Welding Stainless without Backing Gas

Answers to Your Welding Questions

Eye and Neck Safeguards in the Welding Workplace
"THE GOLD MEDALISTS"

There are four good reasons why KOBELCO can produce Gold Medalist Flux-cored wires.

1. Kobelco’s most advanced manufacturing facility enables us to produce high quality wires spool after spool.

2. Kobelco has highly reliable production management system and quality assurance system which is sometimes called “Kobelco Standard” by major heavy industries.

3. Kobelco Flux-cored wire know-how’s were developed based on 100% CO₂ shielding gas market. Accordingly, you can get super results when used in Ar-CO₂ mix shielding gas in terms of less spatter and low fume levels.

4. Kobelco has the largest Research and Development Organization that enables us to create a product just right for specific demands.

Our Gold Medalists

**DW Stainless Series (for all major stainless alloys)**

Our DW Stainless Flux-cored wire series are the Best Selling Stainless FCW in the United States. KOBELCO DW Stainless Flux-cored wires have excellent low fume level, less spattering, arc stability, slag removal, wetting and bead appearance. KOBELCO DW Stainless Flux-cored wires are the benchmark for stainless FCW.

**DW-50 (AWS E71T-1/1M)**

DW-50 is an All Position Flux-cored wire with fast-freeze formulation. DW-50 has the Lowest Fume Level compared to other brands and has excellent weldability not only in flat and horizontal position but in vertical and overhead welding as well.

**Frontiarc-711 (AWS E71T-1/1M, 12/12M)**

Frontiarc-711 is an All Position Flux-cored wire with medium-freeze formulation. Because of its Stable Arc and Fluid Nature, Frontiarc-711 is excellent for long, continuous welds that demand consistency. Fluid Weld Puddle allows Frontiarc-711 to be more forgiving when welding through mill scale or rust.

**MXA-70C6 (AWS E70C-6M)**

MXA-70C6 is a highly efficient Metal-cored wire for carbon steel. MXA-70C6 has an Excellent Wide Range Spray Transfer which eliminates much of the spatter generation.

KOBELCO WELDING OF AMERICA INC.

Corporate Office-Houston
Building B, 4755 Alpine, Suite 250, Stafford, Texas 77477
Tel: 281-240-5600 Fax: 281-240-5625
Distribution Centers: Houston/Cincinnati/Salt Lake City

Sales Office-Chicago
543 W. Algonquin Rd., Suite 201, Arlington Heights (Chicago) Illinois 60005
Tel: 847.439.8450 Fax: 847.439.8455
URL: www.kobelcowelding.com
Powered and Supplied Air Respiratory Solutions For Industrial, Safety and Welding

The Most Auto-Darkening Helmets To Choose From

Toll Free: (800) 223-4685  •  Fax: (508) 884-9666  •  Website: arc1weldsafe.com
When you make the world's best MIG wire, you can back it with the world's best guarantee.

SUPERARC AND SUPERGLIDE
MIGuarantee
100% SATISFACTION

Lincoln Electric's 100% Satisfaction MIG Guarantee.
The best reason yet to switch to the best MIG wire in the world.

www.lincolnelectric.com/superarc
22801 St. Clair Avenue • Cleveland Ohio 44117 • 216.481.8100
Features

25  The AWS Welding Show — Gaining Momentum
The Welding Show has a lot to offer and AWS makes it easy to get there
A. Cullison

28  Knowing the Dangers of Actinic Ultraviolet Emissions
When there are lines of sight to open arcs, a potential hazard exists that may be undetected
T. L. Lyon

32  Welding Stainless Steel Piping with No Backing Gas
Elimination of the traditional backing gas in the fabrication of stainless steel pipe reduced manufacturing costs for Fluor Corp.
B. Messer et al.

36  Tips for Avoiding Neck Pain
Welders can alleviate the stresses placed on their necks by knowing the causes and treatment for the condition
J. W. Western et al.

40  Welding FAQs
Here are the answers to some frequently asked questions about welding
D. K. Miller et al.

Welding Research Supplement

265-S Determination of Gradients in Mechanical Properties of 2.25Cr-1Mo Weldments Using Shear-Punch Tests
Individual microstructural regions in the heat-affected zone were more accurately identified with a new test technique
V. Karthik et al.

273-S Numerical Simulation of Sleeve Repair Welding of In-Service Gas Pipelines
Flow rate effect on HAZ hardness, risk of melt through, residual stress and plastic strain distribution were all evaluated in developing a model to predict in-service repair of pipelines
I.-W. Bang et al.

283-S Weld Morphology and Thermal Modeling in Dual-Beam Laser Welding
A mathematical model helps to define the heat flow patterns with dual-beam laser welding
J. Xie

291-S Chloride Contributions in Flux-Assisted GTA Welding of Magnesium Alloys
A variety of chloride fluxes were tested to ascertain their influence on arc voltage, arc temperature, and joint penetration
M. Marya et al.
Lincoln Electric to Acquire Hyundai Welding

Lincoln Electric Holdings, Inc., Cleveland, Ohio, recently signed an agreement to acquire Hyundai Welding Ltd. for approximately $143 million. Hyundai Welding is South Korea’s leading welding consumables manufacturer and a major supplier to other Asian markets.

Hyundai Welding is headquartered in Seoul and has manufacturing facilities in Pohang, South Korea, plus sales and service subsidiaries throughout Asia. It was founded in 1975 and has approximately 550 employees. Sales in 2002 are expected to be about $130 million.

“I am very excited about this opportunity to increase our footprint in Asia,” said Anthony A. Massaro, Lincoln Electric’s chairman and chief executive officer. “The acquisition of Hyundai Welding will further strengthen our already strong market position in the very important and growing Asian market and will further increase shareholder value. Hyundai Welding Chairman M. S. Chung has built the company into the leading consumables producer in Korea and has established a strong market position in other countries in the region. The company has product approvals from all of the world’s major technical and quality agencies and focuses on high value-added welding products.”

Eclipse Aviation Breaks Ground for Friction Stir Welding Center

Eclipse Aviation Corp., Albuquerque, N.Mex., recently started construction of a facility to house its friction stir welding operations. The company is the first to use the process in the assembly of thin-gauge aircraft aluminum and will replace rivets in more than 60% of the Eclipse 500, a six-person, twin-engine jet.

The 50,000-square-foot facility will house the company’s friction stir welding equipment, which is used to assemble most parts of the fuselage for the Eclipse 500 jet. The facility will be sufficient to support friction stir welding of the company’s planned rate of up to 1500 aircraft per year.

