and property protection from hazards.

ESAB Donates Equipment for World Trade Center Relief

ESAB Welding & Cutting Products, Florence, S.C., recently donated ESAB gas regulators and Purox® "E" cutting outfits to aid in the relief efforts at the World Trade Center site in New York City. The company had received an order from a distributor in Brooklyn, N.Y., but instead elected to donate the equipment to help support the efforts to recover the victims and clear the site of the September 11 terrorist attack.

The equipment had been ordered by the U.S. Federal Emergency Management Agency (FEMA).

Lawmakers Introduce 'Tech Talent' Bill

Legislation aimed at increasing the number of scientists, engineers and technologists in the United States was recently introduced by Senators Joe Lieberman (D-CT), Christopher Bond (R-MO), Barbara Mikulski (D-MD), Bill Frist (R-TN), and Pete Domenici (R-NM). House Science Chairman Sherwood Boehlert (R-NY) and Rep. John Larson (D-CT) introduced a companion bill in the House of Representatives.

Recent studies project the number of jobs requiring significant technical skills will grow by more than 50% in the United States over the next ten years. However, outside of the life sciences, the number of science and engineering degrees awarded over the last decade has been flat or declining.

The "Tech Talent Bill" aims to address the problem by establishing a competitive grant program at the National Science Foundation that rewards universities, colleges, and community colleges pledging to increase the number of U.S. citizens or permanent residents obtaining degrees in science, math, engineering, and technology fields.

The pilot program, which will award three-year grants, authorizes $25 million in fiscal year 2002, with funding expected to increase in the future.

Television Show to Feature Lincoln Equipment

The Lincoln Electric Co.'s equipment will be featured during the upcoming season of TLC's "Junkyard Wars," a television show that bills itself as the perfect forum for those who believe they can build anything out of junk. "Junkyard Wars" takes two teams of three players to a ready-made junkyard in Los Angeles where they compete to build complex machines that are put to the test in a scrap showdown.

Eight teams will compete this season. Albert Castillo, Lincoln's local representative, organized the setup of all the welding and cutting equipment.

The hosts and some of the competitors of TV's "Junkyard Wars" are shown with the Lincoln welding equipment that will be used on the show this season.

The show usually airs Mondays at 8:00 p.m., but check local listings to confirm the time in your viewing area.
Industry Notes

- Arc-Zone.com recently moved its corporate headquarters to an expanded facility in Carlsbad, Calif., that will quadruple the size of the company's assembly, service, and order fulfillment warehouse. The new facility, located a few miles from the company's previous site, includes a showroom, test facility, administrative offices, and warehouse.
- Lincoln Electric Holdings, Inc., Cleveland, Ohio, recently acquired Bester S.A., a manufacturer of welding and related equipment, from the Poland Ministry of the Treasury. Financial terms were not disclosed; however, Bester's sales are approximately $15 million per year. The state-owned company is being sold as part of the Polish government's privatization program. Lincoln will acquire 85% of the company; the work force, including management, will receive the remaining 15%.
- Air Liquide America recently sold seven retail stores to Airgas, Inc., Radnor, Pa. The stores are located in Flagstaff, Morenci, Phoenix, Tucson, and Yuma, Ariz.; Silver City, N.Mex.; and Brawley, Calif. In addition, the company sold its Santa Maria, Calif., welding retail store to Central Coast Gases, an independent supplier of welding gases and hard goods. Central Coast Gases also signed an agreement to join Air Liquide's ALNET™ distributor network.
- United American Sales, Inc., Wilmington, Ohio, recently opened a 25,000-sq-ft distribution warehouse in Atlanta, Ga. The company is a wholesaler of safety, welding, industrial, plumbing, construction, and automotive products and supplies.

Select Arc Expands Plant

- Select-Arc, Inc., Fort Laramie, Ohio, recently celebrated its fifth anniversary. Since its inception, the company, which manufactures tubular welding electrodes, has expanded twice. It now has twice its original manufacturing capacity, including expanded research and development capabilities.
- The Lincoln Electric Co. recently set up and staffed a welding garage at the 2001 Formula SAE® Competition held at the Silverdome in Pontiac, Mich. This year, engineering students from 125 colleges and universities around the world competed in the three-day contest. Students conceive, design, fabricate, and compete with small formula-style racing cars. During the competition, Lincoln representatives weld parts for the teams or students can do the welding themselves. Lincoln also provides seminars on safety practices, gas tungsten arc welding, metallurgy, design principles for welding, and process choice. First place in the 2001 competition went to Cornell University, second to the University of Missouri-Columbia, and third to The Ohio State University.
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For more information on AWS Corporate Membership, call (800) 443-9353, ext. 253 or 260. E-mail: service@aws.org for an application.

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Clamp's Third Arm Allows Welding of Three Workpieces

The optional third arm malleable iron attachment for the company's 90-deg angle clamp allows welding of three-axes workpieces by providing X, Y, and Z clamping surfaces. The iron bracket attaches to the clamp to create an integrated welding vise that allows users to complete a three-point weld in one step. When welding is completed, the workpiece can stay in the clamp to cool, thereby reducing distortion.

Valtra, Inc.
741 Paramount Blvd., Pico Rivera, CA 90660

Conveyor Fits in Tight Spaces

The company offers space-saving conveyors designed to reach into, and operate in, confined spaces around production machinery. Standard models are magnetic to provide continuous control of small- to medium-sized ferrous parts and scrap even on inlines. Standard low-profile conveyors require less than a 2-in. clearance and are built to withstand the punishment of punch press and automated applications. Heavy-duty models are designed for extra-heavy load, high belt speeds, and applications with heavily oiled materials. Options include individual and gang drives, specialized belts, floor supports, and side guards.

Bunting Magnetics Co.
500 S. Spencer Ave., Newton, KS 67114

Weld Monitoring Equipment Uses Space Tracking Algorithm

The company's arc-weld monitoring system uses a state space tracking algorithm to verify the complete process of one or more robots (or welders) through a complex set of welds on a single welded assembly or part. Welds are automatically analyzed, labeled, sorted, displayed, and logged with part and weld number. This system is able to detect missing welds on complex welded assemblies, measure cost and productivity information from the welding cell, and deliver the information in real-time via local intranet servers. Final results from each weld are displayed for the operator and superimposed on a bitmap image of the assembly.

Impact Engineering
500 E. Biddle St., Jackson, MI 49203

Iron Worker Features Four Workstations

The company has added a 120-ton dual operator, dual cylinder iron worker, Model DO 120/200. The machine has four built-in workstations with a punching capacity of 1½-1 in. and flat shear capacity of 200 tons. It is capable of shearing 1 x 12 and ½ x 24 in. The machine is designed with a low rake angle to give distortion-free cuts. The rectangular notcher is 3 x 5½ x ½ in., and the tool table workstation accommodates the 6 x 6 x ½-in. angle shear. Optional tooling is available and there is no loss of speed or capacity when two operations are in use.

Scotchman Industries, Inc.
P.O. Box 850, Philip, SD 57567

Adjustable Shim Provides Various Height Positions

The company's adjustable MicroShim is capable of precision machine leveling, positioning, and mounting applications. Height positions in increments of 0.001 in. over a range of 1 in. for supporting machinery and equipment can be set while providing high load-bearing capacity. The adjustable shim allows users to reposition machinery at any time; the shim can also be permanently locked into place using a special bonding agent.

Pinpoint Laser Systems
3 Graf Rd., Newburyport, MA 01950

Beveling Machine Handles Heavy-Duty Piping

The company's heavy-duty pipe beveling machine is designed to bevel steel and nonferrous metal pipes starting from 18 mm (0.7 in.) up to a wall thickness of 60 mm (2.36 in.). The machine prepares from the outside to the inside and returns to the starting position automatically after reaching the variable adjusted end position. Per rotation, the tool has an axial feed of 0.27 mm (0.01 in.). Mandrel and machine can be mounted separately, either vertically or horizontally.

Georg Fischer Inc.
Pipe Tools, 2681 Dow Ave., Ste. F, Tustin, CA 92780
Stainless Steel Flux Designed for Duplex/Super Duplex Tubing

The company's stainless steel flux is designed for autogenous welding of duplex and super duplex stainless steel tubing. The welding process eliminates the need for welding wire or specialty purge/backing gas mixtures. The stainless steel flux serves as a reactive agent with the arc, enabling welders to reduce bead width, retain phase balance, and increase penetration by as much as 300%.

Swagelok
3400 Aurora Rd., Solon, OH 44139-2764

Portable Welding Machine Designed for Subways and Trains

The company is offering a 300-A, SMA/GTA welding machine that runs off the DC power of the third rail or overhead catenary systems between 500 and 800 V DC. The 80-lb Ironhorse is suited for tunnels where AC primary power is not readily available and provides subway and commuter systems with alternatives to using generators, the thermit welding process, or to powering down.

ARCON Welding, LLC
2201 Northwood Drive, Ste. 10, Salisbury, MD 21801

Hybrid Cables Save Space

The company offers a wide range of hybrid cables designed for different industries. Integrating many individual components into one round cable, the hybrid designs take up less space in cramped machine housing or tight cable tracks and allow for faster, and bullet-proof, installation. By incorporating high conductor stranding and putting unique insulation materials to work, cable diameters are reduced by 30–40% compared to standard products.

elocuh
205 McBrien Dr., Kitchener, Ontario, N2R 1H8, Canada

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<thead>
<tr>
<th>Stainless</th>
<th>Cast Iron</th>
<th>Cobalt</th>
<th>AISI</th>
<th>Nickel</th>
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Circle No. 20 on Reader Info-Card
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British Federal Ltd.
Castle Mill Works, Dudley
West Midlands DY1 4DA, England

Cutting Table System Allows Fuel Switching

The company's cutting table system allows small to mid sized metal fabricators to switch from acetylene or propane to high-pressure natural gas for cutting table operations. The system connects to a shop's low-pressure utility gas service and boosts the pressure to make it suitable for torch cutting. Its design boosts gas pressure, stores the gas in cylinders supplying the table, and automatically refills the cylinders as gas is consumed.

G-TEC Natural Gas Systems
401 William L. Gaiter Pkwy., Ste. 4, Buffalo, NY 14215

Arc Length Control System Is Microprocessor Based

The company's arc length control system for AC or DC GTAW has a microprocessor control with a slide actuator. The arc length control measures the actual arc voltage of either a GTAW or plasma welding arc and makes mechanical adjustments to maintain the predefined arc length or voltage. The ball screw slide actuator gives accurate mechanical control and a weight capacity of 40 lb to handle large torches and wire feed heads.

Jetline Engineering, Inc.
15 Goodyear St., Irvine, CA 92618

Friction Stir Welding Machines for Various Applications Offered

In response to the increased use of aluminum in various production processes, the company offers a range of SuperStir friction stir welding machines in various sizes to accompany the 15 major machines it produces. Machines can be used for small workpieces or heavy welding. The standard range covered includes straight welds of 0.5 m up to working areas of 30 x 10 m.

ESAB AB
Herkulesgatan 72, Box 8004, S-402-77 Gothenburg, Sweden

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G-TEC Natural Gas Systems
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Arc Length Control System Is Microprocessor Based

The company's arc length control system for AC or DC GTAW has a microprocessor control with a slide actuator. The arc length control measures the actual arc voltage of either a GTAW or plasma welding arc and makes mechanical adjustments to maintain the predefined arc length or voltage. The ball screw slide actuator gives accurate mechanical control and a weight capacity of 40 lb to handle large torches and wire feed heads.
Let's Talk About Breathability

There's a trade-off with traditional welding helmet designs: a more "open design" allows better air circulation, but it also increases your exposure to hazards.

On the other hand, the Speedglas® 9000 breathable helmet extends throat and side protection while greatly increasing air circulation. Four patented, aerodynamically-designed, exhaust vents remove CO₂-laden exhaled air without letting in welding smoke.

Welders experience lower humidity, less heat, and reduced CO₂ levels. (Elevated CO₂ levels cause "stuffiness," fatigue, and headaches.) Plus, welders get the world's most reliable auto-darkening lens.

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*University study available upon request. 9000 helmet was tested against two traditional helmets, one with an "open" and therefore more exposed design. 87.5% of tested welders considered the Speedglas helmet superior in every way.

Call 800-628-9218 for a Hornell distributor demonstration, or visit us at www.hornell.com.

Circle No. 27 on Reader Info-Card
The AWS D1.1 Code is renowned throughout the world for its utility, flexibility, and assurance of welding quality. In a continuing effort to improve on each of these attributes, the AWS D1 Structural Welding Committee has approved a number of revisions to the ANSI/AWS D1.1:2000 Code for the 2002 edition. These improvements are described on the following pages.

**Identification Changed**

The first thing you'll notice is the way the code is identified: AWS D1.1/D1.M:2002. The "ANSI" has been dropped because the ANSI logo has been placed on the book's cover, thus serving as adequate identification of its ANSI approval status.

D1.1/D1.M indicates the document uses U.S. customary units (D1.1) and SI metric numbers (D1.M). One set of numbers is in brackets (SI) and the other is unbracketed (U.S.). In effect, the document consists of two codes sharing a common text but distinguished by the use of separate dimensional standards. What is important to note is users must not mix and match the two, as tempting as that might be. For example, a contractor cannot suddenly decide when U.S. dimensions fail to conform to the Code to use the SI version instead. The two sets of dimensions must be kept completely separate.

There is no "dominant" units system; both must be treated independently of the other.

**Expanded Responsibilities**

A new section on Responsibilities (1.4) has been added that describes the responsibilities of the engineer, contractor, and contractor's and verification inspectors. Commentary has been included to elaborate on and demonstrate the code text. A new type of contractor, the original equipment manufacturer, is defined to describe situations where a single contractor assumes the responsibilities of the engineer.

The Code has always recognized that the engineer has sole authority to add to, modify, or delete any Code provision. This authority is intended to provide flexibility when applying the generic D1.1 document to a panorama of industrial applications. Code provisions may be conservative for some applications, but not for others. There may also be situations the Code does not address, which the engineer may need to include in the contract specifications.

For example, Charpy V-notch (CVN) testing of welding procedures is not a Code requirement. If the engineer wishes it to be performed by the contractor, that must be explicitly stated in the contract documents, including such information as test temperatures and impact energies.
Fig. 1 — A portion of a greatly expanded table that presents a variety of stress conditions with accompanying illustrations of connections, joint types, and welds.

Changes in Welded Connections

Parts A, B, and C of Section 2 on "Design of Welded Connections" has been extensively reorganized and modified. Some of the major changes include the following:

1) A provision was added to clarify the Code intent that, when notch tough welds are required, the engineer must specify this requirement in the contract documents.
2) Imposition of new limits on maximum effective length of fillet welds loaded at their ends.
3) T-joints are defined as having joined parts that form angles between 80 and 100 deg.
4) Maximum fillet weld sizes are clearly described as pertaining only to lap joints. There exists an industry myth that the Code prohibits the use of fillet welds larger than the base
metal thickness. While this may be true for certain types of lap joints, it has never been true for T-joints. Therefore, it is hoped the editorial addition of lap joints to the provision will end this persistent and misleading myth.

5) A provision is added on base metal through-thickness loading.

6) A new Table 2.4 describing fatigue limits for weld and joint types has replaced the 2000 version, and also Fig. 2.8. This greatly expanded table, which now includes illustrations (Fig. 1), covers a much broader range of connections and weld types. The allowable stress ranges described in a new Fig. 2.11 are calculated using formulae now described in the new provision 2.15.2.

7) New provisions describing the status of backing were added. Though other provisions in the Code, notably in the Fabrication section, have described situations where backing was to be removed, this new provision (2.16.2) now gives the engineer design instructions about what information must be provided in contract drawings or documents.

Heat Treatment Status

Postweld heat treatment is accorded prequalified status in the new provision 3.14. Certain limitations required to achieve this include yield stress caps, steel manufacturing process, and the absence of contractually specified toughness requirements.

Filler Metals Clarified

Changes made to Table 3.1 (Prequalified Matching Filler Metal Requirements) are detailed below.

1) ASTM A36 and A709 Grade 36 have been divided by thickness limits into Groups I and II. The rationale for this change lies in the steel-making practice of “dual-certifying” ASTM A36 to ASTM A572 Grade 50. Many minimills using electric arc furnaces produce steels that satisfy the chemical and mechanical property requirements of more than one steel specification, with A36/A572 Grade 50 being the most common. This can cause problems when welding since, in previous Codes, A36 has been exclusively in Table 3.1’s Group I, whereas A572 Grade 50 has been in Group II.

Group I steels, owing to lower strength and reduced hardenability (i.e., less sensitive to hydrogen-induced cold cracking), were allowed to be joined with non-low-hydrogen shielded metal arc welding (SMAW) electrodes. Group II higher yield metals, which are more susceptible to cold cracking, exclude the use of non-low-hydrogen SMAW electrodes. (It should be noted the other non-SMAW processes are generally considered to be equivalent to low-hydrogen SMAW in diffusible hydrogen deposition, so their effects on this sensitivity is not a variable between the Groups.)

Thus, a dual cert, A36/A572, Grade 50 steel could conceivably be welded with a Group I non-low-hydrogen covered electrode and still conform to D1.1, yet at the same time be susceptible to cold cracking because of its simultaneous Group II status.

With the wisdom of Solomon, the Committee has decided to resolve the problem by a “splitting of the A36 baby.” This involves placing the A36/A709 Grade 36 thicknesses below ½ in. into Group I (and preheat Table 3.2’s Category A) and ≥½ in. and above into Group II (and Category B). The Committee feels the dual cert steels that fit into Group I will have a low risk of hydrogen-induced cracking even when using non-low-hydrogen SMAW and no preheat per Table 3.2, whereas the Group II variety will need to stick exclusively with low-hydrogen electrodes and the higher Category B preheats in Table 3.2.

2) ASTM A529 (42-ksi yield) has been deleted and Grades 50 and 55 added to Group II.

3) ASTM A572 Grade 55 has been added to Group II.

4) FCAW electrodes with the -11 suffix are limited to welding thicknesses equal to or less than ½ in. Some electrode manufacturers that produce this self-shielded electrode (suitable for single/multiple pass welds made in any position) limit the thickness because of the concern that welding on thicker base metal could produce a buildup of alloying elements in the deposited weld metal that could increase fracture sensitivity. This exclusion from prequalified status does not prohibit such thicknesses from being qualified by welding procedure specification (WPS) testing.

Addressing Toughness Testing

In order to more comprehensively address the issue of Charpy V-notch (CVN) testing for toughness, the following changes have been made:

1) A new Table 4.6 has been added to provide essential variable limits for WPSs that require CVN tests. These variable limits will supplement Table 4.5’s limits only when CVN testing is contractually specified. Table 4.6 focuses on concerns that would not necessarily affect a non-CVN-testing application, such as the change from stringer passes to weave passes when welding vertically. A weave pass represents a higher heat input, with resulting grain coarsening and degraded toughness, so changing a WPS that specifies a lower heat input stringer pass to a weave pass justifies requiring the new weave CVN be qualified separately. Users will need to include these Table 4.6 variables on their CVN-tested WPS.

2) The WPS plate and pipe test assemblies now identify CVN specimen locations when such testing is contractually specified.

3) Annex III (CVN test specimens) has been extensively revised, including the addition of criteria for subsize specimens.

More Commentary

Commentary has been added to facilitate the ultrasonic testing of welded joints with backing left in place. Such joints have, in the past, provided difficulties in interpreting ultrasonic testing (UT) signals that result from reflection off the backing. This Commentary will hopefully enable UT operators to write scanning procedures that recognize these “built-in” reflectors and not automatically reject them.

An addition to Tables 6.2 and 6.3 (UT acceptance criteria) relaxes the scanning sensitivity of double-sided CJP groove joints in tension. The requirement of adding 4 dB to the scanning levels of the root of these welds represented a concern, particularly in the bridge industry, that root flaws resulting from inadequate backgouging might go undetected without heightened sensitivity. The committee has decided to waive this requirement when the contractor demonstrates that, by means of magnetic-particle testing, the backgouged root is free of discontinuities prior to completion of welding. The root would thus be subject to normal scanning levels.

Changes were also made to Annex IX (Manufacturers’ Stud Base Qualification Requirements) that address the welding of studs through decking.

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American Welding Society
Choosing the proper type of GMAW gun for your application — air- or water-cooled — is crucial to maximizing productivity and minimizing cost.
Air-and Water-Cooled Guns for High-Heat Applications

Which platform is best for your application?

BY JULIO VILLAFUERTE

The welding gun is a key component of any gas metal arc welding (GMAW) system and is, perhaps, the most exposed to harsh conditions near the welding arc. Often, overheating and/or weld instabilities are related to GMAW gun failure.

GMAW guns are available in both air-cooled and water-cooled platforms. Choice of platform depends upon a combination of performance requirements and cost targets. Every platform has advantages and disadvantages, so understanding which platform is the most appropriate for an application is crucial if the goal is to maximize productivity and minimize cost.

JULIO VILLAFUERTE (jvillafuerte@toughgun.com), M.A.Sc., Ph.D., P.Eng., is senior technical director for Tregaskiss Ltd., Oldcastle, Ont., Canada.
Factors Affecting Gun Performance

In GMAW, an arc is established between a consumable electrode and the workpiece under a protective atmosphere — Fig. 1. The gun is the means by which consumable electrode, protective gas, and welding current are delivered to the weld joint. All the necessary components are bundled together in the cable assembly. Air-cooled guns normally use a specialized cable with all necessary components built in. Water-cooled guns use individual lines bundled together inside some type of protective jacketing.

Operating temperature is one critical indicator of gun performance. Operating temperature not only affects the longevity of consumables and gun components but also the welder’s comfort. Lower operating temperatures of the front-end components promote less spatter buildup and better materials performance during welding. These factors usually translate into longer consumable life. Operating temperature is determined by heat buildup, the differential between heat input, and heat dissipation in the gun. Heat into the gun comes from two different heat sources: 1) the welding arc and 2) the electrical resistance across the cable and electrical connections in the cable assembly. Heat dissipation relates to the ability of the gun to give away heat. Obviously, a well-designed water-cooled gun can dissipate heat at relatively faster rates than air-cooled systems, which helps minimize heat buildup and, subsequently, minimizes operating temperatures.

The welding arc is, by far, the main source of heat input to the gun. The gun’s share of the arc power depends on welding parameters and gun setup. In high power applications, this can be quite significant. It is generally accepted that only 80% of GMAW power is actually utilized for making a weld. About 20% of arc power gets wasted as radiant, convective, and/or conductive heat to components external to the weld joint. A portion of this energy is taken by the gun itself, depending upon process parameters such as tip-to-work distance and whether a nozzle with recessed or stickout position of the contact tip are used. The gun’s share of arc power for an application running at 600 A, 38 V, and 24-mm tip-to-work distance, for example, could be as high as 4500 W (15,354 BTU/h).

Resistive heat is a smaller portion of heat input to the gun. However, bad or deteriorating electrical connections could unexpectedly escalate resistive heating to extreme levels, causing catastrophic gun failure. Resistive heat depends upon the electrical resistance of the gun, which is defined by design and gun making process. Resistive heat Q is a power function of the welding current I, and a linear function of the electrical resistance R. The electrical resistance is determined by copper area, copper grade, cable length, and quality of all the electrical connections inside the gun.

\[
Q \text{ (Watts)} = I^2R \tag{1}
\]

The power dependency of resistive heat on welding current implies, for example, a twofold increase in rated current requires a fourfold increase in copper cross-section area if one wants to maintain the same level of resistive heating — Fig. 2. In practice, however, this rule is hardly followed by gun designers due not only to increased cost but also to concerns regarding the welder’s comfort. Without water cooling, a cable designed for high currents (>600 A) but low operating temperatures (<30°C) would simply become too heavy for handheld applications. Therefore, above certain current levels (typically 500–600 A), water-cooled guns are often specified.

Traditionally, the use of lightweight water-cooled guns (with water lines and other additional components) has been possible by cutting down on the copper cross-section area and integrating water lines inside the power cable.

Besides overheating, other issues such as energy losses and arc instability can affect cost, productivity, and weld quality. Gun-related energy losses result from resistive heating in the cable assembly, whereas arc instability is caused by the voltage drop through the cable assembly, all in virtue of the inherent electrical resistance of the assembly.

Energy losses resulting from resistive heat are especially predominant in traditional water-cooled guns due to the use of undersized power cables. Traditional water-cooled guns are, in fact, more energy inefficient than equivalent air-cooled guns; the wasted heat is effectively removed by water circulation, which ensures low operating temperatures. Should water circulation stop, resistive heat may be sufficient to cause catastrophic failure of the cable assembly. Typical resistive heat losses in 15-ft-long water- and air-cooled cable assemblies designed for 600-A service are shown in Fig. 3.

Arc instabilities can be originated by factors affecting the true arc voltage, such as voltage drop through the cable assembly. The expected response of a constant voltage (CV) power supply is precisely to maintain, as much as possible, a constant voltage at the output terminals. Anything beyond the output terminals constitutes the welding load unless voltage feedback from near the arc is provided. In the gun itself are several electrical junctions that can affect arc voltage, including power pin, cable crimp, diffuser, and tip connections; copper area; and tip.
Table 1 — Summary of Advantages and Disadvantages of Hand-Held Water-Cooled and Air-Cooled Guns for Heavy-Duty Service (600 A and Up)

<table>
<thead>
<tr>
<th></th>
<th>Air-cooled</th>
<th>Water-cooled</th>
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<tbody>
<tr>
<td>Acquisition cost</td>
<td>Minimum</td>
<td>High</td>
</tr>
<tr>
<td>Maintenance cost</td>
<td>Minimum</td>
<td>High</td>
</tr>
<tr>
<td>Peripheral equipment</td>
<td>Not required</td>
<td>Water cooler, pressure and flow meters, water lines and connections</td>
</tr>
<tr>
<td>Consumable life</td>
<td>Good</td>
<td>Excellent</td>
</tr>
<tr>
<td>Power efficiency</td>
<td>Good</td>
<td>Poor</td>
</tr>
<tr>
<td>Voltage drop related to arc instability</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Ergonomics</td>
<td>Heavy</td>
<td>Lightweight</td>
</tr>
<tr>
<td>Operating temperature at handle and cable</td>
<td>40-70°C</td>
<td>25-40°C</td>
</tr>
</tbody>
</table>

bore condition. Often, arc instabilities are not obvious until the gun reaches a certain critical operating temperature. This is because the electrical resistance of conductors increases with temperature, which augments the differential between set and true arc voltage. Subsequently, arc instabilities often appear after a gun has been continuously used for some time. A voltage drop of as small as 2 V in a gun can cause serious arc instability problems. Figure 4 illustrates voltage drop as a function of copper area for two different current levels.