The plant is scheduled for completion in spring 2003. It is being constructed in the Broadway Industrial Center located in Albuquerque’s southwest side.

“We are pleased to make yet another step toward delivering the Eclipse 500 jet in production volumes,” said Vern Rathurn, president and CEO of Eclipse Aviation.

In May, the company received FAA approval of the friction stir welding process specification. The process specification approval, along with receipt of the Eclipse 500 type certificate, will allow the company to build production aircraft using friction stir welding.

Northrop Grumman to Provide Engineering-Related Scholarships to Maryland Students

Officials of Northrop Grumman Corp.’s Electronics Systems sector recently announced plans to award a total of $240,000 in college scholarships next year to high school students across Maryland. The awarding of the scholarships will be the first of what is planned as an annual event.

“This new scholarship program is intended to support promising high school seniors statewide who intend to pursue a career in an engineering-related field,” said Robert P. Iorizzo, president of Northrop Grumman’s Electronic Systems sector. “High-technology companies across the state, including Northrop Grumman, continue to face a critical shortage of specialized engineering personnel we need for our businesses. Through this scholarship effort, we hope to motivate some of the state’s brightest and best students — with a background and interest in math and science — to consider the engineering professions.”

Individual scholarships of $10,000 will be awarded to a qualified graduating high school senior in each of Maryland’s 23 counties and in the city of Baltimore. Candidates must plan to attend an accredited college or university as a full-time student in an approved engineering program. The funds can be used for tuition, books, lodging, and meals.

More information about the program is available by writing to Northrop Grumman Engineering Scholars at esengscholars@northropgrumman.com.
No flakes!

Copper coating on weld wire can flake and clog gun liners and tips. Flakes cause reduced arc time due to feedability problems that increase cleaning and repairs, elevate consumables costs and reduce tip and liner life.

**N-S CopperFree® wire runs better — no flakes.**

N-S CopperFree® carbon steel wire has no copper coating (and no flakes) so you get more productive welding time. A unique lubricant coating reduces N-S CopperFree® wire’s feed force by up to 75% compared to copper-coated wire. That superior feedability increases arc time and operator control. You get more welds, and more consistent welds. And no flakes.

N-S CopperFree® wire resists rust and oxidation as well as copper-coated wires, but having no copper coating it minimizes toxic copper fumes.

See for yourself. Get a FREE spool of N-S CopperFree® wire.

Try N-S CopperFree® carbon steel wire to see its great feedability, without copper flaking. Call your National Standard Distributor to arrange a free, no obligation demonstration on your own equipment. You have nothing to lose but your flakes.

Welding wire to robotic standards

**National-Standard**

Welding Products Division
Niles, Michigan
Ph: 800-777-1618 Fax: 269-683_9276
www.nationalstandard.com

Circle No. 34 on Reader Info-Card
OSHA Guidelines Address Ergonomics

The U.S. Occupational Safety and Health Administration (OSHA) is continuing its effort to address ergonomics issues without actually issuing regulations. The development of industry-specific “guidelines” are among its most recent efforts. These guidelines are to be the result of extensive and cooperative processes involving a review of both scientific information and existing ergonomic practices and programs in the industries addressed. Importantly, OSHA also plans to meet with major stakeholder groups to gather information on best practices successfully used in each industry to ensure practical solutions that will work in the real world. The guidelines will have no enforcement effect.

The first industries to be addressed will be nursing homes, retail grocery, and poultry processing.

OMB Pursues Regulatory Reform

The current Office of Management and Budget (OMB) is proving to be the most aggressive ever in combating what it views as overly burdensome or unjustified federal agency regulations. The OMB has the authority to review all regulations prior to finalization. While every president since at least 1980 has used the OMB in this manner, those leading the agency currently have implemented two significant changes. First, OMB has elevated the use of monetized cost-benefit analysis to justify every regulation. Second, OMB has started to become involved in the regulatory process at the beginning rather than only after the particular agency has finished its work.

Since January 2001, OMB has rejected 17 standards, more than were rejected during the entire eight years of the previous administration. OMB has also compelled federal agencies to modify more than one-half of all other rules issued over the past 20 months.

Executive Order Seeks to Streamline Environmental Reviews

President Bush has issued an executive order that directs federal agencies to speed environmental reviews for major transportation projects. As part of this effort, the Department of Transportation is to designate “high priority” projects “that should receive expedited agency review,” and an interagency task force is to, among other things, “identify and promote policies that can effectively streamline the process required to provide approvals for transportation infrastructure projects, in compliance with applicable law, while maintaining safety, public health, and environmental protection.”

Congress’s Report Card Reviewed

The 107th Congress is receiving fair grades for its accomplishments over the past 2 years. Major legislation that has been passed include the 2001 tax cut ($1.35 trillion over 10 years); expansion of the president’s trade authority; groundbreaking campaign finance revisions; landmark education reform; corporate accountability legislation in response to the Enron and other corporate scandals; and, most recently, the Iraqi war resolution. Still, there are other bills the 107th Congress was unable to translate into new legislation, including the once-ambitious energy legislation, patient bill of rights and prescription drug benefits, pension reform, bankruptcy reform, and authorization of a Department of Homeland Security.

Of course, the 107th Congress was destined to be unique when Senator Jim Jeffords of Vermont changed from Republican to Independent, thereby giving control of the Senate to the Democrats. Just three months later came the September 11 terrorist attacks.

Study Examines ‘Quiet Crisis’ in Engineering and Science

In a report to the U.S. Congress, a nonpartisan think tank concludes there is a “quiet crisis” building in the United States stemming from the gap between the nation’s growing need for scientists, engineers, and other technically talented workers and its production of them, particularly from traditionally underrepresented constituencies. Among other recommendations, the report advocates professional societies, foundations, and other nonprofit groups work to “project a more positive public image of science, engineering, and technology” and “mobilize at the grassroots level to encourage diversity. Currently, women, African-Americans, Hispanics, Native Americans, and persons with disabilities collectively comprise two-thirds of the overall U.S. workforce but hold only about one-fourth of the technical jobs.

The report was conducted and prepared by Building Engineering and Science Talent (BEST), a public-private partnership dedicated to building a stronger, more diverse U.S. workforce in science, engineering, and technology by increasing the participation of underrepresented groups. BEST is a follow-on to the recommendations of the Congressional Commission on the Advancement of Women and Minorities in Science, Engineering, and Technology Development. A copy of The Quiet Crisis May be obtained from the Web site www.bestworkforce.org.

Contact the AWS Washington Government Affairs Office at 1747 Pennsylvania Ave. NW, Washington, DC 20006; e-mail hwwebster@wc-b.com; FAX (202) 835-0243.
Tools that make you More

Efficient.

Metabo tools are the professional’s first choice. Because he knows that workmanship, design, quality components and the finest engineering pay off. Ask people who have made that choice. They’ll tell you why.

Metabo power tools are individually assembled by hand. Metabo tools last longer, outperform other tools, feel better in your hand, reduce fatigue, and, in short, get the job done better. And even though they cost more, they make you more.

- Longer service life
- Ergonomic design increases productivity
- Heavy-duty components increase efficiency
- Larger gauge power assemblies increase power to the motor
- Outstanding power-to-weight ratios

When you have a choice, make it Metabo…and make more.

Circle No. 31 on Reader Info-Card

metabo

More than worth it.

1231 Wilson Drive, West Chester, PA 19380
800-638-2264  Fax: 800-638-2261
info@metabousa.com
www.metabousa.com
Cohabitation in ISO Standards

In regard to international welding standards (ISO TC44), there have been long hard discussions over the two main systems for filler metal classification — the CEN system, preferred in Europe, and the AWS-like system used in countries bordering or near the Pacific Ocean. Every approach to ISO standards for welding filler metals was based on one or the other of the two systems, without acceptance from the other side.

Then, in September 1998, the Japanese delegation to ISO TC44 proposed "cohabitation" as a means of breaking the logjam. In other words, they suggested a way for the two systems to "live together." The idea was to provide two parallel paths through the classification standard, one based on CEN standards and one based on standards around the Pacific Rim. Common elements were to be treated commonly. The user could then immediately see the similarities and differences between classification in the two systems. And, in many cases, a product could be classified in both systems, so the product could become more standard than the paper standard.

In February of this year, the cohabitation idea came to fruition with the publication of the ISO 14343 standard for bare stainless steel welding wires. One side of this standard is based on EN 12072 and the other side on AWS A5.9 and JIS Z 3321. In this new standard, it can easily be seen, for example, that a 19.9 L wire and a 308L wire are pretty much the same product. A number of other cohabitation standards for welding filler metals are advancing toward publication by ISO.

Publication of the ISO standard is not the ultimate goal. Instead, it is adoption of the ISO standard as the national standard of numerous countries. AWS has been criticized in ISO TC44 for many years, with some justification, because it has not adopted a single ISO welding standard as a national standard. That is about to change. The AWS Technical Activities Committee (TAC) has adopted a policy, endorsed by the International Standards Activities Committee (ISAC) and Standards Council and approved by the AWS Board of Directors, as follows:

Principle

"TAC supports adoption of ISO Standards for welding as replacements for corresponding existing AWS and ANSI Standards provided the AWS Technical Committee responsible for the item of standardization finds the ISO Standard, with Annexes if necessary, suitable for industry in the USA. If no corresponding AWS/ANSI Standard currently exists, TAC supports adoption of suitable ISO standards as new AWS and ANSI Standards."

Implementation

"1) AWS Technical Committee members, acting through the relevant U.S. TAG (Technical Advisory Group) to ISO TC44, an ISO TC44 Subcommittee, or other Working Unit producing ISO Standards, should be active in developing ISO Standards that are compatible with U.S. industry.

2) Once a Technical Committee member identifies an ISO Standard as possibly suitable for U.S. industry, the Technical Committee member should bring this to the attention of the relevant AWS Technical Committee, along with a recommendation as to whether the ISO Standard is suitable for U.S. industry: A) As published; B) With addition of appropriate Mandatory (Normative) and/or Nonmandatory (Informative) Annex(es). A Normative Annex might be used to include filler metal dimensions in U.S. Customary Units, for example, or to include material compositions that are significant in the U.S. market but not included in the ISO Standard. An Informative Annex might be used to include, for example, application information absent from the ISO Standard.

3) If the Technical Committee determines that the ISO Standard is suitable for U.S. industry, the Technical Committee should advance the ISO Standard with an appropriate Normative and/or Informative Annex(es), through the normal route to becoming an AWS and ANSI Standard. If the ISO Standard is to replace an existing AWS Standard, the resulting AWS Standard should, if at all possible, carry the same AWS Standard Number as the AWS Standard that was replaced.

4) If the Technical Committee determines the ISO Standard is not suitable for U.S. industry, the Technical Committee should feed back, through the U.S. TAG, information to ISO concerning what would be required to make the ISO Standard acceptable to U.S. industry."

The Europeans are waiting now to see what we in AWS will do. If we can adopt ISO standards as our own, there will be impetus for them to adopt the ISO standards as their own. If that happens, there will be a universal system of welding standards, which will be good for global trade. The above policy says we are going to do it. It's time to get to work.

Damian J. Kotecki
AWS Vice President
Since 1969, Genstar Technologies has been a world leader in offering the most extensive line of high quality welding, cutting and brazing equipment, pneumatic apparatus, and accessories.

**GENTEC PRODUCTS OFFER**

**THE BEST VALUE IN THE BUSINESS:**

- **Economically Priced**
- **High Quality**
- **Best Warranty in the Industry**

>> Two Year Overlay the Counter Warranty

GENTEC Gas Welding and Cutting Apparatus:

- Gas Welding and Cutting Apparatus
- ISO 9001 CERTIFIED 150,000 SQUARE FOOT MANUFACTURING FACILITY

**BROAD PRODUCT SELECTION:**

- Welding, Cutting and Heating Apparatus
- Brazing and Soldering Apparatus
- Compressed Gas Regulators
- Compressed Gas Flowmeter Regulators
- E-Z-Arc Welding System
- HVAC/R and Plumbing Products
- Welding Accessories
- Safety Products

For a list of wholesalers in your area, please contact us or visit our website.

Circle No. 24 on Reader Info-Card

Genstar Technologies Company, Inc.
4925 Enino Avenue • Chino, CA 91710
Phone (909) 886-2720 • Fax (909) 886-0488
www.genstarTech.com
The difference between one power source and another can be huge. Especially when good enough is not enough. Consider inverters. Only Miller's inverter technology leads the industry in rugged reliability. Pays for itself in power savings. And delivers the superior arc quality guys like Steve bet their reputation on. To learn how any of Miller's advanced welding systems can keep you going strong, visit MillerWelds.com/savings. Call 1-800-4-A-MILLER. Contact your local Miller distributor. And never look back.
The Connecticut Quality Improvement Award — the first and oldest statewide quality award presented in the United States — recognizes Connecticut manufacturing and service companies that excel in managing quality improvement for business success and growth.