**Water- or Air-Cooled Guns?**

Water-cooled guns require an external cooling system capable of dissipating gun heat (from the arc and resistance) to maintain low operating temperatures. The ability of a cooling system to perform such a task is determined by both water flow rate and the cooling power of the cooler. The maximum water flow rate is determined solely by available water pressure, size of water lines, and length of the gun. It cannot be otherwise controlled. Therefore, the water flow rate is a characteristic of every particular gun design when coupled to a cooling unit. Most commercial water-cooled guns show an average flow rate of about 0.5 gal/min when coupled to cooling units, which typically operate at 60 lb/in². The cooling power of a cooling unit refers to the heat rate (W or BTU/h) the cooling unit dissipates at a flow rate of 1 L/min (0.26 gal/min) using the coolant recommended by the manufacturer (IEC60974-1). Cooling power ratings of most commercial coolers range anywhere from 8000-15,000 BTU/h (2300-4400 W). However, actual cooling rates depend on actual water flow rates which, as mentioned earlier, are ultimately determined by both gun design and cooler pressures.

Last, but not least, there are significant differences between the cost of acquisition of air-cooled guns compared to water-cooled guns, as illustrated in Fig. 5. Also, the need for additional equipment as well as the higher amount of sub-components make water-cooled systems prone to more maintenance issues. Therefore, water-cooled systems are costly compared to air-cooled systems.

The advantages and disadvantages of air-cooled and water-cooled systems are summarized in Table 1. The higher cost of water-cooled systems can only be justified in applications where air-cooled guns are not sufficient. For most applications (<500 A), air-cooled guns may suffice. For hand-held applications that require high-power welding (>600 A) and high duty cycle (>60%), while providing an acceptable level of welder comfort and ergonomics, water-cooled guns may be a good alternative since premium costs of these systems may be offset by increased welder productivity and longer consumable life.
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In gas metal arc welding (GMAW), a spool continuously feeds an electrode through a contact tube that positions and transfers current to the electrode. The contact tube is usually made of a copper alloy because the material has good thermal and electrical conductivity. Contact tube failure results when the tube hole grows to where the tube can no longer accurately direct the electrode, when the tube provides intermittent or no current to the electrode, or when the tube-electrode interface causes electrode velocity to fluctuate or stop. The first two failure modes occur when sliding contact causes wear and the hole in the contact tube increases in size. The third failure mode occurs when debris builds up on the tube's interior until mechanical interference between the electrode and tube hinders the electrode feed and causes the arc to become unstable. In all cases, stick-slip mechanisms can cause variations in an electrode's feed speed, making the arc unstable (Refs. 1, 2).

As wear enlarges the hole in the tube, the electrode can suddenly shift contact points, causing intermittent contact, at the least, or arcing inside the tube, at the worst. Arcing could weld the electrode to the tube, causing the electrode to stop and the arc length to increase until the contact tube melts. If debris or dirt accumulates in the contact tube, wire-feed speed (WFS) can fluctuate, resulting in arc instability. Spatter accumulated on the contact tube face that narrows or closes the hole for the electrode is another common cause of failure.

Each mechanism that causes contact-tube failure worsens as temperature rises. Wear also increases with higher temperatures (Refs. 3, 4). The object of this article is to understand the important heating and cooling mechanisms of the contact tube.
Effect of gas flow rate

![Graph showing effect of gas flow rate on the contact tube's heating curve.](image)

Fig. 4 — Effect of gas flow rate on the contact tube’s heating curve.

Effect of Shielding Gas on Temperature

![Graph showing effect of shielding gas composition on the contact tube’s heating curve.](image)

Fig. 5 — Effect of shielding gas composition on the contact tube’s heating curve. The welding parameters for each curve are detailed in Table 3.

### Heat Flux

Heat input to the tube comes primarily from the following sources:

- Radiation from the arc and weld pool. As long as the arc is stable, this source is approximately constant in time and depends primarily on contact-tube-to-work distance (CTWD) and secondarily on arc length. There is also a small amount of radiation from the weld pool.

- Resistive heating at the interface as current is transferred between the contact tube and welding electrode.

- A small amount of ohmic heating due to current flowing through the contact tube (Refs. 4, 5).

- A negligible amount of heat conducts upward through the welding electrode from the weld.

The following processes cool the contact tube during welding:

- Conduction of heat along the rest of the gun.

- Convection via the shielding gas.

- Radiative losses, which are important only for very high contact tube temperatures.

Table 1 shows estimates for these heat sources and the assumptions used to develop them. The estimates were based on a 30-mm-long contact tube with a 6-mm O.D. and 1.6-mm I.D. The gas cup had a 15-mm I.D.

Estimates were developed for thermal equilibrium (after the temperature had stabilized) and balanced to within 10% of the experimental values. The radiation model considered the arc as a planar disk of constant temperature. The disk temperature was calculated as the average temperature over the volume of a 350-A arc (Ref. 8). Radiative transfer was considered only on the contact tube’s face. The convection heat transfer model was for a not yet fully developed flow along a cylinder, either thermally or hydrodynamically. Changing conditions such as current, voltage, or CTWD changed the magnitude of these values, but estimates illustrated the relative effects of the various terms. The conductive terms were nearly linear with temperature and could be scaled to estimate the relative thermal flows for other conditions.

These estimates predicted that resistive heating and radiation dominated the other heating sources and balanced with cooling by conduction. The specific welding parameters used determined the ratio between resistive and radiation.

### Experiments

For the experiment, a commercial air-cooled gun, inverter power source, and matching electrode feeder were used to make
bead-on-plate welds on 10-mm-thick x 50-mm-wide plates. The power source had pulsing capabilities, but the constant current mode was used to eliminate the complexities of pulse parameters. Older GMAW power sources typically have constant-voltage characteristics, and so offer a different response.

The contact tube had a mass of 9.5 grams and a heat capacity of 2.4 J/K, which meant a net heat input of about 100 W would produce an initial heating rate of 40 °/s.

The electrode was AWS type E70S-3 and the shielding gas was an argon-5% CO₂ mixture, flowing at a rate of 18 L/min (40 ft³/h). One weld was made using 100% CO₂ to estimate the shielding gas effect. The air-cooled welding gun was rated at 400 A for CO₂ shielding gas and derated by the manufacturer to a 60% duty cycle for argon-based mixtures. The gun was fixed perpendicular to the plate, which was moved underneath at a constant speed of 7.75 mm/s (0.3 in./s). This speed, except for one test to examine speed effect, was maintained during all experiments. All weld runs lasted about 150 s, a time sufficient to reach thermal stability in the contact tube. Welding current and voltage were measured with a pair of isolated transducers to an absolute accuracy of 1 and 0.5%, respectively, and recorded on a personal computer. Contact tube temperature was measured with a K-type thermocouple inserted into a small hole at the side of the tube. The thermocouple’s output, also recorded on the computer, was fed to a cold-junction-compensated linear amplifier that gave an analog output of 1.6 mV/°C. Sampling rate was 100 Hz.

To learn more about the contribution of radiation to contact tube heating, a number of welds were made with a ceramic radiation shield introduced between the contact tube and the workpiece. In this setup, a square of machinable ceramic (40 x 40 x 5 mm) was placed just below the contact tube. The welding electrode was fed through the ceramic square via a small hole drilled in its center. Three layers of ceramic cloth were placed between the ceramic radiation shield and the contact tube to eliminate any conduction between the two. In this setup, shielding gas was delivered to the weld area by an external tube. To demonstrate shielding can be achieved with more realistic welding conditions, some welds were made with a gas cup and ceramic shield. This shield was narrow enough to shield the contact tube from direct radiation while allowing gas flow to the weld area.

The experimental design was a full factorial matrix. Three CTWDs were used: 19, 25, and 32 mm (0.75, 1, and 1.25 in.). Shorter CTWDs were not investigated because room was needed for the ceramic radiation shield. Four wire-feed speeds were used: 110, 120, 130, and 140 mm/s (260, 285, 305, and 330 in./min). The voltages at the power supply were 27, 30, and 33 V, which corresponded to arc lengths of about 2, 4, and 6 mm, respectively. Some parameter combinations were well outside those normally used in welding, but the aim of this work was to analyze contact tube temperature over the widest possible range. This required a complete experimental matrix. To check the influence of the gas flow rate on contact tube temperature, two additional welds were made with gas flow rates of 14 and 23.6 L/min (30 and 50 ft³/h). To check the influence of welding travel speed on contact tube temperature, one weld was made at a speed of 15.5 mm/s (0.6 in./s).

### Heating Model

A simple model was developed to simulate the contact tube temperature rise with time. It was assumed the contact tube heats from a constant heat input (initially producing linear heating), and cools at a rate proportional to its temperature. The differential equation that describes such behavior is

\[ \frac{dT}{dt} = k - \alpha T \]  

where \( T \) is the temperature (°C), \( t \) the time (s), and \( k \) and \( \alpha \) are constants.

Solving Equation 1 gives:

\[ T(t) = \frac{k}{\alpha} + \left( T(0) - \frac{k}{\alpha} \right) e^{-\alpha t} \]  

According to this model, \( k/\alpha \) is the temperature of the contact tube at very long times. For this work, \( T(t=0) \) was set at 24°C, the ambient temperature in the lab. To let the gun return to room temperature, a wait of 2.5 h minimum was held between welds. The constants \( k \) and \( \alpha \) were varied to minimize the sum of the squares (\( R^2 \)) of the difference between the measurements and the calculated curve. The \( R^2 \) of the fit was typically 0.94.
Table 2 — The Parameters and Results for All Welds

<table>
<thead>
<tr>
<th>CTWD (mm)</th>
<th>Arc Length (mm)</th>
<th>Voltage Setting (V)</th>
<th>W Speed (cm/s)</th>
<th>Average Voltage (V)</th>
<th>Average Current (A)</th>
<th>Final Temp (°C)</th>
<th>Heating Rate (°C/s)</th>
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<tr>
<td>19</td>
<td>2</td>
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</table>

Results and Discussion

Figure 1 shows temperature measurements for the contact tube during a weld. These 15,000 measurements (100 Hz for 150 s) showed a band of data with a standard deviation about 14°C wide. Since the contact tube’s mass was sufficient to damp small thermal fluctuations, the band’s width was mainly due to electrical noise. The noise could not be filtered from the millivolt-scale thermocouple signal. Still, the temperature trend was quite clear. The band was wide enough to hide the model’s prediction on this figure, which fits nicely down the center. Table 2 lists the main parameters and results for the welds that were performed. For the entire matrix, final temperatures ranged from 200 to 550°C (390 to 1000°F), and the temperature reached about 90% of the final value within 50 s. Initial heating rates (measured over the first 5 s) ranged from 6.6 to 40°C/s. At the high end of the final temperature range, the gas cup and contact tube were discolored. As expected, low temperatures and heating rates were obtained while welding with combinations of low WFS, low voltage (short arc length), and high CTWD, whereas high temperatures and heating rates were obtained for combinations of high voltage setting, high WFS, and low CTWD. For α, an average value of 0.059 s⁻¹ was found with a standard deviation of 0.012 s⁻¹. Since changes in α were not correlated to changes in any weld parameters, α was fixed at 0.059 s⁻¹, and the model was fit to the data by varying just the final temperatures. The average effects of CTWD are presented in Fig. 2. As these effects are in descending order, they suggest radiation was a major heat source, especially at low CTWD values. For α, an average value of 0.059 s⁻¹ was found with a standard deviation of 0.012 s⁻¹. Since changes in α were not correlated to changes in any weld parameters, α was fixed at 0.059 s⁻¹, and the model was fit to the data by varying just the final temperatures. The average effects of CTWD are presented in Fig. 2. As these effects are in descending order, they suggest radiation was a major heat source, especially at low CTWD values. This confirmed the heat transfer model data in Table 1. Figure 2 shows a reduction in radiation of 62% (68% increase in CTWD) reduces the equilibrium temperature by 40%.

Figure 3 shows the calculated final temperature as a function of average power (calculated from the measured current and voltage) and CTWD. This expressed heat input as power. As expected, lowering CTWD increased the temperature of the contact tube for a given input power.

Figure 4 shows the heating curves from two welds made with the same welding parameters but with two different gas flow rate values. One flow rate was 25% below that used for most of the test matrix, the other was 25% above. Even though flow rate was changed by 50%, the heating curves were almost identical and
reached the same final temperatures. This result was as predicted by the heat-transfer model, which indicated heat carried away by the gas was less than 10% of the total. Even a 50% change in gas flow rate had only a small effect on the heating curve.

Heating curves for two welds made with the same welding parameters but with different travel speeds (7.75 and 15.5 mm/s) were practically the same. This was explained by the fact that the principal effect of the welding speed was on the size of the weld pool: the higher the travel speed, the smaller the weld pool. The weld pool contributes to heating of the contact tube mainly by radiation. It is further away from the tube than the arc. Since its temperature is only about 13% of that of the arc, the contribution of this heating is small. At these long CTWDs, changes in the size of the pool had minimal effect on the tube's heating curve.

Figure 5 demonstrates how selection of the shielding gas can affect heating of the contact tube. Curve 1 shows the temperature with Ar-5%CO₂, while curve 2 shows the temperature with CO₂ only, produced with the same welding parameters. The differences between these two welds demonstrate that switching to CO₂ resulted in lower contact tube temperature, while depositing the same amount of metal in the weld (same wire-feed speed of 140 mm/s). All weld parameter data for these welds are shown in Table 3. Changes between curve 1 and curve 2 can be explained by shielding gas effects on voltage and current (and total weld power). The model supports this result by indicating reductions in both resistive and arc-radiation contributions to contact tube heating, although the radiation effect appears to dominate here. No attempts were made to quantify the effects of the higher particulate level in the CO₂ arc or the change in the arc spectrum.

Curve 3 shows the temperature when wire-feed speed for the Ar-5%CO₂ weld was decreased until the arc power was the same as for the weld with CO₂ (curve 2). Here, the temperatures of the contact tubes with the two shielding gases followed nearly identical patterns. Thus, the lower tube temperature for the weld with CO₂ at the same power source settings seems most related to the reduction in arc power. Since the current increased while the voltage decreased, the relative changes in the contributions from resistive heating and arc radiation seem to offset each other. Good arc length measurements for the shielding gas tests could not be obtained, so no comparisons were made between these changes and the heat estimates. In general, using CO₂ as a shielding gas enables one to deposit more metal into the weld for a given temperature rise in the tube.

A solid ceramic radiation shield and a few layers of ceramic cloth placed between the arc and contact tube effectively eliminated radiative heating, separating this effect from other heat sources. Note the ceramic became red hot even during these short tests and often cracked during cooling. This further supports the intensity of the radiation from the arc. Figures 6-8 show the heating curves (with and without the heat shield in place) for CTWD values of 19, 25, and 32 mm, respectively. The contribution of radiation from the arc was very pronounced at a CTWD of 19 mm and much smaller at 32 mm. The significant drop in the relative contribution of radiation with distance for the examples in Figs. 6-8 confirms the trends shown in Fig. 2 for the averages of the entire test matrix. Figure 6 shows a 33% reduction in equilibrium temperature when the radiation contribution was eliminated by the ceramic shield. This was close to the 40% reduction in equilibrium temperatures found for the test matrix averaged in Fig. 2. The exact ratios of the contributions of radiation and resistive heating obviously depend on the welding conditions; however, these tests show these contributions can be similar in magnitude.

To fit the ceramic shield and cloth against the contact tube for the tests in Fig. 6–8, the gas cup had to be removed. This meant the shielding gas had to be fed from the side, an arrangement that was convenient for the tests but could be criticized as not accurately simulating actual situations. To come closer to standard practice, another weld was tried with the gas cup in place and a smaller (about 25 x 25 mm) ceramic shield just below it. This smaller shield had a series of holes for the usual axial flow of shielding gas, but the holes also allowed a small amount of radiation to reach the contact tube. This compromise in design meant the tube was expected to heat a little faster than it would with the higher-quality radiation shielding used for Figs. 6–8. After a few seconds, the narrow shield started to melt. This was not surprising because it was mounted on the bottom of the gas cup, much nearer to the arc. As the shield melted, radiation from the arc was able to reach the contact tube, so the heating curve slowly approached the unshielded curve. This experiment demonstrated that radiative shielding can be achieved under normal welding conditions, but it is difficult to develop a shield that can withstand the intense heat of the arc.

**Summary**

The contact tube in an air-cooled GMAW gun often reaches a temperature of 300°C (570°F) or higher for typical welding conditions, nearly halfway to the melting temperatures of many common copper alloys. The contact tube reaches about 90% of its equilibrium temperature in about 50 s. This means higher power inputs can be tolerated for short welds (10–20 s) because the contact tube never reaches the equilibrium temperature. Figure 2 confirms equilibrium temperature goes down with increasing CTWD, but up with WFS and welding voltage. Over the measured range, WFS has the least influence on final temperature. This means that, without overheating of the contact tube, the power input to the weld can be increased by increasing the voltage and the WFS, provided the CTWD is also increased. This is also demonstrated in Fig. 3, which shows how to move along a constant temperature (horizontal) line by increasing power and CTWD at the same time.

Radiation from the arc and resistive heating from the electrode-contact tube interface are two major sources of contact tube heating. Shielding the contact tube from arc radiation can reduce its temperature significantly, especially at low CTWD values, and lengthen its operational lifetime. Conduction of heat into the gun body through the contact tube mount is the most important means of cooling the contact tube. Cooling from shielding gas flowing around the contact tube provides only about 10% of the conductive cooling effect.

**References**

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As shielding gas CO₂ and wire chromium content increase, deposit carbon content rises in stainless steel

BY DAMIAN J. KOTECKI

Argon-CO₂ blends, such as 75% Ar-25% CO₂, are commonly used for flux cored arc welding (FCAW) of stainless steel where slag protects the metal from carbon pickup. However, it is recommended CO₂ in excess of 2.5% in gas metal arc welding (GMAW) of stainless be avoided because the nearly slag-free GMA weld pool picks up carbon from the shielding gas, losing the low-carbon character of the stainless (Ref. 1). As long ago as 1956, Rothschild (Ref. 2) noted 0.099% C in the deposit of a CO₂-shielded, ½-in.-diameter (1.6-mm) 308L wire containing 0.043% C. This carbon pickup seemed independent of welding voltage in what was presumed to be globular transfer. Rothschild further investigated argon-CO₂ blends, but did not report weld metal carbon content for other than 100% CO₂.

In 1959, Hopkinson and McDowell (Ref. 3) reported similar carbon pickup when 308L wire was gas metal arc welded with CO₂ shielding, also using globular transfer. They investigated sensitization of single- and multipass welds using Huey (boiling 65% nitric acid) and Streicher (ferric sulfate-sulfuric acid) tests. Results indicated preferential attack along the ferrite-austenite interface in earlier multipass welds when CO₂ shielding was used, but no attack when argon-1% oxygen shielding was used. In short, single-pass welds were not attacked, nor were the last passes of multipass welds, so carbon pickup was not harmful.

A review of corrosion in stainless steel welds by Gooch (Ref. 4) also indicated more carbon can be tolerated in the weld metal than in the heat-affected zone without sensitization. According to Gooch, a single weld pass causes chromium carbides to precipitate on austenite-austenite grain boundaries in the ferrite-
Table 1 — Chemical Composition of Experimental GMAW Wires

<table>
<thead>
<tr>
<th>AWS Class</th>
<th>% C</th>
<th>% Mn</th>
<th>% P</th>
<th>% S</th>
<th>% Si</th>
<th>% Cr</th>
<th>% Ni</th>
<th>% Mo</th>
<th>% Cu</th>
<th>% Nb</th>
<th>% N</th>
<th>WRC-1992 FN</th>
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</thead>
<tbody>
<tr>
<td>ER90S-B3L</td>
<td>0.05</td>
<td>0.40-0.70</td>
<td>0.025</td>
<td>0.025</td>
<td>0.40-0.70</td>
<td>2.30-2.70</td>
<td>0.20</td>
<td>0.90-1.20</td>
<td>0.35</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
</tr>
<tr>
<td>Lot F8519</td>
<td>0.035</td>
<td>0.55</td>
<td>0.004</td>
<td>0.10</td>
<td>0.59</td>
<td>2.43</td>
<td>0.06</td>
<td>0.06</td>
<td>0.06</td>
<td>0.005</td>
<td>0.099</td>
<td>N.A.</td>
</tr>
<tr>
<td>ER308LSi</td>
<td>0.03</td>
<td>1.0-2.5</td>
<td>0.03</td>
<td>0.03</td>
<td>0.65-1.00</td>
<td>19.5-22.0</td>
<td>9.0-11.0</td>
<td>0.75</td>
<td>0.75</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
</tr>
<tr>
<td>Lot 531T</td>
<td>0.019</td>
<td>2.03</td>
<td>0.027</td>
<td>0.017</td>
<td>0.88</td>
<td>20.42</td>
<td>10.57</td>
<td>0.25</td>
<td>0.27</td>
<td>0.01</td>
<td>0.054</td>
<td>10.3</td>
</tr>
<tr>
<td>ER309LSi</td>
<td>0.03</td>
<td>1.0-2.5</td>
<td>0.03</td>
<td>0.03</td>
<td>0.65-1.00</td>
<td>23.0-25.0</td>
<td>12.0-14.0</td>
<td>0.75</td>
<td>0.75</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
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<td>Lot 432P</td>
<td>0.019</td>
<td>2.29</td>
<td>0.027</td>
<td>0.008</td>
<td>0.87</td>
<td>23.45</td>
<td>13.71</td>
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<td>0.23</td>
<td>0.03</td>
<td>0.068</td>
<td>10.2</td>
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<td>304L</td>
<td>0.030</td>
<td>1.65</td>
<td>0.032</td>
<td>0.031</td>
<td>0.32</td>
<td>18.55</td>
<td>8.23</td>
<td>0.44</td>
<td>0.38</td>
<td>0.01</td>
<td>0.098</td>
<td>7.4</td>
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</tbody>
</table>

N.S. = Not specified
N.A. = Not applicable

Fig. 1 — Regression curve fits to the ER308LSi deposit carbon content GMAW short-circuiting transfer data of Table 3.

Fig. 2 — Deposit carbon content for ER308LSi spray transfer (Table 2), short-circuiting transfer (Table 3), and single-layer short-circuiting transfer (Table 4).

Materials and Procedures

Three 0.045-in.-diameter (1.14-mm) wires were used for weld deposition. Two were AWS A5.9 ER308LSi and ER309LSi stainless steel wires. The third wire, which allowed examination of the effect of chromium content on carbon pickup, was labeled by its manufacturer as ER90S-B3L, although today this wire would be reclassified by AWS A5.28-96 as ER80S-B3L. (The strength requirements have changed, but not the chemical composition requirements.) Table 1 lists the AWS classification requirements and actual analyses of the three wires with calculated ferrite numbers (FN) for the two stainless steel wires. Ferrite numbers are not applicable to the CrMo wire.

Six-layer GMAW deposits were produced with the ER308LSi and ER309LSi on 304L bar stock, 3/8 in. (6.4 mm) thick and 2 in. (51 mm) wide. The composition of the 304L base metal is included in Table 1. An argon-CO₂ gas mixer was used to provide shielding gas containing 2.5, 5, 10, 25, 50, 75, 90, and 100% CO₂ for making deposits with each wire. Both short-circuiting transfer and "spray" transfer welds were produced with ER308LSi and ER309LSi. A true spray could be produced with stainless steel wires using 75% argon-25% CO₂ and with all lower CO₂ concentrations, but not with 50% CO₂ or more, so globular transfer resulted with the higher CO₂ concentrations. "Spray," then, is used herein to indicate either spray or globular transfer. With the ER90S-B3L wire, a true spray...
transfer could not be obtained with the 75% argon-25% carbon dioxide mixture. Short-circuiting transfer was not used with the ER90S-B3L wire. The ER90S-B3L was deposited on mild steel bar stock.

All welding was done semiautomatically at 3/8-1/2-in. (10-13-mm) contact tip-to-work distance and DC electrode negative polarity. Spray transfer welding was accomplished with wirefeed speed of 300 in./min (7.62 m/min), resulting in 220-260 A, with higher currents at lower CO2 content, in general. An attempt to weld in pure argon with ER308LSi produced only 185 A. Voltage for spray transfer welding was adjusted to the lowest level that would produce steady transfer, about 25 V at low CO2, to 27 V at high CO2, with stainless steel wires, and 26-28 V with the ER90S-B3L.

Short-circuiting transfer was accomplished at 175 in./min (4.45 m/min), resulting in 135-150 A for all gas blends; there was no consistent pattern of higher or lower current with more or less CO2. One deposit was made with 90% helium-7.5% argon-2.5% CO2 at 21 V with ER308LSi. All other deposits were made at 15-17 V (higher voltage with more CO2) to get stable short-circuiting transfer. Stable short-circuiting transfer could be obtained over the full range of CO2 contents except 0%.

Using ER90S-B3L, only spray transfer six-layer deposits were made. With ER308LSi, both short-circuiting and spray transfer six-layer deposits were made. With ER308LSi, both short-circuiting and spray transfer six-layer deposits were made, and a series of single-layer short-circuiting transfer deposits on 304L base metal were made as well.

All deposits were approximately 3 in. (75 mm) in length and about 3/8 in. (10 mm) in width. After welding, chips were milled from the top surface of the center 1 in. (25 mm) of each weld length, and a spectrographic sample was prepared from below the chipped surface. The chips were analyzed for carbon, sulfur, and nitrogen with LECO fusion equipment. Ferrite was measured with an instrument calibrated according to AWS A4.4 on the surface of the stainless steel weld pads before spectrographic analysis for other elements.

### Table 2 — Six-Layer Deposit Analyses in Spray Transfer Welding with ER308LSi

<table>
<thead>
<tr>
<th>% CO2 (bal. Ar)</th>
<th>% C</th>
<th>% Mn</th>
<th>% P</th>
<th>% S</th>
<th>% Si</th>
<th>% Cr</th>
<th>% Ni</th>
<th>% Mo</th>
<th>% Cu</th>
<th>% Nb</th>
<th>% N</th>
<th>FN</th>
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<tbody>
<tr>
<td>0</td>
<td>0.019</td>
<td>1.95</td>
<td>0.028</td>
<td>0.015</td>
<td>0.86</td>
<td>20.43</td>
<td>10.51</td>
<td>0.25</td>
<td>0.24</td>
<td>0.01</td>
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<td>12.5</td>
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<td>2.5</td>
<td>0.030</td>
<td>1.86</td>
<td>0.027</td>
<td>0.017</td>
<td>0.82</td>
<td>20.62</td>
<td>10.53</td>
<td>0.25</td>
<td>0.23</td>
<td>0.01</td>
<td>0.052</td>
<td>11.5</td>
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<td>5</td>
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<td>0.028</td>
<td>0.015</td>
<td>0.78</td>
<td>20.48</td>
<td>10.48</td>
<td>0.25</td>
<td>0.24</td>
<td>0.01</td>
<td>0.052</td>
<td>10.2</td>
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<tr>
<td>10</td>
<td>0.050</td>
<td>1.75</td>
<td>0.028</td>
<td>0.016</td>
<td>0.76</td>
<td>20.34</td>
<td>10.47</td>
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<td>0.014</td>
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<td>20.13</td>
<td>10.34</td>
<td>0.25</td>
<td>0.24</td>
<td>0.01</td>
<td>0.052</td>
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<td>50</td>
<td>0.083</td>
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<td>0.029</td>
<td>0.015</td>
<td>0.63</td>
<td>20.24</td>
<td>10.70</td>
<td>0.26</td>
<td>0.24</td>
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<td>5.9</td>
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<td>75</td>
<td>0.097</td>
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<td>0.61</td>
<td>20.25</td>
<td>10.61</td>
<td>0.26</td>
<td>0.24</td>
<td>0.01</td>
<td>0.052</td>
<td>4.6</td>
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<tr>
<td>90</td>
<td>0.107</td>
<td>1.50</td>
<td>0.029</td>
<td>0.015</td>
<td>0.61</td>
<td>20.16</td>
<td>10.44</td>
<td>0.26</td>
<td>0.24</td>
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<td>3.7</td>
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<tr>
<td>100</td>
<td>0.114</td>
<td>1.48</td>
<td>0.028</td>
<td>0.014</td>
<td>0.58</td>
<td>20.27</td>
<td>10.68</td>
<td>0.26</td>
<td>0.24</td>
<td>0.01</td>
<td>0.054</td>
<td>3.1</td>
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analysis of these deposits (Table 4) consisted only of carbon and sulfur results. In each table, increasing deposit carbon content is evident with increasing CO₂ content of the shielding gas. Due mainly to the carbon pickup, the measured ferrite number can be seen to decrease with increasing CO₂ in the shielding gas. As noted above, the quantity of slag formed during welding increased with increasing CO₂ in the shielding gas, and the slag was found by SEM analysis to consist mainly of manganese silicate. Tables 2 and 3 show a corresponding decrease in weld-metal manganese and silicon content with increasing CO₂ in the shielding gas resulted when these elements were transferred as oxides to the slag.

Chemical analyses of ER309LSi deposits are given in Table 5 (spray transfer) and Table 6 (short-circuiting transfer), along with measured ferrite numbers. It was expected that with the higher chromium content of ER309LSi, greater carbon pickup would be observed in comparison to ER308LSi. This was found to be correct, but the effect was small, as seen by comparing deposits made at corresponding CO₂ contents and metal-transfer modes (Tables 2 and 5 or 3 and 6). Similar trends in loss of manganese and silicon in the deposit and reduction of ferrite content, as seen in the ER308LSi deposits, were evident for ER309LSi deposits in Tables 5 and 6.

Chemical analyses of spray transfer deposits made with the ER90S-B3L wire are given in Table 7. Ferrite measurements have no meaning in these deposits, so there is no FN column in Table 7. Again, a trend of increasing deposit carbon content with increasing CO₂ content in the shielding gas is evident, but the magnitude of the effect is much smaller than that of stainless steel wires. The trend of decreasing deposit Mn and Si content with increasing CO₂ content in the shielding gas is also evident.

**Discussion of Results**

Plotting deposit carbon results vs. the CO₂ content of shielding gas for any of the data series in Tables 2 through 7 reveals nonlinear relationships. Figure 1 shows graphical results for the six-layer, short-circuiting transfer ER308LSi deposits. The actual data points are shown in Fig. 1 with three potential regression curve fits — linear, square root, and cube root. The data trend appears to best fit the square root relationship, i.e., the deposit carbon content appears to be proportional to the square root of the CO₂ content of the shielding gas. That would be the expected relationship if Sievert's Law were applicable to this situation. However, Sievert's Law is applicable to dissociation of a diatomic gas molecule into monatomic form that is soluble in the weld pool, e.g., oxygen, nitrogen, or hydrogen. But CO₂ is not a diatomic molecule, so this square root fit is difficult to explain from a thermodynamics viewpoint.

The following is a possible reaction to explain dissociation of
the CO₂ molecule in the arc:

\[ \text{CO}_2 \rightleftharpoons \text{C} + \text{O}_2 \]  

(1)

where CO₂ and O₂ are gaseous components and C is carbon dissolved into the metal. If this were the governing reaction, then dissolved carbon would be a linear function of percent CO₂ in the shielding gas. But Fig. 1 indicates the relationship is nonlinear, so this analysis does not look attractive.

The following possible reaction that produces a nonlinear relationship was offered by Liu as a combination of two reactions:

\[ 2\text{CO} \rightleftharpoons 2\text{C} + 2\text{O}_2 \]  

(2)

\[ 2\text{CO} \rightleftharpoons \text{CO}_2 + \text{C} \]  

(3)

which can be combined to produce

\[ \text{CO}_2 + 2\text{CO} \rightleftharpoons 3\text{C} + 2\text{O}_2 \]  

(4)

where CO is also a gaseous component. The coefficient 3 of C leads to a cubic root relationship between carbon dissolved in the metal and CO₂ content in the shielding gas. But Fig. 1 also shows the best cubic root relationship does not fit the experimental data at all that well either, although it qualitatively has appropriate curvature.

A better fit of the experimental data turns out to be a square root relationship, as seen in Fig. 1, even though a theoretical reaction to produce this type of relationship could not be deduced. The regression fit of linear, square root, and cubic root relationships was repeated for the deposit carbon vs. shielding gas CO₂ for each dataset (Tables 2-7). In all cases, a square root relation fit the experimental data best, so all of the following curves of carbon content versus shielding gas CO₂ content include the square root curve fit.

Figure 2 shows the experimental results for ER309LSi in six-layer spray transfer, in six-layer short-circuiting transfer, and in single-layer short-circuiting transfer. It should come as no surprise the single-layer short-circuiting curve is below the six-layer short-circuiting curve due to dilution effects from the low-carbon base metal. It is noteworthy the six-layer spray transfer carbon content is greater than the six-layer short-circuiting transfer carbon content at any given CO₂ content.

Figure 3 compares spray transfer results and short-circuiting transfer results obtained with ER309LSi wire. The trends are very similar to those observed with ER308LSi. Recall Table 1 shows the carbon contents of the two wires are virtually identical. However, the carbon content of the weld metal at any given shielding gas CO₂ level is somewhat higher for ER309LSi.

This observation prompted further investigation to determine if there is an important effect of chromium content of the wire. The ER90S-B3L wire was obtained specifically to permit investigation of the chromium effect. Table 7 data were obtained, along with the corresponding spray transfer data of ER308LSi and ER309LSi, from this investigation and are plotted together in Fig. 4. While ER90S-B3L deposits start out at higher carbon content with very low CO₂ shielding gas content (because ER90S-B3L wire is higher in carbon content than other wires), the higher chromium deposits quickly overtake the low chromium deposit as CO₂ content increases. There is, therefore, clearly an important chromium effect in carbon pickup from the shielding gas.

Figure 5 reconsiders the spray transfer results of the three wires by looking at the carbon pickup (deposit carbon minus wire carbon) as a function of wire chromium content at each of the various CO₂ shielding gas levels. The data at any given CO₂ level appear to fit a linear relationship, but there are only three data points for any given CO₂ level, so it cannot be said with certainty the relationship is linear. It should also be noted the sum of Mn + Si content for the three wires increases in the same order as the chromium content increases. Since manganese silicate seems to be the principal deoxidation product, there may be an effect of these elements confounded with the chromium effect.

The blend of 75% argon-25% CO₂ produced a stable spray,
albeit with a slight crackle, with both stainless steel wires, but not with the ER90S-B3L. It also produced short-circuiting transfer with good wetting. And in all cases (single-pass or multi-pass, spray or short-circuiting transfer, ER308LSi, or ER309LSi filler metal), it produced deposit carbon content in the 0.04–0.08% range. That is, for example, 25% CO₂ converted the ER308LSi wire into a deposit that is indistinguishable from an E308H-16 covered electrode deposit. E308H-16 is frequently chosen for high-temperature service, and ER308LSi wire with 75% Ar-25% CO₂ shielding gas would seem to be a viable alternative for joining 304H base metal. The carbon pickup also dropped the weld metal ferrite content to a level more compatible with high-temperature service, e.g., to 7.0 FN with the ER308LSi wire.

Conclusions

Carbon pickup in either short-circuiting transfer or spray-to-globular transfer GMAW, with stainless steel wires, is proportional to the square root of the CO₂ content of the shielding gas. Deposit ferrite content decreases in proportion to the carbon pickup. Low carbon (no more than 0.03% C) deposits are not obtained with low-carbon wire when the CO₂ in the shielding gas exceeds 2.5%. Carbon pickup increases with increasing wire chromium content at any given CO₂ level in the shielding gas. A deposit composition very similar to that of a 308H filler metal can be obtained with ER308LSi wire and 75% argon-25% CO₂ gas shielding.

Acknowledgments

The author is indebted to Roger Swain of Euroweld, Ltd., who provided the ER90S-B3L wire used in this study; Professor Steve Liu of the Colorado School of Mines, who offered insight into the thermodynamic relationships; and Bill Spang, who assisted in weld sample preparation. The Lincoln Electric Co. provided the environment and support for the author to conduct this investigation.

References

Quality and consistency are key to any quality assurance program. Whether your goal is ISO certification or maintaining your own internal quality program, you must be confident your processes are consistent and repeatable, and the products being used in production meet specific requirements and specifications.

To maintain a stable, consistent welding process and ensure repeatable results, you should implement welding procedure specifications (WPS). A WPS gives the welder or welding operator the recipe for producing acceptable welds on a given application, time after time. In developing a WPS for gas metal arc or gas tungsten arc welding, many variables must be taken into account such as voltage, amperage, electrode extension, and shielding gas. These, and other, variables are called “essential variables” as defined in AWS D1.1, Structural Welding Code — Steel.

**The Classification System**

With respect to shielding gases, AWS D1.1 states a procedure qualification record (PQR) requires requalification when there is “a change in shielding gas from a single gas to any other single gas or mixture of gases, or in the specified nominal percentage composition of a gas mixture, or to no gas.” Therefore, it is essential your shielding gas composition be accurate and consistent to ensure WPSs are being followed and the desired weld quality is maintained.

It is the responsibility of your gas supplier to ensure you receive an accurate, consistent shielding gas supply that conforms to AWS A5.32, Specification for Welding Shielding Gases. AWS A5.32 prescribes the requirements for the classification of shielding gases, similar to the way AWS 5.18, Specification for Carbon Steel Electrodes and Rods for Gas Metal Arc Welding, prescribes a classification system for identifying carbon steel electrodes and rods. These specifications were developed by the American Welding Society and approved by ANSI as a way of identifying products based on chemical composition.

JOE ZAWODNY (216-901-5783) is a Welding Engineer Manager for AGA Gas, Inc., a member of the Linde Gas Group, Cleveland, Ohio. He is an AWS Certified Welding Inspector and a member of the AWS C50 Subcommittee on Shielding Gases.
### Table 1 — Gas Type, Purity, and Dew Point Requirements for Shielding Gas Components

<table>
<thead>
<tr>
<th>Gas</th>
<th>AWS Classification</th>
<th>Product State</th>
<th>Minimum Purity (%</th>
<th>Maximum Moisture (^a) (ppm)</th>
<th>Dew Point Maximum Moisture at 1 Atmosphere °F</th>
<th>°C</th>
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<tr>
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<td></td>
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<td>99.9</td>
<td>Not Applicable</td>
<td>-54</td>
<td>-18</td>
<td>Type I</td>
</tr>
</tbody>
</table>

*Notes: \(a\) Moisture specifications are guaranteed at full cylinder pressure, at which the cylinder is analyzed. \(b\) Including neon. \(c\) Including helium.*

When these specifications are utilized and implemented by the manufacturer of each product, the end user is assured a consistent quality product.

The classification system outlined in the specification clearly identifies the chemical composition of the shielding gas in question, similar to the way welding wires are identified. For instance, if you order E70S-6 welding wire, you should feel confident you will receive a welding wire that contains certain percentages of silicon, manganese, etc. Similarly, when you order SG-AC-10 shielding gas, you should be confident it contains 10% carbon dioxide, 90% argon, and that the product is consistent from cylinder to cylinder.

AWS A5.32 not only establishes an identification system for shielding gases, it also specifies the purity and dew point levels required for individual gases, as shown in Table 1. The specification also covers the requirements for dew point, purity, and mix accuracy for gas mixtures. To adhere to this specification, your shielding gas supplier must test individually filled cylinders or one cylinder from each filling manifold to verify mix accuracy, purity, and dew point.

Look on the cylinder to make sure your gases comply with A5.32. The attached label should state the gases meet the requirements of the specification. If your shielding gas cylinder contains such a label, you can be assured your gas supplier is taking all necessary precautions to supply your company with consistent, quality gas mixtures.

---

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## AWS CWI/CWE Prep Course and Exam Schedule, January - February 2002

<table>
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<th>JANUARY 2002</th>
<th>Mon.-Fri. Welding Inspection Seminar</th>
<th>Sat. Exam</th>
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<td>Baton Rouge, LA</td>
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<td>1/26/02</td>
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<td>1/14-18</td>
<td>1/19/02</td>
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<td>Miami, FL</td>
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<td>1/26/02</td>
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<td>Nashville, TN</td>
<td>1/28-2/1 API 1104 also available*</td>
<td>2/2/02</td>
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| Baton Rouge, LA   | 2/18-22 API 1104 also available*     | 2/23/02         |
| Charlotte, NC     | 2/18-22 sponsored by NBBPV           | 2/19/02         |
| Columbus, OH      | 2/4-8                                 | 2/19/02         |
| Denver, CO        | 2/4-8                                 | 2/19/02         |
| Kansas City, MD   | 2/4-8                                 | 2/19/02         |
| Louisville, KY    | 2/25-3/1 API 1104 also available*     | 3/2/02          |
| Miami, FL         | Exam only                             | 2/24/02         |
| Mobile, AL        | Exam only                             | 2/23/02         |
| Norfolk, VA       | 2/25-3/1 API 1104 also available*     | 3/2/02          |
| Seattle, WA       | 2/18-22 API 1104 also available*      | 2/23/02         |

*Students registered for API 1104 Seminar must bring API 1104, 19th edition, to the seminar. All other books will be provided.

AWS reserves the right to cancel or change the published date of any exam prep course or exam listed in this brochure if an insufficient number of registrations are received.

Allow six weeks for application review and processing. Call (800) 443-9353, ext. 273, for specifics on fast tracking your application.

---

## Prep Course Schedule

- **D1.1 Code Clinic** ................................................................. Monday
- **API Code Clinic** (evenings: 6:00 - 10:00 p.m.) .................. Tuesday-Wednesday
- **Welding Inspection Technology** ........................................... Tuesday - Thursday
- **Visual Inspection Workshop** ............................................... Friday
- **Exam** .................................................................................. Saturday

To register or for more information on an exam prep course, call 800-443-9353, Ext. 229; to request an application for CWI exam qualification, call Ext. 273. Visit our website www.aws.org/certification for additional dates.

---

Plan now to become an AWS Certified Welding Inspector.
AWS FELLOWSHIPS

To: Professors Engaged in Joining Research

Subject: Request for Proposals for AWS Fellowships for the 2002-03 Academic Year

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

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

Please note, there are important changes in the schedule which you must follow in order to enable the awards to be made in a timely fashion. Proposals must be received at American Welding Society by January 4, 2002. New AWS Fellowships will be announced at the AWS Annual Meeting, March 4-7, 2002.

THE AWARDS

The Fellowships or Grants are to be in amounts of up to $25,000 per year, renewable for up to three years of research. However, progress reports and requests for renewal must be submitted for the second and third years. Renewal by AWS will be contingent on demonstration of reasonable progress in the research or in graduate studies.

The AWS Fellowship is awarded to the student for graduate research toward a Masters or Ph.D Degree under a sponsoring professor at a North American University. The qualifications of the Graduate Student are key elements to be considered in the award. The academic credentials, plans and research history (if any) of the student should be provided. The student must prepare the proposal for the AWS Fellowship. However, the proposal must be under the auspices of a professor and accompanied by one or more letters of recommendation from the sponsoring professor or others acquainted with the student's technical capabilities. Topics for the AWS Fellowship may span the full range of the joining industry. Should the student selected by AWS be unable to accept the Fellowship or continue with the research at any time during the period of the award, the award will be forfeited and no (further) funding provided by AWS. The bulk of AWS funding should be for student support. AWS reserves the right not to make awards in the event that its Committee finds all candidates unsatisfactory.

DETAILS

The Proposal should include:

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

In addition, the proposal must include:

1. Student’s Academic History, Resume and Transcript
2. Recommendation(s) Indicating Qualifications for Research
3. Brief Section or Commentary on Importance of Research to the Welding Community and to AWS, Including Technical Merit, National Need, Long Term Benefits, etc.
4. Statement Regarding Probability of Success

The technical portion of the Proposal should be about ten typewritten pages. Two copies should be sent by January 4, 2002, to:

Richard D. French
Deputy Executive Director
American Welding Society
550 N. W. LeJeune Rd., Miami, FL 33126

Yours sincerely,

Frank G. DeLaurier
Executive Director
American Welding Society
New Fabrication Technologies for U.S. Navy's 21st-Century Surface Combatants

The Navy Joining Center (NJC) is participating with shipbuilders and other Navy MANTECH Centers of Excellence (COE) in several technology development projects for the U.S. Navy's next generation USS Zumwalt (DD 21) class land attack destroyers.

Development projects being performed at NJC include Composite-to-Steel Adhesive Joining, CNC Thermal Plate Forming, and Collarless Construction. Team partners involved in these projects include Bath Iron Works, Northrop Grumman Ship Systems Ingalls Operations, the Boeing Company, Composites Manufacturing Technology Center (CMTC), National Center of Excellence in Metalworking Technology (NCEMT), the Institute for Manufacturing and Sustainment Technologies (iMAST), and Edison Welding Institute (EWI). The NJC leads the team for the Composite-to-Steel Adhesive Joining and NCEMT and iMAST lead the CNC Thermal Plate Forming and Collarless Construction projects, respectively.

**Composite-to-Steel Adhesive Joints.** New material systems present potential solutions to meet the advanced performance criteria demanded by the DD 21 and other Navy ships. As a result of these requirements, there is an increased demand for use of composites. Such materials require new joining technologies for fabrication of large marine composite-to-steel components. Presently, mechanical fasteners are used to join composite-to-steel, and even some composite-to-composite, joints for applications on Navy ships. Because joints using fasteners are expensive to install and maintain, this project seeks to develop and implement producible and cost-effective steel-to-composite adhesive joining technology suitable for the USS Zumwalt (DD 21) class land attack destroyer and other surface combatants and aircraft carriers.

**CNC Thermal Plate Forming.** Various thermal methods have been used by shipyards to induce plate curvature. Specifically, complex shapes that can fit into a structure, reducing both the number of plates and welds, are desired. In its simplest form, line heating is performed by passing a thermal source across the surface of the plate to induce differential heating through the thickness. Upon cooling, the plate deforms. The process may be repeated a number of times to achieve the desired shape.

The goal of this project is to create an automated thermal-forming plate system to replace manual, high-skill operations. NJC project activity is building upon a semiautomatic process to form plates using “line heating” technology developed by EWI with NSRP funding. The CNC project will utilize finite element analysis for modeling of the forming process as it examines heat patterns as a function of gas torch, induction, and laser heating sources. Project activities will begin by performing benchmark analysis of present technology. Once analysis is complete, project activities will be directed toward developing a method to preselect the heat pattern applied to the plate for forming, determining the requirements of a feedback system for monitoring plate curvature during the forming process, and demonstrating the technology.

**Collarless Construction.** Current ship design/construction practice requires welding of “collars” at the intersection of each longitudinal stiffener. This allows through penetration of the transverse stiffeners. In order to restore the structural integrity of the longitudinal stiffeners, each gap is filled by a collar welded to the stiffener and fillet welded to the bulkhead (or deck) and the transverse stiffener. Collared welds can be required to be water-, fume-, and/or light-tight.

Financial considerations have required naval shipbuilders to reevaluate all segments of production for cost-saving opportunities. Although a time-honored tradition, the welded collar is costly to fabricate. Heat from welding creates distortion and residual stresses. Collar weldments are also very labor intensive, requiring extensive fitting and welding. In addition, costs rise when material handling requirements and piece/part fabrication and tracking, as well as coating failures, are increased. Thus, this project will investigate and develop a cost-effective, collarless construction methodology for use in the DD 21 program.

The above-mentioned projects are enabling technologies that address both manufacturing and affordability goals for a variety of U.S. Navy ship platforms. For more information on these projects, contact Larry Brown of NJC at (614) 688-5080 (larry_brown@ewi.org).
Conferences and Exhibitions

Eleventh International Conference on Computer Technology in Welding. December 5–6, Columbus, Ohio. Sponsored by AWS. Contact: AWS Conferences, 550 NW LeJeune Rd., Miami, FL 33126, (800) 443-9353 ext. 223 or, outside the U.S., (305) 443-9353 ext. 223, FAX: (305) 443-1552; www.aws.org.


International Hardware Fair/DIY'TEC Cologne. March 3–6, 2002, Cologne Germany. Sponsored by Köln Messe. Contact: Claudia Cöbler, Sales Manager, Köln Messe GmbH, Messeplatz 1, D-50679 Köln, Germany, 49(0)221/821-2380, FAX: 49(0)221/821-3905, e-mail: c.coebler@koelnmesse.de; www.eisenwarenmesse.de.

Note: A diamond (♦) denotes an AWS-sponsored event.
Educational Opportunities


Hellier NDT Courses. A course schedule is available from Hellier, 277 W. Main St., Niantic, CT 06357, (860) 739-8950, FAX: (860) 739-6732.

Shielded Metal Arc Welding of 2-In. Pipe in the 6G Position — Uphill. Hobart Institute of Welding Technology, Troy, Ohio. This course is designed to develop welding skills necessary to produce quality multipass welds on 2-in.-diameter, schedule 160 mild steel pipe (0.436-in. wall thickness) in the 6G position using E6010 and E7018 electrodes. For further information, contact: Phil Pratt, President, Hobart Institute of Welding Technology, 400 Trade Square East, Troy, OH 45373, (800) 332-9448, FAX: (937) 332-5200; www.welding.org.

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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.

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<tr>
<th>Cities</th>
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<td>Jan. 28-Feb. 1, 2002</td>
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<td>Mobile, Ala.</td>
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AWS International Schedule — CWI/CWE Prep Courses and Exams

**SINGAPORE**
- December 3-7, CWI Training
- December 10, CWI Examination
- Setsco Services Pte Ltd.
- Contact: 65-566-7777
- FAX: 65-566-7718

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

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<table>
<thead>
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</table>

For more information on Continuing Education Seminars, call (305) 443-9353, ext. 229. For on-line registration visit www.maxinternational.com.

American Welding Society
550 N.W. LeJeune Road
Miami, FL 33126
## Inspection Symbols

Inspection symbols that appear on engineering drawings provide a means for specifying the method of examination to be used. Nondestructive examination symbols (NDE) are specified along with welding symbols by using an additional reference line or by specifying the examination method in the tail of the welding symbol. Nondestructive examination symbols are composed of reference line; arrow; tail; letter designation for examination method; extent of examinations; specifications, codes, and other references; and supplementary symbols — Fig. 1.

### Reference Line, Arrow, Tail

The reference line is the basic symbol element about which inspection information is located. The preferred orientation is horizontal. The arrow connects the reference line to the workpiece to be examined. The side to which the arrow points is the “arrow side” and the opposite side is referred to as the “other side.” When more information is needed to convey the requirements of the inspection, it is placed in the tail. If no additional information is needed, the tail is omitted.

### Examination Designations

Nondestructive examination processes are referenced by letter designations — Table 1. The locations of letter designations in relation to the reference line are shown in Fig. 2. To indicate the examination is to be performed on the arrow side of the workpiece, the examination letter designation is placed below the reference line — Fig. 2A. Examinations to be made on the other side have the letter designations above the reference line — Fig. 2B. Examinations on both sides are indicated by designations on both sides of the reference line — Fig. 2C.