**Underwriters Laboratory Issues Canadian Listing Mark to Sellstrom**

Underwriters Laboratories Inc. (UL) recently issued its first Canadian Listing Mark (C-UL) for personal protective equipment to Sellstrom Mfg. Co., Palatine, Ill., for its eye safety wear, goggles, face shields, and welding helmets.

The C-UL mark enables manufacturers to sell products more easily in Canada. The products carrying the mark have been evaluated to Canadian safety requirements, which may be somewhat different from U.S. safety requirements.

For more information regarding UL's personal protective equipment category, contact John Zeng at (630) 942-1069 or at John.E.Zeng@us.ul.com.

**Berry Radiateurs Begins Production Using CuproBraze Process**

Berry Radiateurs of France recently adopted use of the CuproBraze® process and invested in a three-chamber semicontinuous brazing furnace, a header slurry application machine, a fin-tip paste application machine, and a high-frequency tube welding machine. The high-frequency machine uses rapidly alternating electromagnetic fields to induce resistance heating in the parts to be welded.

The company supplies cooling systems to many small- and
midsize original equipment manufacturers for use in applications such as agriculture, trucks, public works, and industrial motors. It produces about 25,000 radiators and 20,000 radiator cores per year in brass/copper, mechanically assembled aluminum, and brazed aluminum.

The International Copper Association, Ltd., developed the CuproBraze process. With its new equipment, Berry has demonstrated a production capacity of about 250 cooling systems per week in one shift, depending on the radiator sizes. It has become one of the first manufacturers of CuproBraze products in volume.

Ford and Alcan Launch ‘Closed Loop’ System for Recycling Aluminum Sheet

Ford Motor Co. and Alcan Inc. recently launched the first “closed loop” recycling program in North America for aluminum sheet scrap. Under the new program, Ford recovers aluminum scrap from its Chicago stamping plant and returns it to Alcan for recycling directly back into autobody sheet. Previously, the recovered aluminum was sold into the general scrap market in combination with other metals, which diminished its quality and value and made it unsuitable for reuse in autobody applications.

The scrap is generated during the stamping of aluminum hoods for the Ford Explorer, Lincoln Town Car, and the F-150 and Ranger pickup trucks. The Chicago plant is the company’s highest-volume user of aluminum sheet metal. Nearly 1.3 million hoods are stamped at the plant annually, generating about 13 million pounds of process scrap to recycle.

Key to the success of the program is segregating the AA6111 scrap from steel and related byproducts generated in the plant. Ford invested nearly $400,000 in modifications to the existing separation system to produce “clean” aluminum scrap.

BUG-GY-VERT
An automated fillet welder that can climb a vertical plate.
• Lightweight and portable.
• Trackless, magnetic welding travel carriage.
• Produces continuous non-stop welding.
• Can perform vertical, horizontal and downhand welds.
• Cordless, rechargeable battery operated.
• Four wheel drive provides constant precise travel speed.
• Available with or without torch oscillation.
• Works with any handheld MIG torch.
For more information on the BUG-GY-VERT call: 800-245-3186 extension 55
Welding and Cutting Automation Since 1948.

3001 West Carson Street
Pittsburgh, PA USA 15204-1899
Phone: 1-412-331-1776 • Fax: 1-412-331-0383
http://www.bugo.com
Praxair Begins Building New Filling Plant

Praxair Distribution, Inc., recently broke ground on a 34,000-sq-ft plant in Pittsburg, Calif., that, when completed, will employ approximately 50 people and perform automated filling of cylinders across a broad range of products. Shown from left are Tom Albert, CSB construction superintendent; James Baughman, general manager for Praxair Distribution’s Central California division; Wayne Yakich, president of Praxair Distribution; Michael Green, president of CSB Construction; and Morgan Ellison, Praxair construction manager.

Industry Notes

Pratt & Whitney recently opened a special technology coatings operation at the U.S. Air Force Air Logistics Command in Oklahoma City, Okla. The coating area will occupy about 11,000 sq ft and operations will include application of special technology coatings for aircraft and engine components. The first products will be heat shields for the F117 weapon system; work on F119 engine components will begin in the second quarter of 2003.

The Greenbrier Companies, Lake Oswego, Oreg., recently announced it has received orders for 4300 railcars valued at $230 million since May 31. The orders pushed the company’s backlog at September 20, to 5600 railcars, the highest level in two years. The orders are principally for the North American marketplace. The company’s president and CEO Bill Furman cited stronger railroad traffic and improved economic prospects for railroads, especially in intermodal double-stack markets.

Do You Have Some News to Tell Us?

If you have a news item that might interest the readers of the Welding Journal, send it to the following address: Welding Journal Dept. Attn: Mary Ruth Johnsen 550 NW LeJeune Rd. Miami, FL 33126.
Items can also be sent via FAX to (305) 443-7404 or by e-mail to mjohnson@aus.org.

Get the gas that sets the GOLD STANDARD in welding performance.

A contaminated welding environment slows production and increases rejects and downtime, ultimately costing you money. Airgas Gold Gas® premium shielding gases enhance weld atmosphere, performance and efficiency. Our welding process experts will help you determine which of our seven industry-leading mixes best fits your needs.

Airgas Gold Gas mixtures improve efficiency by:

- Increasing weld speed—compared to “C25” and “C10”
- Reducing costs incurred from rejects and downtime
- Delivering uniformity, precision and high weld quality (low spatter, less overweld)
- Helping you comply with OSHA emission standards

For more information visit our website: www.airgas.com

Circle No. 3 on Reader Info-Card
Fiber System Provides Back Reflection Protection

The company's Luminator fiber-optic system for lasers protects fibers from possible damage caused by back reflection during high-power welding of highly reflective materials such as copper and aluminum. The system's patented terminations, closed-loop feedback, flexible design, and decrease in required maintenance provide users with a reduction in cost of ownership. The system is now standard on all new industrial welding products from the company. Retrofit kits are available for systems currently in the field.

GSI Lumonic Inc.
22300 Haggerty Rd., Northville, MI 48167

Products Offer Welders Greater Personal Protection

The company's Adflo® powered air-purifying respirator creates an atmosphere of filtered air within the helmet that is 25 times cleaner than the air outside. The respirator's design has a stackable filter configuration that allows for the addition of cartridges that protect against organic, sulfur dioxide, chlorine, and hydrogen chloride fume vapors. Its all-in-one design eliminates external batteries and battery cables and electronics provide a nominal minimum airflow of more than 6 ft³/min at all times. Complete systems are available with one of five different auto-darkening welding filters.