### Table 1 — Letter Designations for NDE Methods

<table>
<thead>
<tr>
<th>Process</th>
<th>Designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acoustic emission</td>
<td>AET</td>
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<tr>
<td>Electromagnetic</td>
<td>ET</td>
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<tr>
<td>Leak</td>
<td>LT</td>
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<tr>
<td>Magnetic particle</td>
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<td>NRT</td>
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<td>Penetrant</td>
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<tr>
<td>Proof</td>
<td>PRT</td>
</tr>
<tr>
<td>Radiographic</td>
<td>RT</td>
</tr>
<tr>
<td>Ultrasonic</td>
<td>UT</td>
</tr>
<tr>
<td>Visual</td>
<td>VT</td>
</tr>
</tbody>
</table>

![Fig. 1 — Standard location for the elements of the nondestructive examination symbol.](image1)

![Fig. 2 — Location and significance of letter designations. A — Examine the arrow side; B — examine the other side; C — examine both sides; D — no side significance.](image2)
Inspection Symbols

Fig. 3 — Extent of examination. A — Desired length of examination is positioned to the right of NDE designation; B — exact location and length of examination are included on the drawing; C — partial examination is indicated by the percentage to the right of the letter designation; D — multiple examinations are indicated in parentheses either above or below the letter designation; E — complete examination of a continuous joint is indicated by an all-around symbol.

Fig. 4 — Nondestructive examination of specific areas. A — Area of a plane to be examined is indicated by straight broken lines with circles to indicate a change of direction; B — examination of areas of revolution is indicated by the all-around symbol and appropriate dimensions; C — examination on both sides is indicated, with proof internally and electromagnetic externally.
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Section Name (if applicable)________________________ Section No.________________________

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For nearly 50 years, only the annual AWS Welding Show has brought the industry together to see the best products on the market. And, year after year, our percentage of first time attendees remains high, which means that you will see new buyers at every show. So even if your product isn’t new, the audience is.

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NEW
By Susan Campbell


The 2000–2001 Nominating Committee has announced those candidates who will stand for election to AWS national offices for the 2002–2003 term, which begins in June 2002.

Nominated are the following:

- For president: Ernest D. Levert.
- For vice president (three to be elected): Thomas M. Mustaleski, James E. Greer, and Damian J. Kotecki.
- For director-at-large (two to be elected): James R. "Rusty" Franklin and Gerald E. Uttrachi.

The National Nominating Committee was chaired by Past President Robert J. Teuscher. Serving with Teuscher were Bernhard J. Bastian, Hil J. Bax, Harrell E. Bennett, Boris A. Bernstein, Shirley W. Bollinger, Scott C. Chapple, Alfred E. Fliery, David G. Howden, Neil R. Kirsch, Oren P. Reich, Thomas A. Siewert, and Amos O. Winsand. John J. McLaughlin served as secretary of the committee.

The Nominating Committees for Districts 6, 9, 12, 15, 18, and 21 have selected the following candidates for election or reelection as District Directors for three-year terms beginning June 1, 2002. The nominees are District 6 director, Neal Chapman; District 9 director, John C. Bruskotter; District 12 director, Michael D. Kersey; District 15 director, Jack D. Heikkinen; District 18 director, John L. Mendoza; District 21 director, Les Bennett. The District 3 director position remains vacant.

Ernest D. Levert, an AWS Distinguished Member, is presently in his third term as AWS vice president. He is employed as a senior staff manufacturing engineer for Lockheed Martin Missiles and Fire Control in Dallas, Tex., and works in the Manufacturing Engineering Department on the International Space Station Thermal Control Units Program, Patriot Advanced Capability (PAC-3), Army Tactical Missile System (Army TACMS), Line-of-Sight Missile Program (LOSAT), Joint Strike Fighter Program (JSF-F22), Advanced Missile Programs, Theater High-Altitude Area Defense (THAAD) project, and the Multiple Launch Rocket System. Previously, Levert worked for General Dynamics, Convair Division, in San Diego as a welding engineer supporting the Atlas Space Vehicle program, Tomahawk Cruise Missile Program, Ground Launched Cruise Missile Program, and the Space Shuttle program. Levert has more than 32 years of welding experience supporting the aerospace and defense industries. He has presented several papers on welding of aerospace applications with emphasis on the electron beam welding process. He is a registered Professional Engineer in the state of Texas and received his B.S. in welding engineering from The Ohio State University.
Levert is currently serving on the AWS Board of Directors, Executive Committee, Communication Council, Government Affairs Liaison Committee, Education Scholarship Committee, Governing Board Authorized National Body, Prayer Breakfast Committee, B1 Committee on Methods of Inspection, and C7B Committee on Electron Beam Welding and Cutting. He is chairman of the Welding Industry Networking (WIN) Committee and a Trustee with the AWS Foundation and the Federation of Materials Societies (FMS). Levert represented the United States as a Delegate for Commission IV, High Energy Density Welding, at the 54th Annual International Institute of Welding (IIW) Assembly in Ljubljana, Slovenia, and served as the U.S. Representative on the Select Committee for Aircraft Engineering.

Presently, Levert serves on the Welding Advisory Boards of Texas State Technical Community College, Waco, Tex.; Mountain View Community College, Dallas, Tex.; Tarrant County College, Fort Worth, Tex.; and Lakeview Centennial High School, Garland, Tex. He also serves on the Executive Board of the AWS North Texas Section. Levert joined the North Texas Section in 1986 and has held several offices, including chairman (1991-1992). He served on the Executive Board of the AWS San Diego Section and was chairman of the AWS Student Chapter at The Ohio State University. Levert served in the U.S. Navy and has earned welding certifications in high-pressure pipe welding, pressure hull welding, and aluminum structure welding. In addition, Levert has also served as chairman of the VIICA chapter at Max Hayes Vocational High School, Cleveland, Ohio.

Nominated for Vice President
Thomas M. Mustaleski

Thomas M. Mustaleski, who is currently serving his second term as vice president, has been with the Oak Ridge Y-12 Plant of BWXT-Y12 LLC (formerly Lockheed Martin Energy Systems, Inc.), Oak Ridge, Tenn., since 1974. He is currently a research staff member in the Development Division. Mustaleski's work is in the areas of welding metallurgy and process and procedure development. He has been active in the technology transfer programs at the Oak Ridge Centers for Manufacturing Technology. From 1980 to 1985, he served as group leader of the Joining Group. He has also served on the National Conference on Welding and Cutting. From 1981 to 1995, he served as chairman of the C7 Committee, of which he is a founding member, and served as the first chairman of its C7 Subcommittee. He was chairman of the Technical Activities Committee (1989-1992). He has also served on the Industrial Advisory Board (IAB) and the Aerospace Industry Advisory Committee (AIAC). He is also a past chairman of the Department of Energy Sciency Manufacturing Operations Groups (IMOG) Joining Subgroup. He has published more than 20 papers in the field of joining research and development, emphasizing weldability of metals and alloys and the application of advanced joining processes to industrial needs.

Mustaleski was inducted as a Fellow of the American Welding Society in 2000 and was the 1994 recipient of the Society's William Irtrgang Memorial Award. He has also received several Energy Systems and Department of Energy awards for Quality Improvements and Technical Achievements.

Nominated for Vice President
James E. Greer

James E. Greer is currently completing his first year as AWS vice president. He has been employed by Moraine Valley Community College (MVCC) for 26 years and is currently a professor and coordinator of the welding program. He is also president of Techno-Welding Consultants. In his more than 20 years as a consultant, Greer has had extensive experience as a welding training specialist and master welder.
has written and supervised the qualification of numerous Welding Procedure Specifications to various codes that use many processes on different types of material. Prior to joining MVCC, Greer was chief welding engineer for General Railroad Co., Marseilles, Ill.; and senior welding specialist for Standard Refrigeration Co., Melrose Park, Ill. He is a hands-on welder qualified to AWS, API, ASME, MIL, and DNV specifications.

Greer holds an A.S. degree from Moraine Valley Community College, a B.S. from Northern Illinois University, and an M.S. from Chicago State University.

Presently, Greer is chairman of the AWS Certifications Committee, first vice chair of the A2 Committee on Welding Terms and Definitions, and a member of the Certification, Operations, Fabrication and Safety Committee for the American Institute of Steel Construction. He is also AWS representative to the Steel Construction Roundtable.

Greer remains active on the Section and District levels. He is a member of the Chicago Section and has served on its Board of Directors and was chairman for two terms (1985-1986 and 1989-1990). Greer served as District 13 director from 1990 to 1997.

Greer has been awarded the AWS District Meritorious Award, the Howard Atkins District Educator Award, and the District CWI of the Year Award.

Nominated for Vice President
Damian J. Kotecki

Damian J. Kotecki received his Ph.D. degree in mechanical engineering from the University of Wisconsin-Madison. In 1989, he joined The Lincoln Electric Co., where he is now technical director for stainless and high-alloy product development. He has been active in the development of welding filler metals, particularly for stainless steels and hardfacing, since 1974.

Kotecki is a member of the American Welding Society's national Board of Directors and is currently serving the Society as a director-at-large. He is past chair of the AWS Technical Activities Committee, the AWS Filler Metals Committee, the WRC Subcommittee on Welding Stainless Steels, and the WRC Subcommittee on Hardfacing and Wear. In addition, he is the chair of the International Institute of Welding (IIW), Commission II, as well as U.S. delegate to that commission. He is a member of the AWS Technical Papers Committee, the IIW Select Committee on Standardization, IIW Technical Committee, and ISO TC14 and its Subcommittees.

An AWS Fellow and registered Professional Engineer, Kotecki holds several patents for arc welding filler metals and is the author of numerous technical papers.

AWS presented Kotecki with the James E Lincoln Gold Medal in 1979 and again in 1987; the William Irgang Award in 1987; the R. D. Thomas Memorial Award in 1983; the R. D. Thomas, Jr. International Lecture Award in 1994; the Prof. Dr. Rene Wasserman Memorial Award in 1995 and 1997; the George E. Willis Award in 1995; and the A.F. Davis Silver Medal in 1996. He was awarded the IIW Thomas Medal in 1999. He was selected by AWS to present the 1996 Comfort A. Adams Memorial Lecture titled "Ferrite Determination in Stainless Steel Welds - Advances since 1974."

James R. "Rusty" Franklin

Nominated for Director-at-Large
James R. "Rusty" Franklin

James R. "Rusty" Franklin, a 25-year member of AWS, has been nominated to serve as Director-at-Large. He is currently vice president of sales and marketing for Sellstrom Manufacturing Co., Palatine, Ill. He holds a B.S. degree from the University of Central Oklahoma, Edmond, Okla.

An active member of AWS, Franklin serves as chairman of WEMCO (the Welding Equipment Manufacturers Committee), and is a member of the Publications, Expositions, Marketing Committee (PEMCO). He is also a member of the Presidential Task Group for ISO Standards and is a past member of the Presidential Task Group on Show Site Selection Criteria and the AWS Congressional Fellow Selection Committee. Franklin is also an active participant in the Industrial Safety Equipment Association, National Welding Supply Association, CII Laboratories, LTD, and the Safety Marketing Group. Additional volunteer activities include the Palatine Chamber of Commerce, Rotary International, and Prevent Blindness America.

Gerald E. Uttrachi

Nominated for Director-at-Large
Gerald E. Uttrachi

Gerald E. Uttrachi is currently president of WA Technology, LLC. He previously served as a development engineer, project engineer, welding materials laboratory manager, and director of welding market development while with the Linde Division of Union Carbide Corp. He served as vice president of marketing for L-TEC Welding & Cutting Systems, then vice president of equipment marketing for the L-TEC brand under ESAB Welding & Cutting Products.

Throughout his 37-year career in the welding industry, Uttrachi's main concern was with the development of automatic welding processes and welding materials. He is responsible for numerous developments that significantly increased welding productivity. Uttrachi has been granted a number of U.S. and foreign patents in the welding processes and filler materials areas.

Uttrachi holds bachelor's and master's degrees in mechanical engineering and a master's of science degree in management from New Jersey Institute of Technology.

An active member of AWS, Uttrachi has served on various filler metals committees, the Welding Handbook Committee, Technical Papers Committee, and...
has chaired the Marketing Committee. He has also acted as representative to IIW Committees on Filler Metals Specifications. Uttrachi is currently chair of the PEMCO Committee, a member of the Conference Committee, Vice Chairman of Metric Practices Committee, and an AWS Foundation Trustee. He is also chair of the High Strength Steel Committee of the Welding Research Council. In addition to being a Life Member of AWS, Uttrachi is also a Life Member of ASME.

**Nominated for Director**

**District 6**

**Neal Chapman**

Neal Chapman is currently employed as site welding engineer for Entergy Nuclear Northeast, James A. Fitzpatrick Nuclear Power Plant, where he is responsible for the development and administration of the site welding program. He has previously served as site ISI repair replacement engineer for New York Power Authority, Scriba, N.Y., and corporate welding/quality engineer for J. P. Bell and Sons, Rochester, N.Y.

Chapman is an active member of AWS on both the local and national level. He has served as treasurer and technical representative for the Syracuse Section, and sits on the National Level Certification Committee and the Ethics Subcommittee. Chapman has also chaired the Subcommittee on Certified Welding Engineers.

Chapman holds an A.A. degree in welding technology from the Community College of Beaver County, Monaca, Pa., and is presently working toward a bachelor's degree in vocational education at the State University of New York - Oswego, Oswego, N.Y.

**Nominated for Director**

**District 9**

**John Bruskotter**

John Bruskotter is currently a project manager with Project Specialists Inc. From 1986 to 2000, he was employed with Houma Industries Inc., where his positions included fabrication and quality control manager and vice president of operations onshore, offshore fabrication and coatings and warehousing and maintenance.


**Nominated for Director**

**District 12**

**Michael D. Kersey**

Michael D. Kersey has been involved in the welding industry since his graduation from Purdue University in 1989. He began his career in welding as a technical sales representative for The Lincoln Electric Company. He is currently responsible for sales of the company's products to about one third of the state of Wisconsin.

Kersey has been a member of AWS for nine years. During that time, he has served as publicity chairman, treasurer, and chairman of the Milwaukee Section. He currently serves on the Welding Advisory Committee of Milwaukee Area Technical College, where his involvement includes curriculum development and course evaluation.

**Nominated for Director**

**District 15**

**Jack D. Heikkinen**

Jack D. Heikkinen has been nominated to serve as District 15 director. He was welding instructor for the Minnesota Vocational School System in Eveleth, Minn., until his retirement in June 1997. He also taught a variety of specialty courses including Welding for U.S. Steel-Minitac, Welding for the Electrical Union, and Welding for Plumber's Union. He is currently owner and president of Spartan Sauna Heaters, Inc., which builds and sells sauna heaters, custom wrought-iron railings, steel step units, and various custom-built items.

Heikkinen is a charter member of the Arrowhead Section of AWS and has held every office, as well as serving as chairman on the Membership, Publicity, Program, Education, Scholarship, and Student Affairs Committees. In 1997, he was the recipient of the District and Section Meritorious Awards as well as the Section Educator Award.

**Nominated for Director**

**District 18**

**John L. Mendoza**

John L. Mendoza is a 27-year employee of City Public Service, San Antonio's gas and electric utility. He joined the American Welding Society 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 1975. He joined City Public Service as a welder's helper, completed a three-year apprenticeship, and attained jour
Mendoza is qualified to ASME Section IX in shielded metal arc and gas 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 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 Langlevin 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 Student 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.

Nominated for Director
District 21
Les Bennett

Les Bennett is a 26-year member of the American Welding Society and a charter member of the California Central Coast Section, where he served as secretary, vice chairman, and two terms as chairman. Bennett is currently a member of the of the Associate Faculty at Allan Hancock College in Santa Maria, Calif. While at the college, he has acted as the VICA state welding coordinator and state leadership specialist to train high school and community college state officers.

Bennett began his career with Victor Equipment Co. as a repair technician, managing the welding apparatus repair department. While serving the company, he advanced to manager of the Fresno branch. In 1967, Bennett joined the instruction staff at The College of the Sequoias in Visalia, Calif., where he designed a new welding facility and developed welding and metallurgy programs. For 21 years, he instructed the college's welding technology program offerings in AWS Certification and Welding Inspection. Bennett has served as president of Welding Technologies Inc. in Visalia, Calif., Sculpture World in Carmel, Calif., and Bennett-Lahr Inc. in Santa Maria, Calif.

Bennett, who has earned a bachelor's degree in vocational education from California State University and an associate's degree in welding technology, holds AWS D1.1 Welder Certification and is an I-Car Certified Test Administrator.
AWS Publications


In this new edition, all tables and figures have been bundled together at the end of each section, making it easier for readers to locate and use information. Other changes include an extensive reorganization of Section 2 on Design, including new commentary and fatigue design parameters. Table 3.1 has added several steels, such as ASTM A529 Grades 50 and 55, that were not included in previous editions. To help users who have trouble interpreting ultrasonic testing signals when examining backed joints, provisions have been added to Subsections 6.26.12 and C6.26.12 describing ultrasonic testing of CJP groove welds with backing. In addition, the annex regarding Charpy V-notch testing has been extensively revised and essential variables have been added to the section on Qualification.

The 2002 edition of D1.1, Structural Welding Code — Steel, is being offered at the same price as the previous edition. It lists for $258 for AWS members and $344 for nonmembers.

Safety Standards Set for Lens Shades, Welding Screens, and Fume Control


These documents inform welding professionals of potential health risks and offer safety procedures in the workplace. The lens shade chart uses electrode sizes, arc currents, and more to prescribe comfortable lens shades for welding and cutting processes. The specification for welding curtains and screens suggests safety equipment for outside viewing of the welding floor. The weld fume guide recommends ventilation systems to control welding fumes and cut energy costs in different weld shops.


Ordering Information

These ANSI-approved documents are available through Global Engineering Documents by calling (800) 854-7179, or by visiting the e-Store on the AWS Web site at www.aws.org.

AWS Membership Will Be Extended for Those Called to Serve

A merican Welding Society members who are called to active duty with the National Guard or the Reserves due to the events of September 11, 2001, will be issued complimentary membership credit for the period of their service.

To receive the courtesy of membership extension, members should call the AWS Membership Department at (800) 433-9553, ext. 480, upon returning to the civilian work force.

This is the AWS’s small way of expressing gratitude for your service to our Country.

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AWS Membership

Member Grades November 1, 2001

Sustaining Companies .......................... 408
Supporting Companies ........................248
Educational Institutions .......................248
Total Corporate Members .................994
Individual Members ......................43,730
Student Members .........................4,546
Total Members ..................48,276

68 | DECEMBER 2001
Intercon Enterprises, Inc. is a leading supplier of GTAW, pipe and vessel welding accessories including purging equipment, tungsten electrodes and grinders, oxygen indicators, and pipe alignment clamps and chains. For more than two decades, Intercon has been supplying the welding industry with weld-on hinges, Jokisch antispaters, and the TIGRIP line of plate clamps and under-the-hook lifting equipment.

Liburdi Dimetrics Corp. manufactures an extensive line of orbital welding equipment and industrial welding system components using technology and industry-recognized products acquired from Dimetrics, Hobart, Merrick, and Weldline.

The company's product lines offer GTAW, GMAW, and PAW power supplies, an extensive range of orbital weld heads for tube, pipe, and tube-to-tube sheet applications. A complete line of industrial system components, including welding lathes, rotary positioners, seamers, turning rolls, and wire-feed and arc voltage controls and mechanisms, is also available.

Liburdi Dimetrics is part of the Liburdi group of companies that also includes Liburdi Engineering, Liburdi Puls焊, and Liburdi Turbine Services.

ARCET is a full-service, independently owned and operated distributor of welding products and industrial gases. The company has 21 locations throughout the state of Virginia that sell welding equipment and industrial, specialty, and medical gases. In addition, ARCET supplies restaurants with gases through its Beverage Carbonation Division. There are also seven company-owned and -operated service centers statewide.

ARCET was founded in 1946 and quickly developed a reputation for outstanding service in all aspects of business, fast deliveries, welding expertise, and equipment repair. The company maintains its commitment to service.

Oilstates Subsea Ventures designs and manufactures a variety of custom subsea equipment such as riser flotation tank systems, guide bases, running tools, and manifolds.

Subsea Ventures offers state-of-the-art design, engineering and manufacturing to meet quick deadlines, provide innovative answers, and respond to any customer needs. Its 77,000-sq-ft facility is available seven days a week for 24-hour operation if needed. Subsea Ventures specializes in the custom design, fabrication, assembly, and testing of mechanical and structural projects.

The company's staff provides extensive experience in engineering and design drafting related to subsea drilling, production, and general fabrication. The staff is dedicated to customer service and satisfaction. Quick turnaround for large projects is a specialty of the company. It has a quality assurance program documented to meet ASME, API, DNV, and other standards. Subsea Ventures can also work to any third-party survey requirements and customer specifications.
SECTION EVENTS
CALENDAR

♦ ALASKA
   All meetings in Anchorage unless otherwise noted.

JANUARY 18, 2002
Topic: Tank fabrication project.

FEBRUARY 16, 2002
Activity: Hands-on equipment show at the University of Alaska Anchorage.

MARCH 16, 2002
Topic: To be announced.
Location: Fairbanks.

APRIL 20, 2002
Activity: Section elections.

♦ FOX VALLEY
JANUARY 3-4, 2002
Activity: Third Annual ASME Section IX Seminar.
Location: Paper Valley Hotel and Conference Center.

JANUARY 8, 2002
Speakers: Adam and Renee Weitzel.
Affiliation: Badger Cryogenics.
Topic: Cryogenic stress relieving.

FEBRUARY 12, 2002
Activity: The Section will tour the Kimberly Clark plant.

MARCH 2002
Activity: Career/Youth/Education Day.

APRIL 2002
Speaker: James Hennessy.
Affiliation: AZCO.
Topic: Welding issues related to commercial electric power plant construction.

♦ PITTSBURGH
JANUARY 15
Activity: Past Chairman’s Night.
Speaker: Ernest Levert, AWS vice president.

FEBRUARY 12
Speaker: Bob Tabernik, District 7 director.

MARCH 12
Speaker: Chip Cable.
Affiliation: Bug-O Systems.
Activity: Student Night.

APRIL 9
Speaker: Bill O’Donnell.
Affiliation: O’Donnell consulting.
Topic: Weld Failure Analysis.

Atlantic Technical Center Holds VICA Contest

Atlantic Technical Center, Pompano Beach, Fla., held its annual VICA welding competition for secondary and postsecondary students on March 8 of this year. The first- and second-place winners received a Journeyman welding torch kit and third-place winners won a torch, helmet, and welding gloves. Prizes were donated by Ray Blew of Uniweld and Larry Cohn of Praxair. Also contributing prizes was the American Welding Society.

Students placing in the competition were Kurt Harris, Leo Larson, Andraj Andino, Alvarez Gonzales, Andrew Smith, and Rolando Sanchez. Schools represented by students included Atlantic Technical Center, McFadden Technical Center, Turner Technical, and Northwestern High School.

Students pose for a photograph after competing in a VICA competition held at Atlantic Technical Center. Instructor Frank Rose is at far right.

International Training Institute Holds Supervisor Training Course

The International Training Institute (ITI) held a test supervisor training course on August 21–25 in South Bend, Ind. The training was held at Sheet Metal Workers’ Local #20 JATC, which is an ITI/AWS Accredited Test Facility. The course was headed by ITI Assessors Bill Beckman and Robert James, who trained Certified Welding Inspectors (CWIs) from Nebraska, Illinois, Missouri, Indiana, and Ohio. All participants successfully completed the course and are now Test Supervisors at their facilities.

At the conclusion of the training, Local #20 was audited by Beckman for its third-year accreditation renewal. The on-site audit of the new building was successful and the facility was granted another year of accreditation.

The International Training Institute in South Bend, Ind.
Pratt & Whitney's F119-PW-100 engine being tested while supported on a test stand at the Arnold Engineering Development Center, Arnold Air Force Base in Tennessee. Members of Districts 1 and 2 attended the September event where Pratt & Whitney was presented the AWS Outstanding Development in Welded Fabrication Award for this engine.

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

* BOSTON
October 1
Activity: The Section visited the Saugus Ironworks in Saugus, Mass. Saugus, which was founded in 1646, was the first integrated ironworks site in North America. The site has been reconstructed to near-original condition and has a working blast furnace powered by a water wheel.

* CONNECTICUT
September 21
Activity: Pratt & Whitney was presented with the AWS Outstanding Development in Welded Fabrication Award by AWS Vice President Ernest Levert in recognition of breakthrough welding technologies used on the F119-PW-100 turbofan aircraft engine. In addition to Levert, AWS dignitaries attending the event included AWS Vice President Tom Mustaleski, District 1 Director Geoffrey Putnam, District 2 Director Alfred E. Fleury, Connecticut Section Chairman Kathleen McGirr-Paulino, Connecticut Section Vice Chairman Don McGirr and his wife, Connecticut Section Treasurer Walter Chojnacki and his wife, and Boston Section Vice Chairman Tom Ferri.

York-Central Pennsylvania Section members making a request of a wandering minstrel aboard the dinner train ride in honor of Spouse's Day.

DISTRICT 2
Director: Alfred F. Fleury
Phone: (732) 868-0768

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

* YORK-CENTRAL PENNSYLVANIA
March 18
Activity: The Section held Spouse's
Enjoying the Lehigh Valley Section’s annual golf outing are, from left, York-Central Pennsylvania Section First Vice Chairman George Bottenfield, Jim Haney, District 3 Director Claudia Bottenfield, and Les Starks.

Washington D.C. Section Chairman Alan J. Bodeaux, left, presenting Ray Karbett with a speaker’s plaque.

Night and enjoyed a Sunday afternoon dinner train ride that also included wandering minstrels.

October 4
Speaker: Bill Gouba, owner.
Affiliation: Bill’s Wildlife Studio.
Topic: Taxidermy and the correct methods for field dressing your trophy.

♦ Washington D.C.
September 19
Speaker: Ray Karbett, proprietor and welding instructor.
Affiliation: Stingray Welding, Inc., and Prince George’s Community College.
Topic: Teaching adult welders the right stuff.

♦ Lehigh Valley
October 6
Activity: The Section held its annual golf outing at the Bethlehem Country Club.

New York Section member Dominick Calusante, left, with guest speaker Hugh Callahan.

South Carolina Section member Jonathan Knight, left, and guest speaker Ben Magrone.

Rochester Section member Guy Malle, left, with guest speaker Dennis Klingman.

Kerry Sabo, right, of the Pittsburgh Section presenting speaker’s gifts to Dennis Klingman.

Affiliation: Millenium Metals, Ladson, S.C.
Activity: The Section toured the Millenium metals fabrication facility and observed various stages of production and welding operations.

DISTRICT 4
Director: Roy C. Lanier
Phone: (252) 321-4285

♦ NEW YORK
September 17
Speaker: Hugh Callahan, district sales manager.
Affiliation: Victor Equipment Co.
Topic: Cutting and heating safety and the proper use of gas cutting and burning torches.

DISTRICT 6
Director: Gerald R. Crawford
Phone: (518) 385-0570

♦ ROCHESTER
October 8
Speaker: Dennis Klingman, director of technical training.
Affiliation: The Lincoln Electric Co., Cleveland, Ohio.
Topic: Welding in the motor sports industry.

DISTRICT 5
Director: Wayne J. Engeron
Phone: (404) 501-9185

♦ SOUTH FLORIDA
September 13
Activity: The Section toured the Paxton facility in Pompano Beach, Fla. Paxton is South Florida’s leading manufacturer of waste water recovery systems.

♦ SOUTH CAROLINA
September 20
Speaker: Ben Magrone, QA manager.

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

♦ PITTSBURGH
October 9
Speaker: Dennis Klingman, di-
Dayton Section Past Chairman Les Vesey teeing off at the Section’s annual golf outing.

Columbus Section Chairman Jim Worman, left, presenting a speaker’s gift to Mario Amata.

District 9 Director John Bruskotter, left, looks on as New Orleans Section Chairman Tony DeMarco, right presents a speaker’s award to Gordon L. Dyer.

Presenting a scholarship to Donald Trissell, second from left, are, from left, New Orleans Section Chairman Tony DeMarco, Section Q&C Chairman Bruce Hallile, and Louisiana Technical College instructor Luther Davis.

New Orleans Assistant Secretary David Foster, left, receiving his winnings from the 50/50 raffle from Second Vice Chairman Shelton Ritter. Foster generously donated his winnings to the FDNY/NYPD Relief Fund.

Presenting a scholarship to Kerry Simms, second from left, are, from left, New Orleans Section Chairman Tony DeMarco, Section Q&C Chairman Bruce Hallile, and Louisiana Technical College instructor Luther Davis.

District 9 Director John Bruskotter, left, presents a speaker’s award to David Raacke, center, with First Vice Chairman Lenis Doiron.

New Orleans Section Chairman Tony DeMarco, left, presents a speaker’s award to David Raacke, center, with First Vice Chairman Lenis Doiron.

Director: John Bruskotter
Phone: (504) 367-0603

New Orleans Assistant Secretary David Foster, left, receiving his winnings from the 50/50 raffle from Second Vice Chairman Shelton Ritter. Foster generously donated his winnings to the FDNY/NYPD Relief Fund.

Presenting a scholarship to Kerry Simms, second from left, are, from left, New Orleans Section Chairman Tony DeMarco, Section Q&C Chairman Bruce Hallile, and Louisiana Technical College instructor Luther Davis.

District 9 Director John Bruskotter, left, presents a speaker’s award to David Raacke, center, with First Vice Chairman Lenis Doiron.

New Orleans Section Chairman Tony DeMarco, left, presents a speaker’s award to David Raacke, center, with First Vice Chairman Lenis Doiron.

Director: John Bruskotter
Phone: (504) 367-0603

New Orleans Assistant Secretary David Foster, left, receiving his winnings from the 50/50 raffle from Second Vice Chairman Shelton Ritter. Foster generously donated his winnings to the FDNY/NYPD Relief Fund.

Presenting a scholarship to Kerry Simms, second from left, are, from left, New Orleans Section Chairman Tony DeMarco, Section Q&C Chairman Bruce Hallile, and Louisiana Technical College instructor Luther Davis.

District 9 Director John Bruskotter, left, presents a speaker’s award to David Raacke, center, with First Vice Chairman Lenis Doiron.
Central Michigan Chairman Jeff Grossman, right, presenting speaker's gifts to Pete Draper, center, and Rudy Najjar.

Receiving their golf winnings from Pascagoula Section member Steven Brown, center, are, from left, Scott Brown, Stevie Martin, Jayson Martin, and Chris Taylor.

Northwestern Pennsylvania Section member Earl Lipphardt, right, presenting John Wittenrich with a speaker's gift.

Northwestern Pennsylvania Section member Earl Lipphardt, right, presenting John Wittenrich with a speaker's gift.

of the Year Award, and Henry Parker with the Meritorious Award.

**MOBILE**
SEPTEMBER 13
Speakers: John Bruskotter, AWS District 9 director, and Jerold Shepherd, AWS Pascagoula Section chairman.
Affiliation: AWS.
Activities: A joint meeting was held with the Mobile and Pascagoula Sections. District 9 Director John Bruskotter presented William R. Davison with the District Dalton E. Hamilton CWI of the Year Award, James Odom with the District Howard E. Adkins Educator of the Year Award, and Mobile Chairman Robert Wells with the District Meritorious Certificate. Wells presented Jackie Morris with a plaque in honor of his work last year as chairman, U. A. "Red" Schneider with a Life Membership plaque and pin, and Henry Trussel with a Silver Certificate.

**PASCAGOULA**
SEPTEMBER 22
Activity: The Section held the 7th Annual Golf Tournament at the Linksman Golf Club of Mobile in Mobile, Ala. The format of the tournament was a five-man scramble. Proceeds from the event benefited the Section's Scholarship Fund.

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

**MAHONING VALLEY**
OCTOBER 18
Speaker: Rodney Massicotte.
Affiliation: Deloro Stellite, Inc.
Topic: Hardfacing processes and solutions.

**NORTHWESTERN PENNSYLVANIA**
SEPTEMBER 13
Activity: The Section held its 20th Annual Golf Outing at the Culbertson Hills Golf Club.
 Trying out a new inspection system are Fox Valley Section members, from left, Lori Kuiper, Todd Holverston, Tim Tenby, Greg Metko, Bruce Albrecht, Sean Moran, and guest speaker Jeff Noruk.

 District 9 Director John Bruskefet, left, presenting James Odom with the District Howard E. Adkins Educator of the Year Award at the Mobile and Pascagoula Section's joint meeting in September.

 SEPTEMBER 24
 Speakers: Mike Simmons and Matt Post.
 Affiliation: TG Systems.
 Topic: Welding gun types and design attributes.

 NORTHEAST OHIO
 SEPTEMBER 25
 Activity: Section Chairman Richard West reviewed the budget, scholarships, national membership drive, awards, and plans for the 2001-2002 year.

 DISTRICT 11
 Director: Scott C. Chapple
 Phone: (734) 241-7242

 CENTRAL MICHIGAN
 September 18
 Speakers: Pete Draper, welding supervisor; and Rudy Najar, general supervisor.
 Affiliation: General Motors, Metal Fabrication Division, Lansing Tooling Center, Lansing, Mich.
 Activity: Members toured the General Motors, Metal Fabrication Division, Lansing Tooling Center facility.

 DETROIT
 October
 Speaker: Khadir Husain, manufacturer's representative.
 Affiliation: Advance Arc Technologies, Canada.
 Activity: Expanding the marketshare of mature products with the global marketplace.

 SEPTEMBER 11
 Speaker: Richard Bielecki, owner and NDT Level III.
 Affiliation: Inspectech Corp., Marinette, Wis.
 Activity: The Section toured the newly constructed Inspectech facility. Demonstrations were given in low voltage RT, MT, UT, and PT nondestructive testing practices.
Enjoying the Northwest Section's dinner cruise on the St. Croix River are, clockwise from left, Lori Sandvig, Debbi Sands, Rich Rashke, Bob Sands, Irma Rashke, and Mark Sandvig.

Attending the Lexington September meeting are, from left, Jonathan Doyle, Dee Cotton, Chairman Frank McKinley, and Jacob Bradford.

**LAKESHORE**

**SEPTEMBER 27**

**Speaker:** Ken Krefting.

**Affiliation:** CAE Alphens at Praxair GasTech., Green Bay, Wis.

**Topic:** Dry ice blasting offers a safe, clean alternative to grit blasting and the use of solvents.

**DISTRICT 13**

**Director:** J. L. Hunter

(309) 888-8956

**DISTRICT 14**

**Director:** Hil Bax

Phone: (314) 644-3500, ext. 105

**INDIANA**

**SEPTEMBER 17**

**Speaker:** Gary Tucker, CWI.

**Affiliation:** Delphi-E Training Center.

**Topic:** Weld testing — what it takes to get a welding certification and the paperwork involved.

**NORTHWEST**

**MARCH 24**

**Activity:** The VICA/SkillsUSA state competition was held. Fifty-four secondary and postsecondary students participated in the event. Each student competed in nine areas and were required to bring a previously completed certification coupon to be bent and inspected at the contest. Section members, including Past Chairman
Attending the Arrowhead September tour of the BendTec facility are, from right, Carey Weckert, LaVonne Heikkinen, District 15 Director Jack Heikkinen, Leven J. Kantela, Perry Jurva, Jason Johnson, and John Penazi. At far left is Dan Lindquist, BendTec’s plant manager.

AWS Vice President Ernest Letterl, left, addressing the North Texas Section.

Mace Harris, Chairman Dwight Affeldt, First Vice Chairman Tom Laberoy, and Executive Committee Chairman Dave Messner, were judges.

**DISTRICT 16**

Director: C. F. Burg  
Phone: (515) 294-5428

September 29  
**Activity:** The Section held a social event and took a dinner cruise on a riverboat on the St. Croix River.

**ARROWHEAD**  
September 20  
**Activity:** Dan Lindquist, plant manager, and Jason Johnson led Section members on a tour of the BendTec weld testing facility and plant. The members saw large-diameter pipe trusses being manufactured for the Dallas Convention Center.

**NEBRASKA**  
September 6  
**Speaker:** Charles F. Burg  
**Affiliation:** AWS District 16 Director  
**Topic:** Increasing young people’s involvement in AWS  
**Activity:** The Section toured the Nebraska Welding Ltd. plant.

**KANSAS CITY**  
October 16  
**Speaker:** Russel Fuchs, senior technical manager  
**Affiliation:** Böhler Thyssen Welding USA, Inc.  
**Topic:** A presentation on consumables manufacturing and recent research and technology innovations for high-strength, low-alloy welding.

**DISTRICT 17**

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

**TULSA**  
September 25  
**Speaker:** John Stoll, regional manager  
**Affiliation:** The Lincoln Electric Co.  
**Topic:** Hardfacing.  
**Activity:** The Section awarded four Tulsa Technology welding students with $500 scholarships.

September 25  
**Speaker:** Rick Reed, fire fighter and union vice president  
**Affiliation:** Tulsa Fire Department, International Association of Fire
**North Texas**  
*September 25*  
**Speaker:** J. Jones, training specialist.  
**Affiliation:** Victor Equipment Co.  
**Topic:** Gas regulation and manifold systems.  
*October 16*  
**Speaker:** Paul LeSage, official welder for NHRA.  
**Affiliation:** Team Torch.  
**Topic:** Motor sports welding.  
**Activities:** Section members watched the TNN episode of "Crank & Chrome" where LeSage welded a tie rod to a Cobra race car. Duane McLaughlin addressed the group on making proper fillet welds and the importance of taking the time to properly prepare your work plates.

**DISTRICT 18**  
**Director:** John Mendoza  
**Phone:** (210) 860-2592  
*San Antonio*  
**September 18**  
**Speaker:** David Savoy, training director.  
**Affiliation:** METCO NDT Services, Sulphur, La.  
**Topic:** General public safety and industrial radiographic operations.  
**Activities:** Members attended the Welding Fiesta, which was sponsored by Airgas. The event featured the latest in safety products, protective wear, tools, and other industrial products from more than 100 manufacturers. In addition the

**Sabine**  
*September 18*  
**Speaker:** John Cascio, emergency management coordinator.  
**Affiliation:** Jefferson County, Tex.  
**Topic:** Emergency response plans and current precautions. How to prepare for an evacuation or other emergency.  
**Activities:** Chairman Jessye Weeks presented $850 scholarships to Juan Collago and Gannon Greer.

**East Texas**  
*September 25*  
**Speaker:** Ernest Levert.  
**Affiliation:** Lockheed Martin Missiles and Fire Control, Dallas, Tex., and AWS vice president.  
**Topic:** Welding technology used on the International Space Station radiators.  
*October 16*  
**Speaker:** John Cascio, emergency management coordinator.  
**Affiliation:** Jefferson County, Tex.  
**Topic:** Emergency response plans and current precautions. How to prepare for an evacuation or other emergency.  
**Activities:** Chairman Jessye Weeks presented $850 scholarships to Juan Collago and Gannon Greer.
Sabine Section Chairman Jessye Weeks, right, presenting a scholarship to Juan Colago.

Members and students from BYU - Idaho with guest speaker AWS Vice President Ernest Levert, second from right in first row, at the Eastern Idaho/Montana Section’s October meeting.

Enjoying the San Antonio Section’s Welding Fiesta are, from left, Dennis Eck, Terry Perez, and Chuck Fassinger.

Andre Lopez, Sharon Jones, and Mike Uroiste at the San Francisco Section’s October meeting.

Section hosted its annual AWS CWI Seminar and Exam. This program, which was attended by more than 50 participants, was facilitated by AWS Past President Ed Bohnart.

DISTRICT 19

Director: Phil Zammit
Phone: (509) 468-2310 ext. 120

ALASKA
OCTOBER 19
Activity: The Section toured the Steelfish Inc. plant and saw demonstrations of the plant’s newest equipment. Section members contributed $400 from the Section treasury plus an additional $400 from meeting attendees to donate to the American Red Cross through the AWS Welding Thanks America’s Heroes fund.

DISTRICT 20

Director: Jesse A. Grantham
Phone: (303) 451-6759

EASTERN IDAHO/MONTANA
OCTOBER 4
Speaker: Ernest Levert.
Affiliation: Lockheed Martin Missiles and Fire Control, Dallas, Tex., and AWS vice president.
Topic: Welding technology used on the International Space Station radiators.

DISTRICT 21

Director: F. R. Schneider
Phone: (858) 693-1657

SAN DIEGO
SEPTEMBER 12
Speaker: Daniel Allford, president.
Affiliation: Arc Specialties, Houston, Tex.

DISTRICT 22

Director: Mark Bell
Phone: (209) 367-1398

SAN FRANCISCO
SEPTEMBER 5
Speaker: Chuck Foster.
Affiliation: Mirant Company.

OCTOBER 3
Speaker: Lance Flanagan.
Affiliation: Alexander Binzel.
Topic: Robotic and gas metal arc welding guns.

SACRAMENTO VALLEY
SEPTEMBER 19
Speaker: Bob Mann.
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 advises of ANSI approval of documents. The following standards are submitted for public review. A draft copy may be obtained by sending the amount shown to Rosalinda O'Neill, AWS, Technical Services Business Unit, 550 NW LeJeune Rd., Miami, FL 33126, or by calling (800) 443-9353 ext. 451, e-mail: ronell@aws.org.


Revised Standard Approved by ANSI


Withdrawn Standard Approved by ANSI


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 81 of this Welding Journal. If you have any questions regarding your member proposer points, please call the Membership Department at (800) 443-9353 ext. 180.

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. Mikelsen, Houston*
W. L. Shreve, Fox Valley*
G. Taylor, Pascagoula*
T. Weaver, Jointstown/Altoona*
G. Wooner, Jointstown/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.)

R. I. Peaslee, Detroit — 24
J. Merzthal, Peru — 22

President’s Roundtable

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

T. A. Perri, Boston — 16
G. W. Taylor, Pascagoula* — 11

President’s Club

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

S. R. Bollhorst, Indiana — 9
J. Compton, San Fernando Valley — 7
D. W. Peters, Chicago — 7
M. Hony, North Central Florida — 6
S. Johnson, Central Texas — 6
L. G. Kvidahl, Pascagoula — 6
D. J. Schulte, Stouourd — 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.

N. Goel, Long Island — 5
H. Walsh, Alaska — 5
R. Colvin, San Antonio, Mexico — 3
J. M. Hunt, Tulsa — 3
C. Mezzie, New Orleans — 3
P. Patel, Mobile — 3
J. S. Armstrong, East Texas — 2
P. Baldwin, Peoria — 2
T. L. Bertche, Colorado — 2
C. Compton Jr., Florida West Coast — 2
C. Dynes, Kern — 2
R. A. Graf, Arrowhead — 2
D. L. Hatfield, Tulsa — 2
R. A. Hauck, Syracuse — 2
J. Koster, Western Michigan — 2
A. Meyland, Spokane — 2
S. W. Roach, Houston Valley — 2
J. S. Stites, Florida West Coast — 2
R. Wiese, New Jersey — 2
R. R. Withers, Birmingham — 2
R. Wright, Southern Colorado — 2

Student Sponsors

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

P. Baldwin, Peoria — 15
E. A. Ruiz, Puerto Rico — 26
J. H. Sullivan, Mobile — 13
B. Huff, Sangamon Valley — 30
T. Huston, Pittsburgh — 25
S. E. Howser, Reading — 24
R. A. Large, Manchester — 24
P. Walker, Ozark — 21
H. Madron, Maryland — 12
K. Ellis, Maryville — 19
R. Grays, Kern — 11
J. Pelster, Southeast Nebraska — 9
S. Green, North Texas — 7
R. Felix, Long Beach/Orange Cnty. — 4
E. C. Davis, New Orleans — 3
A. Honigberg, L/A/Inland Empire — 5
J. Livsey, Nashville — 5
W. P Miller, Jr., New Jersey — 5

TECHNICAL COMMITTEE MEETINGS

All AWS technical committee meetings are open to the public. Persons wishing to attend a meeting should contact the staff secretary of the committee as listed below at AWS, 550 NW LeJeune Rd., Miami, FL 33126; telephone (800) 443-9353.

December 5–6, Safety and Health Committee. Miami, Fla. General and standards preparation meeting. Staff contact: S. P. Hedrick, ext. 305.

80 | DECEMBER 2001
Top Ten Reasons to be an AWS Member:

1. To encourage the next generation with AWS Scholarships awarded through the AWS Foundation and discounted student memberships.
2. To build your network of peers and professionals by attending local Section Meetings and utilizing the AWS Website which now includes AWS JobFind - the ultimate Internet job search site for the materials joining industry.
3. Because the Welding Journal provides invaluable information through informative articles on trends, products and new industry technology.
4. To receive substantial discounts on all AWS publications, conferences, seminars and certification programs.
5. Because AWS seminars and conferences allow you to establish important contacts and increase your knowledge base.
6. To experience the wave of the future through the world's largest materials joining show by attending the AWS Welding Show.
7. To gain access to technical knowledge with 300+ publications available.
8. For discounts on travel accommodations, insurance, and more!
9. To strengthen your leadership skills by serving as a Section Officer or Committee Member.
10. To encourage the next generation with AWS Scholarships awarded through the AWS Foundation and discounted student memberships.

PRIZE CATEGORIES

President's Honor Roll:
Recruit 1-5 new Individual Members and receive an American Welder™ T-shirt.

President's Club:
Recruit 6-10 new Individual Members and receive an American Welder™ polo shirt.

President's Roundtable:
Recruit 11-19 new Individual Members and receive an American Welder™ watch.

President's Guild:
Recruit 20 or more new Individual Members and receive an American Welder™ watch, a one-year free AWS Membership, the "Shelton Ritter Member Proposer Award" Certificate and membership in the Winner's Circle.

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

SPECIAL PRIZES

Participants will also be eligible to win prizes in specialized categories. Prizes will be awarded at the close of the campaign (June 2002).

Sponsor of the Year:
The individual who sponsors the greatest number of new Individual Members during the campaign will receive a plaque, a trip to the 2003 AWS Welding Show, and recognition at the AWS Awards Luncheon at the AWS Welding Show.

Student Sponsor Prize:
AWS Members who sponsor two or more Student Members will receive an American Welder™ T-shirt.

The AWS Member who sponsors the most Student Members will receive a complimentary one-year AWS Membership.

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

LUCK OF THE DRAW

For every new member you sponsor, your name is entered into a quarterly drawing. The more new members you sponsor, the greater your chances of winning. Prizes will be awarded in November 2001, as well as in February and June 2002.

Prizes Include:
- American Welder™ T-shirt
- One-page black/white ad in the Welding Journal
- Complimentary AWS Membership renewal
- American Welder™ polo shirt
- American Welder™ baseball cap

SUPER SECTION CHALLENGE

The AWS Section in each District that achieves the highest net percentage increase in new Individual Members before the June 2002 deadline will receive special recognition in the Welding Journal and a District Membership Award.

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

550 NW LeJeune Rd., Miami, FL 33126
Phone (305) 443-9553; (888) WELDING
Fax (305) 443-7559; Internet: www.aws.org
Phone extensions appear in parentheses.

AWS PRESIDENT
Richard L. Ann
Teledyne Technologies, Inc.
5710 Loughlin Rd.
Lisbon, OH 44432

ADMINISTRATION
Executive Director
Frank G. DeLaurier, CAE (210)

Deputy Executive Directors
Richard D. French (218)
Jeffrey R. Ridley (204)
John J. McLaughlin (255)

Assistant Executive Director
Debra A. Garfield (222)

Corporate Director of Quality Management Systems
Linda K. Henderson (298)

Chief Financial Officer
Frank R. Tenza (252)

INFORMATION SERVICES
Corporate Director
Joe Gilli (258)

HUMAN RESOURCES
Director
Luisa Hernandez (266)

ADMINISTRATIVE SERVICES
Corporate Director
Jim Lankford (214)

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) 666-2870
Fax (202) 885-0214

Identities 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)
Jeff Weber (246)

COMMUNICATIONS
Corporate Director, Communications
Namario M. Zapata (309)

CONVENTION & EXPOSITIONS
Exhibiting Information (242, 256, 295)
Managing Director of Exposition Sales
Tom L. Davis (231)

Director of Exposition Sales
Dennis Bileca (458)

Director of Convention & Expositions
John Ospina (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
Department Information (318)
Director
Andrew Callison (249)

WELDING JOURNAL
Publisher
Jeff Weber (246)

Editor/Editorial Director
Andrew Callison (249)

National Sales Director
Rob Saltzstein (243)

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 Inspection Trends, the Welding Handbook and books on general welding subjects.

MARKETING AND DESIGN
Corporate Director
Jeff Weber (246)

Plans and coordinates marketing of AWS products and services. Responsible for print advertising, as well as design and print production of the Welding Journal, Inspection Trends, the annual Welding Show Program, and other AWS promotional publications.

MARKET RESEARCH AND PRODUCT DEVELOPMENT
Corporate Director
Delbert C. Wein (482)

Investigates and/or proposes new products and services. Researches effectiveness of existing programs.

MEMBER SERVICES
Department Information (480)
Associate Executive Director
Casie J. Burrell (253)

Director
Rhonda A. Mayo (256)

Serves as a liaison between Society members and AWS headquarters informs members about AWS benefits and other activities of interest.

EDUCATION AND CONFERENCE SERVICES

EDUCATION
Director
Christopher B. Bablock (304)

Information on education products, projects, and programs. Also, seminars designed for preparation for certification. Responsible for the S.E.N.E.P. program for welding education, and dissemination of training and education information on the Web.

CONFERENCES
Director
Giselle L. Rodriguez (275)

Responsible for national and local conferences/exhibitions and seminars on industry topics ranging from the basics to the leading edge of technology.

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

AWARDS, FELLOWS, AND COUNSELORS
Managing Director
Wendy S. Reeve (215)

Coordinates awards and AWS Fellows and Counselors programs.

INTERNATIONAL BUSINESS DEVELOPMENT
Director
Walter Herrera (475)

For information about AWS technical publications, contact the Technical Services personnel listed below.

TECHNICAL SERVICES
Department Information (340)
Managing Director
Leonard P. Cooper (302)

Qualification, Friction Welding, Food Processing Equipment, Computerization, Welding Dynamics, Aerospace, Renewable Energy, Autonomous, Time, Speed, Energy Demand, Welding, Automotive, Aerospace, Railroads

Stephen P. Fredrick (305) Safety and Health Manager, Metric Practices, Mechanical Testing Engineers

Harley H. Campbell III (300) Structural Rakesh Gupta (301) Filler Metals, Instrumentation

John L. Gayler (472) Sheet Metal, Plastics and Composites, Personnel Qualification, Metals & Alloys, Robotics

Ed F. Mitchell (254) Thermal Spray, High Energy Beam Welding and Cutting, Resistance Welding, Automotive, Aerospace, Railroads

Antony Y. Ositivity (514) Oxidation Gas Welding & Cutting, Arc Welding and Cutting, Machining and Equipment, Welding Iron Castings, Piping & Tubing

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AWS publishes more than 160 volumes of technical material, including standards that are used throughout the industry.

With regard to technical inquiries, oral opinions are internal and should not be used as a substitute for an official interpretation. However, such opinions represent only the personal opinions of the particular individuals giving them. These individuals do not speak on behalf of AWS, nor do these oral opinions constitute official or unofficial opinions or interpretations of AWS. In addition, oral opinions are informal and should not be used as a substitute for an official interpretation.

It is the intent of the American Welding Society to build the Society to the highest quality standards possible. We welcome any suggestions you may have.

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.

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, must be frequently available to the National Office, and should be of executive status in business or industry with experience in financial affairs.