The company also offers helmet accessories for users of its Speedglas® 9000 autodarkening welding helmet. A leather
sweatband, a direct replacement for the plastic sweatband, can be snapped in place on the helmet's adjustable headband. A head protector is made from flame- and spark-resistant Endura® material. It attaches to the top of the helmet via two elastic loops and a Velcro® strip. A throat and side protector, a set of three leather pieces, extends the helmet's protection along the sides and bottom of the welder's neck. The three pieces can be attached or removed, as desired. A throat protector has a bib-like design to extend spark protection along the entire front of the welder's throat and upper chest.

Gas Autoswitch Monitors Supply, Provides Readout, and Guards Safety

The 626 AutoSwitch series of gas distribution systems are designed to safely deliver a continuous supply of laser gases used typically in industrial CO₂ lasers. The systems automatically change cylinder or bank priority from primary to reserve supply without transmitting pressure fluctuations to the use line, offering reliability and precise system control. Pressure switches alert remote locations of the need to replace depleted cylinders. Computer monitoring and recordkeeping provide digital readout of inlet/delivery pressure and consumption.

CONCOA
1501 Harpers Rd., Virginia Beach, VA 23454

Half Facepiece Respirator Is Reusable

The company's 7500 series reusable respirators have a Cool Flow™ exhalation valve that makes breathing easier and...
helps reduce heat and moisture buildup in the facepiece. Advanced silicone material is part of a soft-seal design. Combined with a unique dual-mode head harness, the respirator helps reduce tension and pressure points on the face. Respirators are available in three color-coded sizes for easy identification.

3M Occupational Health & Environmental Safety 104
3M Center Bldg. 235-02-W-70, St. Paul, MN 55144-1000

Pigskin Gloves Offer Optimum Heat Protection

Model 42 top-grain pigskin GMAW gloves work in wet and oily conditions and have a foam-lined back and unlined palm, giving the welder increased heat protection while still allowing for maximum feel and dexterity. The gloves also feature thumb strap reinforcement, Kevlar™ stitching for greater strength, and a straight thumb for better gripping of GMAW guns. Product is available in medium and large sizes.

John Tillman Co. 105
2555 S. Dominguez Hills Dr., Compton, CA 90220

Reels Feature Rewind Safety System

The company's EZ-COIL safety series of welding reels features a patented recoil safety system. Built for rugged-duty applications, these welding reels increase operator safety, as well as the safety of people and property in the surrounding area, by eliminating high-speed recoil and backlash common to conventional spring motor hose reels.

Coxreels 106
6720 S. Clementine Ct., Tempe, AZ 85283

Visitor Badges Expire Automatically

The company's time-sensitive badges provide plants with added security in controlling access for visitors, contractors, and temporary employees. After a 24-hour period, the badges display “Expired” with red diagonal stripes across the front. This prevents misuse of temporary ID badges to regain plant access. The badges make use of a migratory ink technology that works indoors or out, day or night, and require no hardware or electronics for activation. They are available with preprinted headers of “Visitor,” “Contractor,” or “Temporary.”

Brady Signmark 107
2221 West Camden Rd., P.O. Box 2999
Milwaukee, WI 53201-2999

Reel Provides Solution for Specialized Needs

The Safe-T-Reel meets specialized reel needs for environmentally sensitive work applications. The compact, stackable reels are designed to handle hoses and cords in applications requiring the use of welding cable, welding gases, air or water hoses, or electric cords. The product is spacesaving and can be installed in a variety of configurations. The reel is equipped with high-flow swivels, has a powder-coated, aircraft aluminum base, and has 30% glass-filled nylon reel flanges.

Reelcraft Industries, Inc. 108
2542 E. Business 30, Columbia City, IN 46725

Introducing

To analyze, identify and sort metals

ARC-MET® 8000 MobileLab

X-MET® 3000T

The new handheld, battery operated XRF Analyzer based on X-ray tube technology

The new portable, battery operated OES Analyzer with AIR and ARGON measurements

Metorex

Circle No. 32 on Reader Info-Card
WELDING SHOW 2003
Celebrating 50 years of Service

If You Have Joining Needs, We Have Your Solutions.

April 8-10, 2003
Cobo Center, Detroit, Michigan USA

The right TIME and OPPORTUNITY for...

C.E.O.
President
Vice President
Distributor
General Manager
Plant Manager
Job Shop Owner
Welding Engineer
End User
Manufacturer
Production Engineer
Shop Foreman
Educator
Welder
C.G. Manager
Consultant
Maintenance Specialist
Industrial Hygienist
The 2003 AWS Welding Show can give you the competitive edge you need in today’s tough economy. Globalization of markets, increased competition, and the accelerating pace of technological advancement mean you need to be smarter than ever about improving your company’s productivity. At the 2003 AWS Welding Show, you’ll find all the equipment, product applications and expertise you need to improve your business and remain among the top in your industry.

AWS cares about giving you the best for your time and money. The AWS Welding Show is dedicated to providing proactive industry leadership to you, its customers. Through its nearly 400,000 gross square feet of exhibits, leading-edge educational programs, and industry sponsors, the AWS Welding Show is helping industry meet the tough challenges facing cost-conscious consumers today.

The 2003 AWS Welding Show will feature everything from production arc welding systems to laser, resistance, electron beam and robotic arc welding technologies, plus safety gear, welding consumables, cutting equipment and more. The 2003 AWS Welding Show covers it all.

WELDING SHOW 2003
Celebrating 50 years of Service
April 8-10, 2003
Cobo Center, Detroit, Michigan USA
If you attend any show this year, make sure it’s the 2003 AWS Welding Show. It’s the smartest decision you could make for your business and industry. Don’t miss the world’s premier welding, fabricating, and materials-joining exposition. At the 2003 AWS Welding Show, you’ll be able to:

- Get close-up and hands-on with the newest equipment and latest products in your industry.
- Make new equipment purchases to improve your company’s production levels and to stay technologically competitive.
- Network with experts in your field for cost-effective solutions to your manufacturing problems.
- Identify new opportunities to build your business.
- Attend valuable seminars, conferences and free lectures.
- Mingle with the top minds of your trade to gain insight into how to drive your company’s future innovatively.

Advance your career or your business by attending the AWS Welding Show.