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

Interested 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 the AWS President, 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 5, 2002, in Chicago, Ill. 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 descriptions 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 reflects "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 an honorary distinction. An Honorary Member shall have full rights of membership.
I. PREFACE
A. Technology is affecting society to an ever-increasing extent;
B. Public policy issues affecting a broad constituency are increasingly based on technological factors;
C. Informed decisions regarding public policy issues require the input of the engineering profession, among others;
D. The engineering professional constitutes one of the nation's most valuable resources, and
E. This resource should be applied in the public interest to matters having a technological content.

II. POLICY
A. AWS declares that it is the continuing policy of the American Welding Society to
   1. be sensitive to the public's interests;
   2. provide government at all levels with advice on engineering matters and policies affecting the public interest; and
   3. maintain a climate of understanding and credibility that will foster continuing dialogue with the government.
B. As one measure for furthering its policy, The Board of Directors establishes a Congressional Fellow Program to assist legislators and officials of the Congress in public policy deliberations. Each year, AWS will select a member, in a manner herein described, to serve as Congressional Fellow to assist legislators and other federal officials.
C. It is preferential that AWS and the Fellow's employer share the compensation and the expenses of the Fellow so that all parties have a financial interest in the program. However, a Fellow may serve with full employer support, provided that she or he is selected in accordance with this policy and she or he adheres to all AWS policies and guidelines of the program. AWS's share shall not exceed the amount annually budgeted. A Fellow may also participate with no employer support but recognizing the limited stipend.
D. Although the Congressional Fellow is sponsored by AWS, the Fellow's primary objective is to provide assistance to Congress while representing the welding engineering profession in objective fashion without bias or favor toward AWS or her or his employer.

In addition, AWS will help in furnishing whatever technical assistance a Congressional Fellow will request of the Society.
E. It is desirable that the Congressional Fellow be familiar with AWS operations and organizational structure in order to obtain assistance promptly and efficiently.
F. Congressional Fellows must comply with the AWS policy on Conflict of Interest and any appropriate rules of ethics of the host federal office.
III. PROCEDURE

A. Solicitation of applicants and Selection of Congressional Fellows

1. AWS will solicit applicants through appropriate means, including letters to companies, announcements in the Welding Journal, and appeals to the AWS leadership to identify candidates.

2. The Candidate Review Committee shall
   a. Review applications;
   b. Interview highly marked applicants;
   c. Identify the best qualified among these for possible selection as a Congressional Fellow;
   d. Forward list of recommendations for the AWS Congressional Fellows and necessary support documents to the Government Affairs Liaison Committee for final selection and approval.

3. Individuals chosen to be Congressional Fellow(s) will be assisted by the AWS Washington Government Affairs Office in his or her placement with the staff of a Representative, Senator or a congressional committee.

4. The selection of the Fellow will be announced by the President of AWS.

B. Requirements

The requirements for the Congressional Fellow Program are as follows:

1. A Congressional Fellow’s term shall be twelve months, beginning in September.

2. Government Affairs Liaison Committee shall select the Fellow(s) using objective selection criteria, including a candidate’s application, to determine a candidate’s ability to communicate both orally and in written form, and such other attributes as the committee deems necessary for a candidate who will represent the welding profession.

3. Sex, creed, race, ethnic background and political affiliation are expressly excluded as selection criteria for Congressional Fellows.

4. Fellows shall hold at least the AWS grade of Member prior to submitting an application for Congressional Fellow.

5. Fellows shall be citizens of the United States of America.

Deadline for Receiving Applications is February 1, 2002.

For a complete application package, contact:
Richard French
Deputy Executive Director
1-800-443-WELD, ext. 218

American Welding Society
550 N.W. LeJeune Rd.
Miami, Florida 33126
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• 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
Assembly and Test Systems Brochure Available

The company offers a color brochure detailing its capabilities for custom-engineered assembly and test systems for manufacturers of automobiles, appliances, and durable goods. Various assembly systems are described, such as integrating multi-axis robotic cells for automotive part production, ignition coil construction and testing, and dial and rotary assembly lines used for products such as shock absorbers. Testing systems highlighted in the brochure include automated leak testing, flow tests, dimensional gauging, and vision systems.

Newcor
1846 Tremblay Ave., Bay City, MI 48706-4700

The Safety Supplies Buyer’s Guide has 1536 full-color pages of safety products and equipment. It features personal protective equipment, training aids, emergency response equipment, spill cleanup products, lockout/tagout supplies, and more. Complete product descriptions are included in the catalog and a toll-free product support line and fax-on-demand service are also available.

Lab Safety Supply
P.O. Box 1368, Janesville, WI 53547-1368

Guide Features Safety Light Curtains

The company's guide features the MC4700 series of safety light curtains including flexible and jointed versions that are ultracompact for integration into the design of small machines. Descriptions, specifications, ordering information, and illustrated application examples are included, as well as the company's complementary controllers and resource modules.

Scientific Technologies Inc.
6550 Dumbarton Circle, Fremont, CA 94555

Pipe Size Reference Chart Available

A single page pipe chart giving pipe size dimensions for 1/4- through 24 in. in schedules 5 to 160 is available free from the company. The chart includes measurements for size, wall thickness, and inside diameter. It is useful for sizing the company's line of high-pressure hydrotest stoppers. Charts can be obtained by calling (800) 331-3827 or by e-mail: hytech@fbi.net.

Thaxton
25 Leonberg Rd., Cranberry Twp., PA 16066

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“Great leading edge program with real world applications”

This two-day conference and exhibition is targeted at welding engineers, welding specialist and technicians, and others concerned with the practical application of robotic arc welding systems.

Topics and speakers will cover the latest developments in the United States, Canada, and overseas. There will also be a keynote address by an industry leader. In addition, a breakfast tutorial has been planned for first time attendees and all others interested in reviewing the basic terms and concepts of robotic arc welding and associated technology.

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Sixth Robotic Arc Welding Conference and Exhibition

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Circle No. 41 on Reader Info-Card
Q: I heard that many years ago there was an all-brazed automobile engine primarily stamped out of carbon steel sheet metal. Do you know anything about this engine?

A: Three years ago, I visited a vintage auto exhibit at Greenfield Museum where a Crosley car owned by Jeff Rider of Troy, Mich., was on display. The car had a brazed gasoline engine. We had an interesting discussion about the car and the engine and Rider told me about an article by James J. Hockenhull in the Automobile Quarterly (Vol. 34, No. 2). This article chronicled the history of the brazed gasoline engine.

The gasoline engine was invented by Lloyd Taylor of Taylor Engines Inc., Oakland, Calif. These engines were fabricated from sheet metal rather than cast iron. The numerous details were stamped, assembled, and brazed with copper filler metal in a large continuous furnace with an exothermic atmosphere. The valve seats were machined from a special alloy steel and installed in the assembly prior to brazing. Taylor saw an advertisement for "Bundy Weld" tubing from the Bundy Co. in Detroit, Mich. Bundy tubing was made from sheet steel coated with copper paste, rolled tightly around itself, and then heated in a furnace, which brazed it into one seamless piece. What Taylor saw was a metal joining technique very much adapted to mass production.

The brazing process was not new. Charles Hyde received a British Patent for it in 1910. Because Hyde had used hydrogen for the furnace atmosphere to copper braze, many were reluctant to use the process because hydrogen and fire make uneasy bedfellows, so it was relegated to only small furnaces. In 1929, General Electric Co. began experimenting with "controlled-atmosphere brazing" using large continuous furnaces. In the early 1930s, Joseph Lucas Ltd. introduced brazing to automobile manufacturing to replace riveting of small window components. By the 1940s, companies began to specialize in copper brazing.

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Brazing Q&A

BY R. L. PEASLEE

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BY R. L. PEASLEE

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ILL-MO Products Announces Management and Staff Changes

ILL-MO Products Co., Jacksonville, Ill., has announced changes in its management and staff.

In upper management, Linda Standley assumed the role of chief executive officer and Brad Floeth [AWS] became president.

The company also expanded its sales staff. Anthony "Tony" McLaughlin was named sales manager for sales and marketing of the company's products and services in the fabrication, process, and health care industries for central and southern Illinois and northeastern Missouri; Jerry Cox joined the company as an outside salesperson; and Mike Banks was hired as specialty gas manager.

PRC Laser Annoints Vice President

Kevin Laughlin

PRC Laser, Landing, N.J., has appointed Kevin Laughlin vice president of sales. In this position, he will be responsible for the sales and service of the company's products throughout North America, South America, and Asia. Laughlin joined PRC in 1998 as North American sales manager.

Motoman Names Vice President

Motoman, Inc., West Carrollton, Ohio, named Kenji Harada as senior vice president and presidential advisor. Harada comes to the company from Yaskawa Electric Corp., where he served for 32 years and attained the status of general manager for the Overseas Sales Department for the Robot Strategic Business Unit.

Astro Arc Names Vice President

Jeffrey A. Mann was named vice president of Astro Arc Polysoude, Menomonee Falls, Wis. Mann, most recently North American orbital pipe welding manager at the company, has nearly 25 years of orbital welding experience.

Swagelok Announces Four New Directors

Swagelok Company, Solon, Ohio, announced the appointments of four new directors in marketing and information systems.

David E. O'Connor has been named director of information systems. O'Connor joined the company in 1999 as applications development manager. His previous experience includes MIS consulting with the Cleveland office of Ernst and Young.

As director of e-business and information technology planning, Thomas J. Gub unc will provide leadership in information systems and technology planning, while assuming overall development responsibility for the company's e-commerce products. He has been with the company for 16 years and previously served as IT planning manager and a systems development supervisor.

Larry D. Vandendriessche has been named director of marketing. With the company since 1999, Vandendriessche played a pivotal role in the initial development of the company's eStore and other e-commerce offerings.

Michael L. Butkovic was appointed director of product and market development. He will target market teams to develop market strategies, new products, and new product training. With the company for 16 years, Butkovic most recently served as director of customer service, technical service, and assembly operations.

US Inspection Services Adds Director

Mike Higgins

US Inspection Services, Dayton, Ohio, has appointed Mike Higgins director, Materials Testing Division. In this position, Higgins is responsible for sales, coordination, and execution of the company's mechanical, metallurgical, and laboratory management activities.
Hypertherm Appoints Manager

Hypertherm, Inc., Hanover, N.H., has appointed John Carroll to the position of manager of corporate improvement. Formerly a Vermont state senator who served as Senate Majority Leader and chair of the Appropriations Committee, Carroll will be charged with managing the company’s Continuous Improvement programs as well as directing its 7-Step Problem Solving Activities.

Meritus Hires Manager

Meritus, St. Albans, Hertfordshire, England, has hired Andrew Godfrey as manager of Meritus products. His responsibilities include engineering, marketing, and sales of the company’s resistance welding products. Prior to this appointment, Godfrey was a concept engineer with engineered products at British Federal.

Obituary

Frank W. Corbett

Frank W. Corbett [AWS], a long-time member of the American Welding Society, died on August 17 in Springfield, Pa. Corbett was a sales representative for Atlas Welding Accessories, Inc. After serving in the U.S. Navy, where he began his welding career, Corbett pursued sales positions with national welding firms, including Atlas.

Brazing Q&A

One of these companies was Sockover Metals in Cincinnati, Ohio, home of Crosley Corp., owned by Powell Crosley, Jr.

During my high school and college days, Cincinnati newspapers were full of the exploits of Powell Crosley, Jr., who was considered the Henry Ford of radios. Crosley believed radio wouldn’t succeed until there was a radio in every home. So he built the “Harko” radio, which sold for $9. By the 1920s, he was the largest radio manufacturer in the world. Following that he worked on the first car radio, the 500,000-W WLW radio station, and refrigerators. He then entered the automobile market with a small car powered by an all-brazed gasoline engine.

With all of the facilities and processes falling into place, Crosley built many thousands of the small Cobra cars, incorporating the four-cylinder, lightweight, brazed Cobra gasoline engine. He also produced small, lightweight, six- and four-cylinder, Taylor brazed gasoline engines during World War II —Figs. 1 and 2. The four-cylinder engine was used as an auxiliary power plant in field equipment, aboard PT boats, and in B17 bombers. Many thousands of these engines performed admirably under war conditions.

Unfortunately, the copper brazed engine made of carbon steel had an “Achilles’ heel.” In the late 1940s, when we were looking for a brazing source, our purchasing agent and I visited the plant that manufactured the brazed Cobra engines. We met with Lewis Crosley, Powell’s brother. Lewis indicated the demise of the brazed engine was caused by a corrosion problem. He said drivers let the engine water level become low and galvanic corrosion at the edge of the copper to steel caused leakage.

As welding engineer on jet engines at Curtiss Wright Corp. in New Jersey, I saw the corrosion problem first hand when I torch brazed the leak areas in two brazed engine blocks for coworkers. The braze repair had to be made in an inaccessible location inside the port under the valve seat. Fortunately, the operation was a success.

Taylor had designed the brazed engine for use in race cars and continued to improve and use his Super Sports engine for racing. In 1959, Taylor and Ted Tyce of Tyce Engineering Corp., Chula Vista, Calif., got together to build the TnT engine made of brazed stainless steel. It is believed some of these engines are still in use, but I cannot confirm that.

I am sure with today’s knowledge of brazing and filler metals, along with our knowledge of corrosion, it would be possible to make some excellent brazed engines.

R. L. PEASLEE is Vice President, Wall Colmonoy Corp., Madison Heights, Mich. This article is based on a column prepared for the AWS Detroit Brazing and Soldering Division’s newsletter. Reader may send questions to Mr. Peaslee c/o Welding Journal, 550 NW LeJeune Rd., Miami, FL 33126 or via e-mail to bobpeaslee@wallcolmonoy.com.
Brochure Features Pipe and Tube Cutting Equipment

The company's 12-page, full-color brochure features its pipe cutting, beveling, alignment equipment, reforming clamps, welding electrode and flux ovens, and a variety of pipefitter's tools. The brochure is available in seven languages including English, Spanish, French, Italian, German, Arabic, Russian, and Chinese.

Mathey Dearman, Inc. 126
4344 S. Maybelle Ave., Tulsa, OK 74107

Catalog Features Temperature Products

The company's catalog showcases its line of temperature-indicating crayons, quick-drying liquids, self-adhesive labels, high-temperature paints, and antirust weldable primer.

Tempil® 127
2901 Hamilton Blvd., South Plainfield, NJ 07080

Brochure Highlights Mechanized Welding Equipment

A four-page, color brochure from the company outlines mechanized welding for complex, high-purity applications and describes the company's services in the design and planning of complete turnkey solutions for mechanized welding. Welding generators and compatible equipment appropriate for various applications are described. Discussion includes information about the function of welding generator control and how it records welding parameters and welds executed to help users meet ISO 9000 requirements.

Astro Arc Polysoude, Inc. 129
W33 N5138 Campbell Dr., Menomonee Falls, WI 53501

Catalog Highlights World of Clamping

Manual and pneumatic clamping products are showcased in the company's catalog. The cover includes a foldout tab that provides quick reference to new products and a table of contents that can remain open as users leaf through the pages. More than 500 standard manual, pneumatic, and hydraulic clamping products are featured.

DE-STA-CO 128
2121 Cole St., Birmingham, MI 48009

Corrosion Alloy Brochure Updated

The company's revised corrosion-resistant alloy product brochure incorporates corrosion tables on rolled-alloy products and more than 36 other corrosion-resistant alloys. Design stress information, alloy compositions, mechanical and physical properties, specification, and welding guidelines are also included. The brochure is available by calling (800) 521-0332 or via the Web site, www.rolledalloys.com.

Rolled Alloys 130
125 W. Sterns Rd., Temperance, MI 48182

Brochure Describes Welding Positioner and Gripper

The company's four-page, full-color brochure provides an overview of and specifications for the model WEH 3000# positioner and gripper designed for pipe fabricators by pipe fabricators.

Team Industries, Inc. 131
1200 Maloney Rd., Kaukauna, Wis. 54130

Work Tools Featured in Catalog

The company's 112-page, full-color catalog features more than 1800 high-quality professional tools. Insert/power bits, T-handles, L-keys, screwdrivers, sockets, tweezers, cushion grips pliers, and cutters are among the products showcased.

WIHA Quality Tools 132
1248 Dundas Circle, Monticello, MN 55362-8434
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Interstitial Diffusion of Carbon and Nitrogen into Heat-Affected Zones of 11–12% Chromium Steel Welds

The possibility of introducing austenite stabilizers into the HAZ to restrict grain growth is investigated

BY A. M. MEYER AND M. du TOIT

ABSTRACT. The welding of 11–12% chromium steels is subject to the traditional concern with ferritic grain growth in the heat-affected zone of ferritic stainless steels. The grain growth could be inhibited if austenite on the ferrite grain boundaries could be stabilized at high temperatures.

This article discusses the possibility that diffusion from the weld metal can increase the carbon or nitrogen content of the heat-affected zone, and consequently stabilize grain boundary austenite.

Introduction

In recent years, considerable interest has developed in the use of 3CR12 by the automotive and agricultural industries (Ref. 1). The cost of additional thickness requirements and surface treatments needed to counteract corrosion loss in conventional carbon steel presents a large portion of the material cost over the life cycle of a component. The interest in 3CR12, therefore, arises from its relative resistance to atmospheric corrosion (Ref. 1). The chemical composition of this corrosion-resistant steel is shown in Table 1. However, the traditional concerns regarding grain growth and embrittlement in the heat-affected zones of welds in ferritic stainless steels also apply to 3CR12.

The heat-affected zone in 3CR12 consists of three zones, namely the high-temperature heat-affected zone (HTHAZ), the duplex zone and the low-temperature heat-affected zone (LTHAZ) (Ref. 2). The grain growth that occurs in the HTHAZ during welding is the main cause of concern. The phase composition of the heat-affected zone at high temperatures depends on the relative amount of austenite and ferrite stabilizers in the steel (Ref. 3). During cooling, grain growth is restricted by grain boundary austenite (Ref. 3). Considerable ferrite grain growth occurs during the heating cycle and close to the peak temperature when the phase composition is fully ferritic (Ref. 3).

The research done for this article explores the possibility of introducing austenite stabilizers into the heat-affected zone during welding to restrict grain growth through forming a dual-phase ferrite-austenitic structure close to the peak temperature reached during welding. The width of the heat-affected zone is a function of the heat input during welding (Ref. 4).

The Influence of Ferrite Grain Size on Impact Properties

Ferrite grain size has a marked effect on the impact properties of the HTHAZ. Ductile-to-brittle-transition-temperature (DBTT) results from samples obtained through temperature-cycle simulation by Gooch and Ginn (Ref. 5) indicate the DBTT of 12% ferritic-martensitic steel increases with the ferrite grain size.

The Petch relationship between transition temperature and grain size is given by the form (Ref. 5)

\[ \text{DBTT} = F + G \ln(d) \]

where F and G are constants and d is the grain diameter.

The DBTT results obtained by Gooch and Ginn (Ref. 5) are plotted against \( \ln(d) \) in Fig. 1. An approximate correlation with Equation 1 was found. This indicates the ferrite grain size would play a major role in the fracture toughness of the HTHAZ in 3CR12 welds.

The Influence of Martensite

It is well established that grain growth may only account for part of the observed
loss of toughness in the heat-affected zone of welded 3CR12 (Refs. 2, 3, and 5). Gooch and Ginn (Ref. 5) observed a general trend for transition temperatures to increase with higher martensite contents in microstructures dominated by high-temperature δ ferrite. They observed cleavage facets to have originated from martensite colonies. Intergranular martensite will inhibit the transmission of slip from one grain to the next and act as an internal stress raiser (Ref. 5). It would thus seem likely the presence of martensite in a predominantly ferritic structure would facilitate cleavage fracture.

These comments assume fracture occurs in a predominantly ferritic structure. The mechanism could be quite different when martensitic is the principal phase. Metallographic examination by Gooch and Ginn (Ref. 5) showed secondary cleavage to be arrested at martensite colonies. Due to this effect, the total energy absorbed during fracture will increase at higher martensite contents. The delta ferrite grain growth at high temperatures will also be restricted by a higher fraction of austenite on the grain boundaries (that would transform to martensite on cooling) (Ref. 5). Improved toughness should thus be obtained at higher fractions of martensite provided the structure is already predominantly martensitic.

The above-mentioned effect was observed in temperature simulation experiments executed by Zaayman (Ref. 3). Different amounts of martensite were obtained by applying different thermal cycles to samples of the same alloy. The results in Fig. 2 indicate an increasing fraction of martensite is harmful to the impact properties up to 90% martensite. The DBTT starts to decrease at 90% martensite, and continues to decrease as the fraction of martensite increases further. The martensite raises the stress in the softer ferrite at a martensite fraction of less than 90% (Ref. 3), and the higher stressed ferrite benefits cleavage fracture. Simultaneously, however, an increase in the fraction of martensite decreases the grain size of the remaining ferrite. This refining effect dominates at martensite fractions of more than 90% and this accounts for the observed decrease in DBTT (Ref. 3).

The Influence of Carbon and Nitrogen

Carbon and nitrogen affect the impact properties of the heat-affected zone in 11-12% chromium steels in two different ways. First, the hardness of the intergranular martensite that forms in the high temperature heat-affected zone increases with increasing carbon and nitrogen contents, which is harmful to the impact properties. Second, both carbon and nitrogen are strong austenite stabilizers and can restrict δ-ferrite grain growth by producing a dual phase at the high peak temperatures reached during welding (Ref. 3). The expansion of the austenite loop (γ loop) on the iron-chromium phase diagram can be seen in Fig. 3.
An optimum amount of carbon and nitrogen exists where the detrimental effect of a harder heat-affected zone exceeds the beneficial effect of a finer structure (Ref. 3). The ideal amount of carbon and nitrogen is strongly dependent on the content of other alloying elements, and therefore varies considerably (Ref. 3). The combined effect of carbon and nitrogen is shown in Fig. 4. The line P indicates the carbon and nitrogen levels of the base metal.

The Diffusion of Carbon and Nitrogen into the Heat-Affected Zone

A small addition of nitrogen to 3CR12 could restrict the δ-ferrite grain growth in the high-temperature heat-affected zone through the promotion of a dual phase at high temperatures. As discussed earlier, too much nitrogen would be detrimental to the impact properties. Therefore, it would be preferred if the nitrogen content could be increased locally in the vicinity of the weld. Hawkins, Beech, and Valtierra-Gallardo (Ref. 6) performed a series of experimental welds with a shielding gas of pure argon and different additions of nitrogen gas. The mixtures ranged from argon + 0.5% nitrogen to argon + 75% nitrogen. The results obtained are illustrated in Fig. 5. The results indicate the nitrogen content of the weld metal can be increased if the fraction of nitrogen in the shielding gas is increased.

The weld interface can then be visualized as a diffusion couple. Constant temperature is assumed for the sake of simplicity. The concentration of nitrogen into the base metal away from the weld interface can then be illustrated by the graph in Fig. 6.

The concentration of nitrogen is given by the following equation:

\[ C = C_0 \text{erfc} \left( \frac{x}{2(Dt)^{1/2}} \right) \]  

where \( x \) is the distance from the weld interface, \( D \) is the diffusion coefficient for nitrogen in steel at a specific temperature and \( t \) is the time in seconds, \( C \) is the concentration of nitrogen at a distance \( x \) after time \( t \), and \( C_0 \) is the concentration of nitrogen in the base plate. The distance between the weld interface and the intercept of the tangent to the graph in Fig. 6 is defined as the fusion distance and is given by \( x = 2(Dt)^{1/2} \). These distances were calculated and are given in Table 2.

Diffusion distances for carbon can be calculated similarly (only the coefficient \( D \) is different). The calculated distances for carbon are shown in Table 3. The carbon content of the weld metal can be increased by simply welding with a filler metal with a higher carbon content. The results are shown graphically in Figs. 7 and 8.

Isothermal conditions are implicitly assumed in the above calculations. This assumption is in reality not valid, as the welded plate is cooling continuously. However, if the temperature sequence prediction from the Rosenthal equation (Ref. 4) in Fig. 9 is considered, the weld interface will be at a temperature higher than 1400°C for more than three seconds. Therefore, it was considered possible that a higher carbon or nitrogen content in the weld metal may increase the interstitial content of the HTHAZ significantly.

Experimental Welding and Results

Shielded Metal Arc Welding with E309L and E307 Electrodes

Shielded metal arc welding was done on 8-mm 3CR12 plate using an E309L electrode (0.03% C) and an E307 electrode (0.16% C), respectively. Welding was done parallel to the rolling direction. The ASTM grain size number of the remaining ferrite in the high-temperature heat-affected zone of the E307 welds was 4–5, while the grain size number of the remaining ferrite in the same region of the E309 welds was 1–2. A smaller ferrite grain size in the heat-affected zone of the E307 welds was thus observed. The grain size was determined by the use of the Hillards equation (a standard line intercept method). The microstructures of both high-temperature heat-affected zones consisted of ferrite and grain boundary martensite, with a higher fraction of grain boundary martensite in the E307 welds.

Both weld metal microstructures consisted of austenite and ferrite. The ferrite numbers (obtained from Fischer Fer-
**Gas Metal Arc Welding**

Experimental gas metal arc welding (GMAW) was done on 12-mm hot-rolled 3CR12 plate. The heat input was held constant at 1.3 kJ/mm. Three separate welds were made using the following:

1) ER309L filler metal containing 0.03% carbon (1.2 mm) and pure argon shielding gas. The microstructure of the heat-affected zone is shown in Fig. 12.

2) ER307 filler metal containing 0.16% carbon and a pure argon shielding gas. The microstructure of the heat-affected zone is shown in Fig. 13.

3) ER309L filler metal containing...
0.03% carbon (1.2 mm) and an argon +33% nitrogen shielding gas mixture. The microstructure of the heat-affected zone is shown in Fig. 14.

The weld metal microstructure of each of the welds consisted of austenite and ferrite. The average Fisher Ferrite scope readings were 15.1 FN for the ER309L welds with pure argon shielding gas, 12.8 FN for the ER307 welds with pure argon shielding gas and 5.9 FN for the ER309L welds with the Ar-N₂ mixture. The low ferrite number of the weld with the Ar-N₂ mixture suggests that the nitrogen level in the ER309L weld metal was raised and that the austenite was stabilized by the higher nitrogen content. Although the ferrite number is still more than five, the susceptibility of the weld metal to hot cracking may be increased by the lower ferrite content.

The grain sizes in the heat-affected zones of the different welds were determined in a similar fashion as described earlier with the shielded metal arc welds. The average ASTM grain size number in the heat-affected zone of the ER309L weld with pure argon shielding gas was 1-2, while in the heat-affected zones of the ER309L welds with the Ar-N₂ shielding gas mixture and the ER307 welds with pure argon shielding gas, the average ASTM grain size number was 4-5. Therefore, a smaller ferrite grain size was observed in the heat-affected zones of the ER309L welds with the Ar-N₂ shielding gas mixture and the ER307 welds with pure argon shielding gas than in the heat-affected zone of the ER309L weld with pure argon shielding gas. In the heat-affected zones of the ER309L weld with the Ar-N₂ mixture and the ER307 weld, a larger fraction of grain boundary martensite was also observed. In accordance with these observations, the heat-affected zones of these two welds were harder than the heat-affected zone of the ER309L weld with pure argon shielding gas. Hardness profiles across these welds are shown in Fig. 15. Contrary to expectation, the ER307 weld metal hardness is only marginally higher than that of the ER309L. This may be due to the fact higher peak temperatures are reached in GMAW as compared with SMAW, and, consequently, the interstitial elements could diffuse out of the weld metal faster than during SMAW.

The smaller grain size in the heat-affected zones of the ER309L weld with the Ar-N₂ mixture and the ER307 weld with the pure Ar shielding gas, together with the higher hardness, would render the protection of the zone by the softer weld metal and base metal to be more likely in impact situations (Ref. 2), and would increase the overall integrity of the weld. Similar to the SMAW specimens discussed previously, three types of failures were observed in the full-size Charpy specimens (10 x 10 x 55 mm) machined from the welds. The notch was placed perpendicular to the rolling direction and the plate thickness. Proper Charpy specimens could not be obtained from the Ar-N₂ welds because of the excessive spatter that occurred in these welds. The spatter is similar to that observed when shielding gas flow is insufficient to prevent air contamination of the shielding gas, and may therefore be directly attributed to the nitrogen present in the shielding gas. As a result, only the ER309L and ER307 welds (both with pure argon shielding gas) were evaluated. The results are shown in Fig. 16. Higher impact energies were observed in Fig. 16 than in Fig. 10, due to the fact full-size Charpy specimens were used instead of the half-size specimens used with the shielded metal arc welds.

**Chemical Analysis**

Chemical analysis of the base metal, weld metal, and heat-affected zone was done to confirm the transfer of carbon and nitrogen across the weld interface. The heat-affected zone samples were obtained from very fine drillings (0.5-mm-diameter drill) from lightly etched specimens. Etching was done by quick swabbing with Kalling's nr. 2. The results are tabulated in Table 4.

The high levels of carbon (HTHAZ of ER309 + Ar) and nitrogen (ER309L + Ar-N₂) suggest that interstitial diffusion of carbon and nitrogen may have taken place. Contamination of the heat-affected zone samples from either the weld metal or the base metal was inescapable but care was taken to take the drilling as far as possible from the weld metal to get contamination from a region with a lower interstitial content rather than from the weld metal with the higher carbon and nitrogen content. The results nevertheless show an increase of 96% in carbon content and 78% in nitrogen content. The large increase in interstitial content suggests that contamination of the sample drillings of the heat-affected zone zone in 3CR12 (GMAW, 1.3 kJ/mm, ER309L filler metal, argon-nitrogen shielding, 100X).

**Continuous Cooling and Diffusion**

It was mentioned earlier that the isothermal conditions assumed in the diffusion distance calculations were not valid, since the welded plate cools continuously. In order to get a more acceptable model of the interstitial diffusion of car-

**Table 4 — Carbon and Nitrogen Contents in Different Zones of Welds in 3CR12**

<table>
<thead>
<tr>
<th>Process (welding wire %C %N</th>
<th>Base Metal %C %N</th>
<th>Heat-Affected Zone %C %N</th>
<th>Weld Metal %C %N</th>
</tr>
</thead>
<tbody>
<tr>
<td>ER309L + Ar</td>
<td>0.029 0.019</td>
<td>0.031 0.018</td>
<td>0.032 0.014</td>
</tr>
<tr>
<td>ER309L + Ar-N₂</td>
<td>0.033 0.018</td>
<td>0.042 0.015</td>
<td>0.032 0.019</td>
</tr>
<tr>
<td>ER307 + Ar</td>
<td>0.027 0.017</td>
<td>0.053 0.019</td>
<td>0.130 0.020</td>
</tr>
</tbody>
</table>
microstructural changes and the difference in impact properties as observed in the experimental welds discussed earlier therefore seems to be the result of interstitial diffusion from the weld metal into the base plate across the weld interface.

Conclusions

Ferrite grain growth in the heat-affected zones of welds in 3CR12 has a detrimental effect on the impact properties of the welded joint. Ferrite grain growth can be inhibited by increasing the amount of grain boundary austenite in the heat-affected zone at high temperatures. Increasing carbon or nitrogen contents in the heat-affected zone should act to stabilize grain boundary austenite. Consequently, a decrease in ferrite grain growth should be observed in the heat-affected zone of 3CR12 welds.

A decrease in the ferrite grain size occurs in the heat-affected zones of welds in 3CR12 if the carbon or nitrogen content of the weld metal is increased. The finer heat-affected zone structure improves the impact properties of the welded joint. Diffusion distance calculations suggest that the finer structure, increase in grain boundary austenite, and improvement in impact properties are the result of diffusion of carbon and nitrogen from the weld metal, across the weld interface and into the heat-affected zone. Although an increase in the interstitial content of the heat-affected zone was observed in chemical analysis, contamination of the heat-affected zone samples by the weld metal could not be ruled out. Therefore, the chemical analysis should not be viewed as conclusive. A filler metal with a different interstitial content, however, may conclusively alter the phase composition of the heat-affected zone.

References

Factors Affecting the Properties of Friction Stir Welded Aluminum Lap Joints

Critical sheet interface was eliminated by either a second weld pass or refined tool dimensions, resulting in exceptional joint efficiency

BY L. CEDERQVIST AND A. P. REYNOLDS

ABSTRACT. Friction stir welding (FSW) is a solid-state joining process invented at The Welding Institute (TWI) in 1991. The ability to produce high-quality welds in high-strength aluminum alloys sets FSW apart from typical fusion welding techniques. The process has mainly been used for making butt joints in aluminum alloys. Development of FSW for use in lap joint production would expand the number of applications that could benefit from the technique.

In this study, an extensive investigation was carried out on FSW lap joints, including interface morphology and mechanical properties. Two materials, Alclad 2024-T3 and Al7075-T6, sheet materials commonly used in the aerospace industry, were joined. Welding variables included welding speed, rotational speed and, of particular importance, tool dimensions.

Examination of metallographic cross sections and failure locations showed a critical sheet interface present in all welds. Consequently, a second weld pass was added to eliminate the critical sheet interface. Results indicated FSW lap joints may, on the basis of strength, potentially replace other joining processes like resistance spot welding and riveting.

Introduction

Friction Stir Welding

Friction stir welding (FSW) is a solid-state thermo-mechanical joining process, where the actual mechanism of weld formation is most nearly described as a combination of in-situ extrusion combined with forging. To produce a full-penetration groove weld in a butt joint, the bottom of the tool must be close to the bottom of the workpiece (which must be supported on the back side). In order to make a lap joint, the bottom of the tool must only extend through the bottom of the top sheet and into the bottom sheet, creating a metallic bond between the two sheets. Schematic drawings of the lap joint welding process are shown in Fig. 1 (Ref. 1).

Figure 1 also provides information regarding the terminology used to describe friction stir welds. Due to the tool rotation, friction stir welds are not symmetric about the weld centerline. The side of the weld on which the rotational velocity of the tool has the same direction as the welding velocity is designated the advancing side of the weld. The side of the weld on which the two velocities have opposite direction is designated the retreating side of the weld.

Friction stir welding of aluminum alloys results in the characteristic microstructure described in several previous studies (Refs. 2, 3). In lap joint welding, the movement of material within the weld was more important than the microstructure, due to the interface present between the sheets. The general features of the movement of material in butt joint welding have also been described in previous papers (Refs. 4, 5). Of particular interest was the transport of material from the retreating side to the advancing side at the top surface of the weld. This material transport resulted in vertical transport of material about the longitudinal axis of the weld. This same vertical transport occurred in lap joint welding (Ref. 6). If the vertical motion of material took place outside of the pin diameter, the unbonded sheet interface material could also be transported vertically, affecting the strength of the lap weld, as will be shown later.

Figures 2A-D show the vertical transport in several FSW butt joints of 8.1-mm-thick Al 2195-T8 produced using different welding parameters. The marker insert technique used to elucidate the vertical flow has been described in previous publications (Ref. 5). The figure illustrates the positions of inserted markers prior to welding (2A) and after welding using different welding pitches (tool advance per revolution, 2B-D). The positions of the markers are projected onto the transverse plane of the weld and the plate thickness direction is vertical in the figures. In each of Figs. 2A-D, the retreating side of the weld is on the left and the advancing is on the right. It can be seen a lower ratio of welding speed to rotational speed (resulting in a "hot" weld) caused more vertical transport on the retreating side (compare Fig. 2B with 2C), while a higher welding speed (resulting in a "colder weld") caused less vertical transport on the retreating side (compare Fig. 2C with 2D). The amount of vertical
Competitive Joining Processes

Riveting is currently the primary method of joining aerospace structures and has been used in aircraft fabrication since the 1920s (Ref. 7). The maximum overlap shear strength found in MIL-HDBK-5 (Ref. 8) was 10.3 kN using Alclad 2024-T3 and bare 7075-T6 sheets were 610 mm long and 127 mm wide and were positioned as shown in Fig. 1. Sheets were degreased prior to welding; the advancing side of the first weld, while welding direction and top sheet were projected onto a transverse cross-section plane. The re-

Overlap Shear Testing

A Lap Joint Test is a process of welding by use of force and current. RSW is currently the joining method of choice in the automobile industry (steel sheet primarily) for economic reasons (Ref. 9). However, in an ongoing effort to reduce weight, alu-

Experimental Procedure

Materials

Alclad 2024-T3 and bare 7075-T6 were used, respectively, as the top and bottom sheet of the lap joints. The nominal composition in weight percent (major alloying additions) of the 2024 is 4.4% Cu-1.5% Mg-0.6% Mn and balance aluminum. The nominal composition of 7075 is 1.6% Cu-2.5% Mg-0.23% Cr-5.6% Zn-1.5% Zn and balance aluminum. Sheet thickness for 2024-T3 and 7075-T6 are 2.29 mm (0.090 in.), while the cladding of 2024-T3 sheets is 0.06 mm thick on both sides. The ultimate tensile strength (UTS) of 2024-T3 base metal is 475 MPa; the UTS of 7075-T6 base metal is 595 MPa.

Welding Procedures

All FSW lap joints were made on a 15-hp vertical milling machine. Both top and bottom sheets were 610 mm long and 127 mm wide and were positioned as shown in Fig. 1. Sheets were degreased prior to welding using a household cleaner. No mechanical means of oxide removal were employed. However, scale on the sheets was very light.

Table 1 lists the welding parameters used for all welds, as well as the failure load and failure location(s) in overlap shear testing. The welding speed (WS) ranged from 2.3 to 5.6 mm/s and the rotational speed (RS) of the tool ranged from 300 to 983 rpm. Seven different WS-RS combinations were used for the 25 welds produced in this study.

Nine different tool configurations were used. Pertinent tool dimensions are detailed in Table 2 and defined in Fig. 3. Due to relatively short pin lengths and no fixed rotational direction, the tools were made without threads. Tool-to-workpiece angle was maintained at 2.5 deg for all welds. A shoulder plunge of 0.5 x (shoulder diameter) x sin (2.5 deg) was used for all welds. This shoulder plunge resulted in shoulder contact with the base plate at the tool centerline perpendicular to the welding direction.

Welds were made in either one pass (single pass) or two passes (double pass). When double-pass welds were made, both passes were made with the same tool and welding parameters. However, the tool rotation was reversed for the second pass and the tool was moved over toward the advancing side of the first weld, while welding direction and top sheet were maintained constant. As a result, the advancing sides of both passes were adjacent to each other and contained within the weld nugget, while the retreating sides of both passes were on the periphery of the weld nugget. The separation distance, designated SE (column 6 in Table 1), refers to the distance between the centerlines of the two weld passes in double-pass welds.

Overlap Shear Testing

Lap joints may be loaded primarily ei-
ther in shear or by peel. In this study, the strength of lap joints loaded nominally in overlap shear is examined. In an ideal lap shear test (no bending), the tensile stress in the top and bottom sheets progressively decreases from a maximum at the loaded end to zero at the unloaded end. Figure 4 shows the theoretical tensile stress distribution in a lap joint with no sheet interface present and no bending. In a real lap shear test, particularly if no guides are used, additional tensile stresses will be generated at the bottom of the loaded side of the top sheet and at the top of the loaded side of the bottom sheet. Corresponding compression stress components will be generated on the opposite sides of the sheets. These stresses arise due to bending of the sheets around axes perpendicular to the loading direction and passing through points near the edges of the metallic-bonded interface (Ref. 10). These bending stresses decrease the test's severity and may be deleterious when the lap joint interface has components normal to the nominal shear-loading direction (that is when the unbonded-interface direction is in the sheet-thickness direction).

Due to the asymmetric nature of FSW, a lap joint can be loaded with the advancing side loaded (experiencing maximum stress according to Fig. 4) on the top sheet (Fig. 5B) or with the retreating side loaded on the top sheet (Fig. 5A). Double-pass welds can also be loaded in two ways according to Figs. 5C–D. The shapes of the sheet interfaces in Figs. 5A–D are general representations for FSW lap joints produced in this study. It can be seen how the sheet interface on the retreating side has moved upward (interface pull up), while the advancing side can have both upward and downward movement. The sheet interface on the retreating side is generally curved, while on the advancing side, the interface generally exhibits abrupt changes in direction. Because of the stress distribution described in Fig. 4 and due to the bending stresses present, the critical locations in Fig. 5A will be in the top sheet on the retreating (R) side and in the bottom sheet on the advancing (A) side.

The time between welding and shear testing was typically 120 h so that postweld natural aging would not vary appreciably from weld to weld. All overlap shear tests were performed on a 100-kN MTS testing machine at a constant crosshead displacement rate of 2.5 x 10^{-6} mm/s. The maximum (failure) load and failure location were recorded for each specimen. In this study, specimens were designated according to which side of the top sheet (2024-T3) was loaded (experiences maximum load): A for advancing and R for retreating in the case of single-pass welds, and A1 or R2 (meaning the retreating side of pass 1 or pass 2) in the case of double-pass welds (Fig. 5A–D). Relative positions of the sheets during welding (Fig. 1) were such that specimens could be cut out of the welded sheets in both possible loading conditions. Two specimens for each weld and each loading condition were tested and the failure loads averaged. All specimens tested were 25.4 mm wide (see Fig. 6 for dimensions of test specimens). The failure load for a 25.4-mm-wide specimen of the Al clad 2024-T3 base metal sheet was 27.6 kN, which was used to calculate the joint efficiency of the welds.

### Optical Microscopy

Optical microscopy was used to study transverse cross sections of the welds. Standard metallographic polishing procedures were used with Keller’s reagent.
to prepare the specimens. In addition, it was concluded that the shape and amount of upward or downward translation of the sheet interface was an important parameter. Therefore, a scale was used to measure how much of the original sheet thickness was left after welding. On the basis of these measurements, a new parameter — effective sheet thickness (EST) — was introduced and defined according to Figs. 7A and D. The EST is the minimum sheet thickness determined by measuring the smallest distance between any unbonded interface and the top of the top sheet or bottom of the bottom sheet.

Hardness Measurements

One single-pass (No. 7) and one double-pass (No. 23) weld made with the same tool and welding parameters were sectioned and polished so the hardness could be measured using a Vickers hardness tester with a load of 200 g. Hardness measurements were performed to reveal possible changes due to the second weld pass. The middle of both the top and the bottom sheets were tested throughout the cross section with 0.5-mm spacing between data points.

Results

Overlap Shear Testing

The failure load and failure location from overlap shear testing for all of the welds are shown in Table 1. Failure locations (columns 8 and 10) are designated with a weld side (A, R, R1, or R2) and a sheet (either top, T, or bottom, B); t.n. indicates through-nugget failure. The failure load for single-pass welds (not including weld No. 7) ranged from 5.6 to 14.0 kN (avg. 9.6 kN). Welds loaded on the top sheet, retreating side (R loaded) averaged 8.6 kN, while the top sheet advancing side-loaded (A-loaded) specimens for the same welds averaged 12.4 kN. For the R-loaded single-pass specimens, 80% failed on the advancing side, top sheet and 20% failed through the nugget (through-nugget failure). For the A-loaded single-pass specimens, 64% failed at the advancing side, bottom sheet and 36% failed through the nugget. In other words, no retreating side failures were observed in single-pass welds. As a result, there was a need to eliminate the critical advancing side and prevent through-nugget failure. Accordingly, the double-pass welding technique was developed, since it would eliminate...
both the advancing side and make the weld nugget wider, hence preventing through-nugget failure.

The failure load for double-pass welds ranged from 14.4 to 23.8 kN (avg. 18.7 kN). RI-loaded specimens averaged 18.2 kN, while the R2-loaded specimens averaged 19.2 kN. For the RI-loaded double-pass specimens, 100% failed on the RI side, top sheet. For the R2-loaded double-pass specimens, 56% failed on the R2 side, top sheet, and 44% failed on the RI side, bottom sheet.

The failure load for the single-pass weld No. 7 was 21.4 kN for the R1-loaded specimens and 15.6 kN for the A-loaded specimens. All weld No. 7 specimens failed on the advancing side either top or bottom sheet. Weld No. 7 will be discussed further in another section.

Optical Microscopy

Figures 7A-1 show metallographic cross sections of several single- and double-pass welds. Figures 7A-C are single-pass welds with the advancing side on the right and the retreating side on the left. The difference between the advancing and retreating side interfaces can be readily observed in the first single-pass weld — Fig. 7A. For Fig. 7B, all parameters were kept the same as for Fig. 7A except the pin length was reduced by 25%. It can be seen this lessened the amount of pull up on the retreating side and caused pull up, instead of pull down, on the advancing side. Figure 7C has the same pin length as Fig. 7B but twice the pin and shoulder diameter. As a result, a larger weld nugget and a smoother shape of the interface on the advancing side were produced.

Considering the double-pass welds shown in Figs. 7D and 7E, all weld parameters are the same except that Fig. 7E has a larger separation distance between the first and second passes (greater than the pin diameter), resulting in an unbonded interface in the middle of the weld nugget. For Fig. 7F, welding speed was increased relative to Figs. 7D and E resulting in less pull up of both retreating sides (R1 and R2) compared to Fig. 7D. This is consistent with the trends in vertical flow of material shown in Fig. 2. The effect of pin length on interface shape of the retreating side can once more be observed in Figs. 7G, H and I, which used pin lengths of 3.6, 3.3, and 3.0 mm, respectively. The longest pin caused interface pull up, while the middle length pin resulted in a flatter interface, and the shortest pin caused interface pull down. This correlates well with the work presented by Colligan (Ref. 4).

Figure 8 is a graph of the failure load as a function of effective sheet thickness (EST) for all single- and double-pass welds that did not exhibit through-nugget failures. It is apparent that increasing EST results in increased failure loads for both single- and double-pass welds. Comparing single- and double-pass welds having the same EST, double-pass welds exhibit higher failure loads.

Hardness Measurements

Figures 9 and 10 show results from the hardness measurements of a single-pass weld (No. 7) and double-pass weld (No. 23) respectively. The vertical lines indicate the position of the tool shoulder and pin during welding. For the single-pass weld, hardness varied between 105 and 154 and 120 and 154 for the top and bottom sheet, respectively. For the double-pass weld, hardness varied between 105 and 151 and 118 and 168 for the top and bottom sheet, respectively. The base metal hardness was 155 for the top sheet (2024-T3) and 170 for the bottom sheet (7075-T6).
Discussion of Results

Effective Sheet Thickness

As mentioned earlier, from examination of metallographic cross sections of the single-pass and double-pass welds, it was supposed the effective sheet thickness, (defined in Figs. 7A and D), can be related to the strength of both single- and double-pass welds. Figure 8 confirms this hypothesis. The reason a single-pass weld with the same EST as a double-pass weld has lower strength is likely due to the sharpness or minimum radius of curvature of the interface (higher stress concentration) on the advancing side of the single-pass weld compared to either retreating side in the double-pass welds.

Figure 8 indicates the strongest welds are obtained using welding parameters and tool dimensions that result in as little interface pull up of the retreating side as possible (indicated by the maximum EST). Two important findings were made. First, higher welding speed or lower rotational speed (both resulting in a "colder" weld) result in less pull up on the retreating side (compare Figs. 7D and F). This observation agrees with the paper by Seidel and Reynolds (Ref. 5) that found a colder weld has less vertical mixing of material, especially on the retreating side — Figs. 2A–D. However, it has been shown in other aluminum alloys (e.g., Ref. 11) that if weld parameters result in too cold a weld, poor metallic bonding between the top and bottom sheets may result. Second, shorter pin length results in less pull up of the retreating side — Figs. 7G, H, and I. On the retreating side, material flows less upward near the bottom of the pin than at the middle of the pin, which results in less pull up of a sheet interface that is closer to the bottom of the pin than to the middle. In fact, pull down of the sheet interface was achieved for the shortest pin (Fig. 7I), and for the combination of alloys used in the joint studied. This is beneficial because it causes thinning of the stronger sheet (7075). In summary, improved interface shape is obtained when the faying surface between the two sheets is near the bottom of the pin.

Separation Distance

Table 1 shows a larger separation distance (the distance between the centers of the first and second weld passes) in double-pass welds usually gives a stronger weld, although there is a "crack" or unbonded interface left in the middle of the weld if the separation distance is greater than the pin diameter. The likely explanation for this is the longer weld nugget inhibits bending of the loaded specimen (Ref. 10), reducing the bending-induced tensile stress at the critical interface between metallic bonded and unbonded material at the faying surface of the lap weld. A separate investigation was made (Ref. 12) to further understand the influence of weld nugget length on weld strength. The result (failure loads for R1- and R2-loaded specimens averaged) can be seen in Fig. 11. The failure load increases with increasing separation distance up to approximately 15 mm. Beyond 15 mm, separation distance has only a small effect on strength. For SP welds, weld nugget length equals pin diameter, while for double-pass welds, weld nugget length equals pin diameter plus separation distance.

A- vs. R-Loaded Single-Pass Welds

For single-pass welds, A-loaded specimens are significantly stronger than R-loaded specimens because on the advancing side, the interface pull down is generally more severe than the interface pull up, causing greater reduction in EST on the bottom sheet (7075-T6) than on the top sheet (2024-T3). As seen in Fig. 7A, there is undetectable pull up but critical pull down of the advancing side, which causes A-loaded specimens to be twice as strong as the R-loaded specimens (which failed on the advancing side, bottom sheet) for weld No. 1.

Weld No. 7 (Fig. 7C) is a single-pass weld made with a tool (No. 9) modified to produce interface pull down of the retreating side. However, the tool also produced a desirable interface on the advancing side. Unlike other single-pass welds, the interface on the advancing side had no sharp corners. In addition, the R-loaded specimens exhibited exceptional strength, due to the interface pull up on the advancing side.

R1- vs. R2-Loaded Double-Pass Welds

For double-pass welds, the R2-loaded specimens were marginally stronger than the R1-loaded specimens. Comparing failure locations for double-pass welds, R2-loaded specimens failed 44% on the R1 side, bottom sheet, while R1-loaded specimens never failed on the R2 side, bottom sheet (always on the R1 top sheet). This was probably the result of using weaker material (2024) on the top sheet and the effect of the second pass on the R1 hardness distribution, which will be discussed below.

For two of the strongest welds, No. 21, R2-loaded (23.0 kN, 83% joint efficiency), and No. 24, R1-loaded (23.2 kN, 84% joint efficiency), the failure location was in the hot-affected zone (HAZ), in terms of microstructural zones (Ref. 2). At this location, no vertical mixing occurs, so the failure load is unaffected by the sheet interface. The failure loads and locations...
are similar to results of FSW butt joints in Al 2024-T3. For example, in Ref. 13, Reynolds, et al., report a joint efficiency of 83% was achieved and the failure occurred in the HAZ of the retreating side.

Hardness Measurements

For the single-pass weld (Fig. 9), there was minimum hardness in both the advancing and retreating side HAZs. The hardness of the nugget was higher than in the HAZ, but lower than the base metal values. No substantial differences could be seen between the advancing and retreating sides. For the double-pass weld (Fig. 10), the hardness profile was similar to that of the single-pass weld except the gradient in hardness between the HAZ minimum and the local peak in the nugget was much more gradual on the R1 side than on the R2 side. It appears the additional heat treatment imposed by the second weld pass caused softening of the R1 nugget. This phenomenon could explain why R1-loaded specimens tended to be weaker than the corresponding R2-loaded specimens. Comparison of the minimum hardness values for the single- and double-pass welds indicates almost no difference; only the distribution of hardness is modified by the second weld pass. This indicates the HAZ regions of both the single- and double-pass welds may be in a minimum hardness condition for the two alloys.

Conclusions

Testing results and analysis conducted on FSW lap joints have provided the following conclusions and salient observations:

1) A maximum joint efficiency of 86% (23.8 kN of max. 27.6 kN) was achieved for the FSW lap joints in this study. This is comparable to joint efficiencies reached for FSW butt joints of the same materials. For single-pass welds, a maximum joint efficiency of 78% was achieved, which is at least 60% stronger than comparable riveted and RSW lap joints.