You’ll see the results in your profit margins!
Plant Tours

Wednesday, April 9, 2003
- General Motors Flint Truck Plant
- Chrysler Viper and Prowler Plant
- DaimlerChrysler Sterling Stamping Plant
- Ford Rouge Plant

Monday, April 7, 2003
- Gas Metal Arc Welding
- Laser Welding I
- Issues in Materials Joining I

Tuesday, April 8, 2003
- Laser Welding II
- Aluminum Joining
- Microstructural Evolution I
- Modeling of Weld Stresses and Distortion
- Issues in Materials Joining II
- Resistance Welding

Wednesday, April 9, 2003
- Weld and Structure Design: Today and Tomorrow
- Friction Stir Welding
- Issues in Materials Joining III
- Welding Process in Industry
- Weldability
- Microstructural Evolution II
- Process Automation

Thursday, April 10, 2003
- College Life – Careers in Welding Engineering and Engineering Technology

Commercial Sessions

Tuesday, April 8, 2003
- Advances in Robotic Materials Joining

Wednesday, April 9, 2003
- Advances in Laser Processing – Co-sponsored by Laser Institute of America
Conferences/Seminars

Monday, April 7, 2003
• Road Map Through the 2002 D1.1 Code
• Design & Planning for Cost-Effective Welding

Monday & Tuesday, April 7-8, 2003
• 9th AWS/AA Aluminum Welding Conference

Tuesday, April 8, 2003
• Inspection to the 2002 D1.1 Code
• Arc Welding and Power Sources

Tuesday & Wednesday April 8-9, 2003
• What Professionals Need to Know about Metallurgy

Wednesday, April 9, 2003
• Safety and Ventilation Strategies for Welding and Finishing Operations Conference
• Why and How of Welding Procedure Specifications
• Conference on High Currents Used in Resistance Welding

Wednesday & Thursday, April 9-10, 2003
• Welding of Stainless Steels – Parts 1 & 2

Thursday, April 10, 2003
• Safety in Welding & Cutting Operations – How to Improve your Company’s Profitability

FREE SESSIONS

Tuesday, April 8, 2003
• AWS Certified Welding Fabricator Program
• Personnel & Facility Qualification Committee’s B5 Qualification Standards
• Welding Safety and Health: A How-to Session for Independent Shops

NEW AWS MEMBERS’ SPECIAL OFFER

GET TWO YEARS OF AWS INDIVIDUAL MEMBERSHIP FOR ONLY $125! (SAVE $25)

A BONUS FOR NEW MEMBERS... Save nearly 90% on a welding publication (up to $188 value) when you join the American Welding Society (AWS) today. SAVE $25 when you join for two years!

Call the AWS Membership Department today at: (800) 443-9353, ext. 480

Remember – this offer is valid for New AWS Individual Members only.

Education Sessions

Tuesday, April 8, 2003
• Plummer Lecture: “Automotive Training”
• “Modernizing the Welding School at Northrop Grumman Newport News Shipbuilding”
• “Work in Progress”
• Production MIG: “Three Weeks, Two Modes, One Process”
• “Welder Training: Upgrading to First Class”
• “Metal Sculpture”

Wednesday, April 9, 2003
• “How the NAVY Trains its Welders”
• “Higher Education”
• “SENSE – Questions and Answers”
• “Training at Vermeer”
<table>
<thead>
<tr>
<th>Exhibitors: AT THE WELDING SHOW 03</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A</strong></td>
</tr>
<tr>
<td>Abicor Binzell Corp.</td>
</tr>
<tr>
<td>Abmast Abrasives Corp</td>
</tr>
<tr>
<td>Academy Precision Materials</td>
</tr>
<tr>
<td>Accra-Wire Controls, Inc.</td>
</tr>
<tr>
<td>Advanced Fabricating Equipment</td>
</tr>
<tr>
<td>Advanced Measuring Systems</td>
</tr>
<tr>
<td>Agfa NDT, Inc./Krautkramer Ultrasonic, Inc.</td>
</tr>
<tr>
<td>AicoTec Wire Corporation</td>
</tr>
<tr>
<td>Alfa Tools Div. of Alfa Mfg. Industries, Inc.</td>
</tr>
<tr>
<td>Allied Flux Reclaiming/Harberts Products, Inc.</td>
</tr>
<tr>
<td>Amercable</td>
</tr>
<tr>
<td>America Fortune Company</td>
</tr>
<tr>
<td>American Chovel Industries</td>
</tr>
<tr>
<td>American Friction Welding</td>
</tr>
<tr>
<td>American Machining Specialties, Inc.</td>
</tr>
<tr>
<td>American Torch Tip Company</td>
</tr>
<tr>
<td>Amet, Inc.</td>
</tr>
<tr>
<td>Antenen Research</td>
</tr>
<tr>
<td>Applied Robotics, Inc.</td>
</tr>
<tr>
<td>Arc Machines, Inc.</td>
</tr>
<tr>
<td>Arcon Welding</td>
</tr>
<tr>
<td>ArdOne</td>
</tr>
<tr>
<td>Argenta Tecnologia En Soldadura</td>
</tr>
<tr>
<td>Armstrong Blum Mfg. Co.</td>
</tr>
<tr>
<td>ATI Industrial Automation</td>
</tr>
<tr>
<td>Atlas Welding Accessories, Inc.</td>
</tr>
<tr>
<td>Avestapolarit Welding, Inc.</td>
</tr>
<tr>
<td><strong>B</strong></td>
</tr>
<tr>
<td>Bacou-Daloz</td>
</tr>
<tr>
<td>Behringer Saws, Inc.</td>
</tr>
<tr>
<td>Beijing Advanced Metal Materials Co. Ltd.</td>
</tr>
<tr>
<td>Beijing Metals &amp; Minterals Import &amp; Export Corp.</td>
</tr>
<tr>
<td>Bernard</td>
</tr>
<tr>
<td>Bluco Corp.</td>
</tr>
<tr>
<td>BMS/BU</td>
</tr>
<tr>
<td>Bonal Technologies</td>
</tr>
<tr>
<td>Bore Repair Systems, Inc.</td>
</tr>
<tr>
<td>Bosch Rexroth</td>
</tr>
<tr>
<td>Boss Mfg. Co.</td>
</tr>
<tr>
<td>Broco, Inc.</td>
</tr>
<tr>
<td>Bug-O Systems/Cypress Welding Equipment</td>
</tr>
<tr>
<td><strong>C</strong></td>
</tr>
<tr>
<td>C &amp; G Systems – A Thermadyne Company</td>
</tr>
<tr>
<td>C S Unitec</td>
</tr>
<tr>
<td>Carell Corporation</td>
</tr>
<tr>
<td>Cebora Spa.</td>
</tr>
<tr>
<td>Cebotech, Inc.</td>
</tr>
<tr>
<td>Centerline (Windsor) Ltd.</td>
</tr>
<tr>
<td>Cerbaco Ltd.</td>
</tr>
<tr>
<td>CGW Abrasive Mfg. USA</td>
</tr>
<tr>
<td>Chung I Silver Solder Co. Ltd.</td>
</tr>
<tr>
<td>CK Worldwide</td>
</tr>
<tr>
<td>Cloos Robotic Welding, inc.</td>
</tr>
<tr>
<td>CMW, Inc.</td>
</tr>
<tr>
<td>COB Industries, Inc.</td>
</tr>
<tr>
<td>Colorado School of Mines</td>
</tr>
<tr>
<td>Comeq, Inc.</td>
</tr>
<tr>
<td>Computer Weld Technology, Inc.</td>
</tr>
<tr>
<td>Computers Unlimited</td>
</tr>
<tr>
<td><strong>Conam Inspection</strong></td>
</tr>
<tr>
<td>CONCDA – Controls Corp. of America</td>
</tr>
<tr>
<td>Cooper Crouse-Hinds Molded Products</td>
</tr>
<tr>
<td>Cor-Met, Inc.</td>
</tr>
<tr>
<td>Corex, Inc.</td>
</tr>
<tr>
<td>Cryogenic Industries</td>
</tr>
<tr>
<td>CyL-Tec, Inc.</td>
</tr>
<tr>
<td><strong>D</strong></td>
</tr>
<tr>
<td>Dataweid, Inc.</td>
</tr>
<tr>
<td>De-Sta-Co. Industries</td>
</tr>
<tr>
<td>Direct Wire &amp; Cable, Inc.</td>
</tr>
<tr>
<td>DVS-German Welding Society</td>
</tr>
<tr>
<td>Dynabrade, Inc.</td>
</tr>
<tr>
<td><strong>E</strong></td>
</tr>
<tr>
<td>Eagle Bending Machines, Inc.</td>
</tr>
<tr>
<td>Edward’s Manufacturing Company</td>
</tr>
<tr>
<td>Electric Heating Systems</td>
</tr>
<tr>
<td>Electron Beam Technologies, Inc.</td>
</tr>
<tr>
<td>ESAB Welding &amp; Cutting Products</td>
</tr>
<tr>
<td>Essen Trade Shows</td>
</tr>
<tr>
<td>Essex Grp Div Superior Essex</td>
</tr>
<tr>
<td>EWI</td>
</tr>
<tr>
<td><strong>F</strong></td>
</tr>
<tr>
<td>F.W. Winter, Inc., &amp; Co.</td>
</tr>
<tr>
<td>Fein Power Tools</td>
</tr>
<tr>
<td>F&amp;M Magazine (Cygnus Publishing)</td>
</tr>
<tr>
<td>Ferris State University</td>
</tr>
<tr>
<td>Flame Technologies, Inc.</td>
</tr>
<tr>
<td>Flexovit U.S.A., Inc.</td>
</tr>
<tr>
<td>Frommelt Safety Products</td>
</tr>
<tr>
<td><strong>G</strong></td>
</tr>
<tr>
<td>Garryson, Inc.</td>
</tr>
<tr>
<td>Gedik Kaynak Sanayi ve Ticaret A.S.</td>
</tr>
<tr>
<td>Genesis Systems Group</td>
</tr>
<tr>
<td>Genstar Technologies Co. Inc.</td>
</tr>
<tr>
<td>Goodweld Corporation</td>
</tr>
<tr>
<td>Goss, Inc.</td>
</tr>
<tr>
<td>GOW-MAC Instrument Company</td>
</tr>
<tr>
<td>Griffin Automation</td>
</tr>
<tr>
<td>Gross Stabil Corporation</td>
</tr>
<tr>
<td>Guard-Line, Inc.</td>
</tr>
<tr>
<td>Gulf Wire Corp.</td>
</tr>
<tr>
<td>Gulico International, Inc.</td>
</tr>
<tr>
<td><strong>H</strong></td>
</tr>
<tr>
<td>Harris Calorific, Inc. – Lincon Electric Co.</td>
</tr>
<tr>
<td>HE&amp;M Saw</td>
</tr>
<tr>
<td>Heck Industries</td>
</tr>
<tr>
<td>Hercules Welding Products –</td>
</tr>
<tr>
<td>Division of Obara Corporation</td>
</tr>
<tr>
<td>High Test Industries Corp.</td>
</tr>
<tr>
<td>Hitco Carbon Composites, Inc.</td>
</tr>
<tr>
<td>hornell, Inc.</td>
</tr>
<tr>
<td>Hogen Manufacturing, Inc.</td>
</tr>
<tr>
<td>Huys Industries Limited</td>
</tr>
<tr>
<td>Hyd-Mech Group Limited</td>
</tr>
<tr>
<td>Hypertherm</td>
</tr>
<tr>
<td><strong>I</strong></td>
</tr>
<tr>
<td>IGUS, Inc.</td>
</tr>
<tr>
<td>Impact Engineering, Inc.</td>
</tr>
<tr>
<td>Industrial Machine Trader</td>
</tr>
</tbody>
</table>
Stork-Herron Testing Labs
Sumner Mfg. Co., Inc.
Superheat Services
Superior Products, Inc.
Systematics, Inc.
Tec Torch Co.
Techalloy Co., Inc.
Techna Spa.
Teijin Seiki Advanced Technologies
Texas State Technical College
Thermacut TATRAS, Inc.
Thermadyne Industries
Thermal Arc, Inc., - A Thermadyne Company
Thermal Dynamics - A Thermadyne Industries Company
Thermco Instrument Corp.
Thermo Measure Tech
3M
Tocco, Inc.
Tregaskiss Ltd.
Tri-Tool, Inc.
Trimark
Triple Crown Products, Inc.
Trumpf, Inc.
Tweco/Arcair Products - A Thermadyne Company
Tyrrell Abrasives
United Abrasives, Inc.
United Air Specialists
Unitek Miyachi Corporation
Universal Flow Monitors, Inc.
US Open Weld Trials
Victor Equipment Company - A Thermadyne Company
Wachs Company
Watts Specialties
Weartech International, Inc.
Weller Corp.
Weld Aid Products
Weld Engineering Co., Inc.
Weld Mold Company
Weldes Company
Weldcoa
Weldcraft Products, Inc.
Welding Design & Fabrication
Welding Technology Corporation
Weldmatic, Inc.
Weldsource Company
Wellform Electrodes, Inc. - Milco Manufacturing Co.
Wentgate Dymaweld, Inc.
Western Enterprises
Wilson Industries
Wing Enterprises, Inc.
Wisconsin Wire Works, Inc.
Young Do Ind. Co. Ltd.
ZahnTech, Inc.
Hit the Road to the Motor City — AWS Helps Pay the Way

That's right — AWS National will pay half of the cost (up to $500) to any AWS Section or welding distributor who charters a bus to the 2003 Welding Show in Detroit.