2) For double-pass welds, the second weld pass does not cause a reduction in minimum hardness. However, hardness distribution is modified compared to that of the single-pass welds.

3) In the presence of sufficient bonded interface width to prevent through-nugget shear, two critical factors influencing overlap shear strength of FSW lap joints are EST and sheet interface shape. Sheet interface should not have any sharp corners (stress concentrations) or defects (cavities). For double-pass welds, separation distance should be less than or equal to, the pin diameter to prevent the formation of unbonded interface within the weld.

4) A "cold" weld (low rotational speed and/or high welding speed) causes less vertical mixing of the retreating side. Likewise, a shorter pin (as long as the pin length exceeds the thickness of the top sheet) causes less vertical mixing of the sheet interface, hence maximizing the EST.

5) In addition to providing sufficient area to prevent failure by through-nugget shear, a wider weld nugget is beneficial because it decreases the amount of bending in a nominally shear loading configuration. Therefore, a tool with a large pin diameter may be favorable for welds loaded in overlap shear.

6) If a single-pass weld is produced, the welding direction should be chosen so the joint is A loaded, because the advancing side usually exhibits undetectable pull up, but critical pull down. However, if tool dimensions are used that cause pull down of the retreating side, an R-loaded joint may exhibit higher strength (i.e., weld No. 7). Likewise, if a double-pass weld is produced, a R2-loaded joint will usually exhibit higher strength.

Acknowledgments

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References

An Enhanced Faraday Cup for Rapid Determination of Power Density Distribution in Electron Beams

An improved Faraday cup promises to provide rapid and accurate beam profiles, eliminating sources of error that are detrimental to a production environment

BY J. W. ELMER AND A. T. TERUYA

ABSTRACT. Enhancements have been made to a modified Faraday cup (MFC) diagnostic device for measuring the power density distribution of high-power electron beams used for welding. The modifications consist of additions to the hardware components of a previously developed MFC for more complete capture of the electrons, better electrical grounding, and the addition of a new method for orienting the measured beam profile with respect to the coordinates of the welding chamber. These modifications improve the quality of the acquired data and enable a more accurate computed tomographic (CT) reconstruction of power density distribution of the electron beam than has been possible in the past. Comparisons were made between previous and enhanced versions of the MFC. Results demonstrated improved electron capture and improved signal-to-noise ratio with the new design, allowing the acquired beam profile to be CT reconstructed without noise filtering. In addition, Gaussian distributed beams were used to simulate beam profiles acquired by the MFC diagnostic as a function of the finite width of the slits used to measure beam properties. From these simulations, the amount of error in the beam profile introduced by the slits was determined and a method for compensating for this error proposed.

Introduction

The diagnostics necessary to repeatedly produce a focused beam of known power density are not currently available on commercial electron beam welding machines. Rather, the beam focus is operator dependent and influenced by the desired welding parameters and machine characteristics (Refs. 1–9).

A diagnostic tool for rapidly measuring the power-density distribution of electron beams is currently under development. This technique uses a modified Faraday cup technique and employs a tungsten disk with regularly spaced radial slits (Refs. 8–9) to sample the electron beam. This diagnostic technique captures multiple beam profiles in a fraction of a second as the beam is oscillated in a circular pattern over the tungsten disk. These individual beam profiles are then reconstructed using a computed tomographic method to render an image of the beam shape, size, and power density distribution (Ref. 10). All this data is gathered and processed in less than a minute, making this technique very attractive for potential use in production environments. The speed and ease of use of this diagnostic will eventually provide welding operators with the ability to acquire a permanent quality control record of the beam, to repeat welds on the same machine over a period of time, and to transfer welding parameters between machines and facilities.

This diagnostic technique needs to be robust, reliable, and must provide dependable data with minimal decision-making on the part of the welding operator for acceptance in a production environment. In the previous MFC design, the beam current passing through the slit was sampled using an otherwise conventional Faraday cup (Ref. 8).

Although this technique worked well, the overall design required improvement in several areas. First, since a portion of the beam's current passing into the Faraday cup could be transported out of the cup and back to the tungsten slit as backscattered electrons, this portion of the beam's current would not be properly accounted for by the diagnostic. Second, with repeated use, the electrical contact between the tungsten slit disk and the copper heat sink body could degrade, adding electronic noise to the measured beam profiles. Third, the beam orientation was determined using one slit that was twice as wide as the others, which created an unnecessary error in the wide-slit profile.

Although these sources of errors do not pose serious problems in a research and development environment, they would create unnecessary complications in a production environment. This paper describes enhancements made to the MFC to help minimize these potential sources of error and to make measurements more reliable.

Experimental Procedures

Enhancements to the Modified Faraday Cup

Figure 1 shows a schematic of the MFC diagnostic's original design. This device consists of a copper Faraday cup within an electrically insulating ceramic cup, a tungsten disk containing 17 slits, and a cylindrical copper heat sink that...
holds the tungsten disk above the Faraday cup (Ref. 8).

During operation, the electron beam deflection coils are used to sweep the beam in a circle of known diameter at a constant frequency over the tungsten slit disk. The majority of the beam’s current is intercepted by the tungsten disk and conducted by the copper heat sink to ground. However, when the beam passes over a slit, a portion of the beam current passes through the slit and into the Faraday cup where it can be measured as a voltage drop across a known resistor.

A current vs. time profile is collected using a fast-sampling, analog-to-digital (A/D) converter as the beam passes over each slit. This beam profile information is stored on a personal computer, which later reconstructs the power-density distribution in the beam. The tungsten disk (38-mm diameter and 2.5 mm thick) containing the 17 radially positioned slits was manufactured by electro-discharge machining (EDM) using a 0.1-mm-diameter wire. A 3.0-mm-diameter hole is further machined through the center of the disk, which allows a sharp focused spot beam to pass entirely through the tungsten disk and into the Faraday cup to measure the full beam current.

Incomplete electron capture and signal degradation after repeated use of the MFC were observed while using the original MFC diagnostic, and the following changes were made to the diagnostic to minimize these errors.

Electron capture was improved through several modifications that were made to the MFC hardware, as illustrated in Fig. 2. First, an additional slit disk, made of copper, was added to the top of the internal Faraday cup. This copper slit disk captured the majority of backscattered electrons and prevented them from leaving the Faraday cup.

Second, a beam trap was added inside of the MFC to provide even more containment of the electron beam when the full beam current was measured through the center hole of the MFC. Third, a graphite ring was added below the copper slit disk, and a graphite disk added at the bottom of the beam trap to minimize the amount of backscattered electrons that passed through the slits.

To improve grounding of the tungsten slit disk, a 0.020-in.-diameter tantalum wire was vacuum brazed to the tungsten slit disk then attached to the copper heat sink body. That way, if the copper heat sink became oxidized with repeated use, there would still be a low-resistance electrical path from the tungsten slit disk to ground. In addition, a copper clamp was employed to maintain pressure on the tungsten slit disk for maintaining good electrical and thermal contact with the heat sink body.

The final enhancement was to change the method for determining beam orientation. Previously (Ref. 8), one of the 17 slits in the tungsten disk was made twice as wide as the others to provide a large profile in the captured waveform to indicate the beam’s orientation. In the new design, two adjacent, wide-spaced slits produced one wide temporal gap in the 17-peak waveform for proper orientation of the beam. This allowed all slits to be machined with the same (small) width and reduced the error introduced by the previously used wide slit while still maintaining a method for determining the beam’s orientation.

Data Acquisition and Computed Tomographic Imaging

Data acquisition was performed as before (Ref. 10) using an A/D converter and a personal computer running LabView software (Ref. 11). Data was acquired as a voltage drop across a 210-W resistor.

![Fig. 1 — Cross-sectional illustration of the original MFC diagnostic. Copper Faraday cup (a) is surrounded by an insulating ceramic cup (b). The tungsten slit disk (c) is centered over the Faraday cup and supported by the outer copper heat sink (d). The signal from the Faraday cup is carried through a wire attached to lug (e) and the remainder of the beam’s current is carried directly to ground through a wire attached to lug (f). The interior allows backscattered electrons to exit the Faraday cup through the opening (g) below the slit disk.](image)

![Fig. 2 — Cross-sectional illustration of the enhanced MFC diagnostic. Enhancements include the following: (a) an internal slit disk made of copper; (b) an internal beam trap; (c) graphite beam interceptors; (d) a clamp for the tungsten slit disk; and (e) an integral BNC connector. The ground wire from the tungsten slit disk to the heat sink body is not shown.](image)

![Fig. 3 — A — Comparison of the total beam current measured by the original and enhanced MFCs with the true beam current. B — the percentage error in the measured total beam current for the original and enhanced MFCs.](image)
which was then converted into a digital signal with the A/D converter sampling at 500 kHz. In this study, the electron beam was swept around a 25.4-mm-diameter circle at 30 Hz. The digital waveform containing the 17 consecutive beam profiles was created as the beam passed over the slits and was captured in 35 ms.

CT reconstruction of power distribution in the beam was performed using LabView running a custom-designed CT program on the same personal computer that acquired the data. The beam profile conditioning and tomographic reconstruction algorithm have been previously discussed (Refs. 8–10). This algorithm consists of separating individual beam profiles, normalizing areas under the peaks, filtering this data if necessary, creating a sinogram from the series of profiles. CT reconstructing the power density distribution, and calculating the beam's power density distribution. A 128 x 128 pixel reconstruction of this beam took approximately 10 s to perform and display on a Pentium-based laptop personal computer.

Some modifications were made to the CT algorithm to reconstruct data from the new tungsten slit disk having one wide-spaced set of slits rather than one wide slit as used in the past. In addition, the computer tomography algorithm was modified to account for reconstruction artifacts caused by the small number of beam profiles gathered by the 17-slit tungsten disk. This modification allowed more accurate reconstructions to be performed than before and resulted in higher calculated peak power densities than previously reported.

Results and Discussion

Electron beams were investigated using both original and enhanced MFCs. The total beam current and power-density distribution were measured for electron beams generated by a 150-kV/50-mA Hamilton Standard (HS) welding machine (Serial Number 175) fitted with a ribbon filament and an R-40 gun. Work distance was kept constant at 178 mm from the top of the chamber, and the vacuum level in the chamber was maintained at 1 x 10^-5 torr. Power density distribution measurements were made on 5-mA beams at 140 kV, which is a convenient power level to use since special precautions are not required to prevent melting of the tungsten slit disk.

Enhanced Electron Capture

To demonstrate the improved electron capture of the enhanced MFC, sharp-focused beams were examined to measure the beam current using each MFC design. In this set of experiments, both 60-kV and 140-kV beams were examined for a range of beam currents from 5 to 19 mA. These experiments measured the total beam current as it passed through the center hole of both the original and enhanced MFCs. Results of these measurements are summarized in Table 1 and plotted in Fig. 3A, showing the beam current measured by the enhanced MFC is closer to the true machine value than that measured by the original MFC. These data are further compared in Fig. 3B, where the percentage error in the measured beam current values are plotted. Here, the percentage error is calculated from the difference between the measured value and the value set on the electron beam welding machine, and is the average of the measured values at 60 and 140 kV. This error represents the percent of the true beam current that is not accounted for by the MFC diagnostic. The error is largest for the original MFC.
which varies between 5 and 10% of the total beam current, whereas the enhanced MFC is relatively consistent and shows less than a 1.5% error in the measured beam current.

Even with the enhancements made to the MFC, the beam current is being underestimated by about 1% on average. This underestimation of the beam current is related to the width of the slits in the copper slit disk and the geometry of the beam trap, which allows some backscattered electrons to escape from the cup. Reducing the slit widths of the copper slit disk and the diameter of the hole in the beam trap will further improve electron capture with the enhanced MFC if more precise beam current measurements are required from the MFC diagnostic.

The Effect of Slit Width on the Measured Power Density Distribution

The present version of the CT reconstruction algorithm assumes that the width of the slit is small compared to the diameter of the beam and can therefore be neglected. This assumption is reasonably valid for defocused beams where the ratio of slit width to beam diameter is small. However, for sharp-focused beams where the finite slit width represents a larger fraction of the beam's diameter, the diagnostic will overestimate the beam's diameter and thus underestimate the peak power density of the beam. The amount of error introduced by the finite width of the slit can be calculated for Gaussian distributed beams, which is useful for selecting the appropriate slit width for a given beam.

Since the amount of error in the measured power density distribution depends on both slit width and beam size, simulations were performed using sharp-focused beams to calculate the worst-case scenario (highest error introduced by a given slit) that we expect to measure with the CT diagnostic technique. Furthermore, since the beam size depends on accelerating voltage (Ref. 8) and electron optics, we measured the beam size for different accelerating voltages and on two different welding machines. These data are summarized in Table 2 for sharp-focused, 5-mA beams. Some of this data was previously obtained from Hamilton Standard EB welding machine No. 605 (Ref. 8), showing that the beam on this machine is full width at half maximum (FWHM) at 0.36 mm at 80 kV, and a smaller FWHM of 0.28 mm at 140 kV.

A similar comparison was made in the present investigation using Hamilton Standard welding machine No. 175. Figure 4 shows one result from this study, comparing the tomographic reconstructions of the 60- and 140-kV beams. Here, the sharp-focused beams were measured to have a FWHM of 0.26 and 0.15 mm for the 60- and 140-kV voltages, respectively. For both welding machines, the beam became smaller as the voltage was increased, showing that higher voltage beams focus to smaller spot sizes than lower voltage beams for a given electron beam welding machine. In addition, the comparison between the two welding machines shows that HS welding machine No. 175 focuses to a smaller spot size than HS welding machine 605 at a given beam voltage.

The smallest measured beam size in this study was a 5-mA, 140-kV beam on HS No. 175, which had a CT-reconstructed FWHM of only 0.15 mm. This beam was chosen for the calculations that follow for estimating the maximum error introduced by the finite slit width into the CT reconstructions for these machines. In these calculations, the beam profile measured by the diagnostic is simulated by passing a Gaussian distributed beam over a slit of a given width. The error introduced by the finite width of the slit can then be calculated from the difference between the simulated beam profile and the true beam profile. This simulation assumes the electron beam has a circular Gaussian distribution that most closely represents the sharp-focused beam condition represented by the following equation (Ref. 9):

$$J(x,y) = \frac{1}{2\pi\sigma^2} \exp \left[ -\frac{x^2}{2\sigma^2} + \frac{y^2}{2\sigma^2} \right]$$

where $J(x,y)$ is the current density of the beam, $\sigma$ is the standard deviation of the Gaussian distribution, I is the total beam current, and $x$ and $y$ are rectangular spatial coordinates. For a beam moving in the positive $x$-direction and perpendicular to the slit, the instantaneous current passing through the slit as a function of position, $I_x(x)$, can be calculated. This calculation is performed by integrating the current density distribution given by equation 1 along the $y$ direction for a slit of width $w$ as follows:

$$I_x(x) = \int_{-w/2}^{w/2} \int_{-\infty}^{\infty} J(x,y) dy dx$$

Equation 2 was integrated using MathCad (Ref. 12) for a series of simulated slit widths between 0.01 and 1 mm. This range of slit widths more than spans the range of slit widths used for electron beam tomography, which are typically on the order of 0.1 mm wide (Refs. 8, 9).

Figure 5A compares the results of three simulated beam profiles as the...
Fig. 6 — Calculated error of the FWHM as a function of slit width up to the true FWHM of the beam.

Fig. 7 — A — Illustration of the original slit disk where one slit is machined to be twice as wide (0.2 mm) as the remaining 16 slits, but all slits are equally spaced at 21.18 deg. B — Illustration of the new design where all slits are machined with the same width (0.1 mm), but one set of slits has a wide spacing (24 deg) and the remaining slits are equally spaced at 21 deg. The small hole on the outside of the slit disk is used for alignment purposes, while the hole in the center is used to measure the full beam current.

Fig. 8 — Results of the defocus study for the 140-kV, 5-mA beam. A — Plots of the FWHM for the tomographically reconstructed data (solid circles) and the slit width corrected data (open circles); B — plots of the same for peak power density measurements.

beam passes over slits 0.6, 0.35, and 0.1 mm wide. The 0.15-mm FWHM beam is significantly smaller than the 0.6-mm-wide slit, therefore, the entire beam passes through this slit for a period of time, creating a flat-topped shape to the beam profile. This slit is clearly too wide to be used for tomography since it would average out any beam inhomogeneities that exist.

The slit current as measured by the 0.35-mm-wide slit is Gaussian shaped and nearly reaches the full beam current when the beam is centered over the slit. As will be shown later, the 0.35-mm slit would overestimate the measured FWHM of this beam by a significant amount, and is therefore considered to be too wide for CT reconstruction.

The slit current, as measured by the 0.1-mm-wide slit, is also Gaussian shaped, but allows a much lower percentage of the beam to pass through the slit. This is the preferred slit width for tomography, because it allows the beam's shape to be measured with higher precision. Although smaller slit widths would provide an even more precise measurement of the beam shape in theory, practical considerations created by the high aspect ratio of these slits (tungsten thickness slit-width), the reduced slit current, and fabrication considerations make slits smaller than 0.1 mm difficult to work with.

The beam profiles shown in Fig. 5A contain significantly different areas because wider slits allow more electrons to pass through. So, these raw beam profiles need to be normalized to account for their different areas and for comparisons to be made. This type of normalization is also required in the CT reconstruction program due to inherent variations in slit widths (Refs. 8-10). Figure 5B shows what these normalized beam profiles look like after being divided by their respective areas so all contain the same unit area.

It is clear from the results shown in Fig. 5B that the FWHM of the normalized beam profiles increase as the width of the slit increases, and the widest slit would result in the lowest peak power density measurement for a given beam. Since the amount of error in the measured beam depends not only on the slit width but also on the beam size, it is important to understand how the percentage error in the measured FWHM of the beam varies as a function of both parameters.

In the calculations that follow, the error in the FWHM measurement was determined for Gaussian-shaped beams.
Simulations of beam profiles were made for a 0.15-mm FWHM beam using different slit widths up to the FWHM of the beam, i.e., for 0 < R < 1. Figure 6 plots these results, showing a nonlinear increase in the error as R increases. The error in the measured FWHM of the beam can be quite large, exceeding 20% as the slit width approaches the FWHM of the beam, but drops off to values less than 5% for R < 0.33. These data were fit to a second order polynomial to determine a predictive relationship between R and the percentage error in the FWHM measurement, E_{FWHM}, as follows:

$$E_{FWHM} = 0.132 + 0.0061R + 25.2R^2$$

where the variables \(E_{FWHM} \) and R are defined as:

$$E_{FWHM} = 100 \left( FWHM_{measured} - FWHM_{true} \right)/FWHM_{true}$$

$$R = \text{slit width}/FWHM_{true}$$

Using these relationships, the percentage error introduced by tungsten slits of 0.1 and 0.2 mm were calculated for different beams. These slits represent the two different sizes used in the original tungsten slit disk design whereby 16 small slits (0.1 mm) and one large slit (0.2 mm) were used for beam orientation purposes. Four different beam sizes were investigated as well, representing two different accelerating voltages on HS Nos. 175 and 605 welding machines.

Table 3 summarizes the results of these calculations. In this table, the measured FWHM data are the FWHM values as experimentally determined from the CT reconstruction of the beam, while the true FWHM data are those required to produce the CT-reconstructed value for a given slit width.

The true FWHM value was back-calculated using an iterative procedure from the tomographically reconstructed (measured) FWHM of the beam, the slit width, and Equations 3–5. The error in the FWHM measurement represents the percentage that the CT reconstruction overestimates the true FWHM of the beam, as calculated from the difference between the true and measured FWHM values.

These results show the 0.1-mm-wide slit produces errors between 3.58 and 14.9%, while the double-wide slit produces significantly higher errors, between 18.0 and 102% in the FWHM of these different beams. It is clear the amount of error introduced into the FWHM measurement by the 0.2-mm-wide slit is excessive for small-diameter beams. Furthermore, the fact that not all the slits in the tungsten slit disk are the same size makes it difficult to properly compensate for the effect of slit width on the CT-reconstructed beam. Because of this potential error, we investigated a new method for orienting the beam using 17 small, uniform slit widths that would allow the amount of error in the CT reconstruction to be more accurately predicted.

### Determining Beam Orientation Using Equal Width Slits

The original 17 slit tungsten disk design is illustrated in Fig. 7A. In this design, the slits are equally spaced at 21.18 deg, giving an equivalent spacing of 10.59 deg per beam profile in the reconstructed beam (Ref. 8). The beam orientation is determined using one wide slit (0.2 mm) (Ref. 8), which can produce a large error in the beam profile as discussed above.

The new tungsten slit disk design is illustrated in Fig. 7B. In this design, all of the slits are machined with the same width (0.1 mm) to reduce the amount of error introduced into the CT reconstruction, and the beam orientation is determined with one wide-spaced set of slits.

The spacing of the wide slit was chosen to be as small as possible to keep the overall spacing of the remaining slits as regular as possible. Here, we chose 24 deg for the wide-spaced slit, which produced enough of a temporal gap in the acquired data waveform for the sharp-focused and defocused beams investigated in this study to be characterized.

The remainder of the slits were equally spaced at 21 deg. This nonregular slit spacing required only minor changes to be made to the CT algorithm for reconstructing the beam. Since this disk also contained 17 slits, the CT reconstruction was performed with the same average angular resolution as that of the original slit disk design.

Using the new tungsten slit disk design, a 140-kV, 5-mA beam was investigated through a range of focus settings of ±0.040 A. This beam was shown to have a measured FWHM of 0.148 mm at sharp focus, which corresponds to a corrected true FWHM value of 0.128 mm. Waveform analysis of raw data was performed in preparation of tomographic reconstruction and showed the wide angle was able to be distinguished in the 17-slit waveform for both sharp-focused and defocused beams (±0.040 A).
Table 4 — Summary of Properties for a 140 kV, 5 mA Electron Beam on HS No. 175 Welding Machine as a Function of Defocus

<table>
<thead>
<tr>
<th>Focus Setting (A)</th>
<th>Relative Focus (mA)</th>
<th>Measured FWHM (mm)</th>
<th>Measured FWe2 (mm)</th>
<th>Measured PPD (kW/mm²)</th>
<th>True FWHM (mm)</th>
<th>Corrected PPD (kW/mm²)</th>
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Note: The true FWHM and corrected peak power density (PPD) for each condition are derived from the measured values and slit width of 0.1 mm.

wide angle was capable of being identified and the data was capable of being tomographically reconstructed, while at the same time retaining the orientation of the beam.

The results of the defocus study are summarized in Table 4 for the 25 different focus settings. In this table, the measured FWHM, measured FWe2, and measured PPD data refer to the data as tomographically reconstructed prior to correction of the finite width of the slit.

The results of the defocus study are plotted in Fig. 8A (FWHM) and 8B (peak power density). Two sets of data are presented in each figure. The solid circles represent tomographically reconstructed beam parameters, while the open circles represent the same data after correction of errors introduced by the finite width of the slit.

Looking first at the uncorrected FWHM data in Fig. 8A (solid circles), the FWHM values reach a minimum value of 0.148 mm at the 0.568-A setting where the highest peak power density is achieved. As the beam is defocused, the FWHM increases to values as high as 1.0 mm at the 0.530-A focus setting (-0.038-A defocus).

Conclusions

1) An enhanced MFC was designed and used to measure total beam current and power density distribution for high-power electron beams used in welding.

2) The enhanced MFC demonstrated improved electron capture over the original MFC and resulted in capturing, on average, 99% of the electron beam.

3) A new method for orienting the electron beam was developed using one set of wide-spaced slits rather than the
one wide slit used in the past. This new method for beam orientation allowed all the slits to be machined with the same (small) slit width of 0.8 mm, which eliminated the large error caused by the double-wide slit used in the past.

4) Calculations were performed to simulate beam profiles as measured by slits of various widths. Results showed slit widths of 0.1 mm overestimated the measured FWHM values by amounts up to 15% for small-diameter, sharp-focused beams. This FWHM error corresponds to an underestimation of the peak power density by 33% for these same beams. The errors drop off quickly for larger-diameter beams.

5) A method was developed to compensate for beam size error introduced by the finite width of the slits. This method assumes the beam has a Gaussian distribution, which is a reasonable assumption for sharp-focused beams. Corrections were made to the CT reconstructions of a 140-kV, 5 mA beam through a wide range of defocus settings. These corrections are particularly important when the ratio of the slit width to the true FWHM value of the beam, R, is larger than 0.4, where the error in FWHM is greater than 5% and the error in the peak power density is greater than 10% of its true value before performing the correction.

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1. Platform:
   Macintosh or PC accepted

2. Files accepted:
   QuarkXpress, Adobe Photoshop, Adobe Illustrator, Tiff or EPS files only.

3. Color:
   Send all files in CMYK mode, RGB files must be converted.

4. Images:
   Minimum resolution required for magazine printing is
   266 dpi for full color artwork or grayscale
   At least 1000 dpi for Bitmap (B&W/Line Art)
   Images and logos from Web sites are NOT usable for printing. They are low resolution
   images (72 dpi).
   Images taken with a digital camera are not acceptable unless they meet the
   minimum 266 dpi requirement.

Proof:
A proof of the images should always be provided.

Electronic File Transfer:
Files larger than 68k are not acceptable as an email attachment; please use a zip disk.

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Check list for submitting electronic files:

<table>
<thead>
<tr>
<th>Colors:</th>
<th>4/C</th>
<th>Grayscale</th>
<th>B&amp;W/Line art</th>
</tr>
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<tbody>
<tr>
<td>File Type:</td>
<td>TIFF</td>
<td>EPS</td>
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<tr>
<td>File sent via:</td>
<td>Floppy Disk</td>
<td>Zip Disk</td>
<td>Jaz Disk</td>
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<td>□ Proof supplied/faxed</td>
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<tr>
<td>□ CMYK images at 266 dpi or higher, B&amp;W/Line art at 1000 dpi or higher.</td>
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<tr>
<td>□ All color in all images set to CMYK process (not RGB)</td>
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</tbody>
</table>
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