The American Welding Society will subsidize the cost to charter a bus to the Welding Show, April 8–10, using the following formula:
• 50% rebate, up to $500, for a bus with 35 or more people on it
• 50% rebate, up to $250, for a bus with 10–34 people on it
• No rebate for a bus with less than 10 people on it.

To further offset the charter cost, Sections might want to charge a nominal fee to each person who rides the bus.

Happy to Help, but Start Now

Get together with your Section officers soon and organize a special committee to help coordinate the event. A “to do” list is available from National, courtesy of the AWS Milwaukee Section, which operates a very successful bus trip program.

National will also be happy to provide 1) A sample flyer (or we can create a flyer for you) that your Section can use in promoting your event, 2) Section labels to use in mailing out promotions on your Section bus charter, and 3) “Welcome” packets for you to distribute on the bus ride to Detroit.

Interested

If you have questions or you are interested in organizing a bus charter to Detroit, contact Cassie Burrell at (800) 443-9353, ext. 253, or e-mail cburrell@aws.org.

Hot Topics for Conferences

The topics of safety and health, welding aluminum, and resistance welding have a broad appeal, but they are especially appropriate for Detroit where they attract great interest from the auto industry. The AWS has put together some great conferences on these subjects. Take a look below for what to expect from this lineup.

- 9th AWS/AA Aluminum Welding Conference. Cosponsored with the Aluminum Association, this comprehensive program will cover the following overview of aluminum joining, aluminum designation system, characteristics of aluminum alloys, metallurgy, safety and health considerations, preparation for welding, and filler metal selection.
AWS has put together some great conferences

The conference will also detail the welding processes used to join aluminum including GMAW, GTAW, and variable polarity plasma arc, resistance spot, high energy beam, and friction stir welding.

Other topics covered include robotic welding of aluminum; design and performance; weld discontinuities: causes and cures; and application of AWS D1.2, Structural Welding Code — Aluminum.

Safety and Ventilation Strategies for Welding and Finishing Operations. This one-day conference, cosponsored with Autovent International, will address issues on health, fire, and explosion dangers related to steel and aluminum welding, polishing, and grinding operations, as well as process and local ventilation strategies.

High Currents Used in Resistance Welding. This conference on resistance welding will offer a review of high currents used with the process, a brief review of the newly published AWS A10.1M, Specification for Calibration and Performance Testing of Secondary Current Sensing Coils and Weld Current Monitors Used in Single Phase AC Resistance Welding. Members of the A10 Committee will make the presentation.

For additional information on any of these conferences, contact Martica Ventura, (800) 443-9353, ext 224, or e-mail: mventura@aws.org.

Great Way to Support Welding Education

The AWS Foundation provides $300,000 a year in grants, scholarships, and loans for welding students. The Silent Auction, held every year at the Show, is one more way to fill the Foundation's treasure box to help those students. All the proceeds go toward the cause of welding education.

Places To Go in Detroit

When you arrive in Detroit, put some time aside to see the sights. You will find the Motown Historical Museum, a tribute to that era of unique music; the Henry Ford Museum and Greenfield Village, which celebrate American innovation and showcase many of the country's most notable historic treasures; and the Detroit Zoo's Arctic Ring of Life, which contains the world's largest polar bear exhibit.

In 1999 Detroit became the largest city in the United States to offer casino gambling. You can try your luck at MGM Grand, MotorCity, and Greektown, three Las Vegas-style casinos featuring 75,000 sq ft of gaming space each. The region is also home to The Detroit Museum of Arts and Charles H. Wright Museum of African American History. You may also want to go to a Detroit Tigers baseball game or just leisurely stroll the new riverfront promenade.

For trip-planning assistance and a complementary issue of Visit Detroit magazine, call 1-800-Detroit or visit www.visitdetroit.com.
ABICOR Binzel is your global solutions partner. Flexible management combined with quality and innovative products enable ABICOR to deliver standard or customized solutions for welding torches and accessories. From Air-Cooled to Water-Cooled. From MIG to TIG. From Semi-Automatic to Automatic to Robotic. ABICOR Binzel...we make torches that make welding work.
Those who work around electric arc welding and cutting operations should be aware of the potential health hazards caused by these electromagnetic waves

BY TERRY L. LYON

TERRY L. LYON
(Terry.Lyon@APG.AMEDD.ARMY.MIL) is a Physicist in the Laser/Optical Radiation Program, USACHPPM. He is also an alternate member of the AWS Safety Committee.

While open arc welding operations are common worldwide, the general population is largely unaware of the potential hazards. Before the mid 1970s, measures of optical radiation hazards and protection were largely empirically determined, even for welders and their helpers.

Today, we know serious potential hazards can exist wherever there are lines of sight to open arcs created by invisible emissions called “actinic ultraviolet radiation (UVR).” These UVR emissions are simply electromagnetic waves, like light, that travel in straight lines at the speed of light. A summary of the actinic UVR hazards to persons working around electric arc welding and cutting operations is contained in Table 1.
Table 1 — Distances (a) to Common Electric Arc Welding or Cutting Processes (b) at which the Actinic Ultraviolet Radiation (UVR) (c) Is Below the U.S. Daily Threshold Limit Value (TLV) (d) for Various Exposure Times (e).

<table>
<thead>
<tr>
<th>Arc Welding/Cutting Process</th>
<th>Shielding Gas</th>
<th>Arc Current in Amperes</th>
<th>Distance for 1 min</th>
<th>Distance for 10 min</th>
<th>Distance for 8 h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shielded Metal Arc (Stick)</td>
<td>None</td>
<td>100-200</td>
<td>3.2</td>
<td>10</td>
<td>71</td>
</tr>
<tr>
<td>GMAW</td>
<td>CO₂</td>
<td>90</td>
<td>0.95</td>
<td>3</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>CO₂</td>
<td>200</td>
<td>2.2</td>
<td>7</td>
<td>48</td>
</tr>
<tr>
<td></td>
<td>CO₂</td>
<td>350</td>
<td>4.0</td>
<td>13</td>
<td>87</td>
</tr>
<tr>
<td></td>
<td>95% Ar + 5% O₂</td>
<td>150</td>
<td>2.3</td>
<td>7.3</td>
<td>51</td>
</tr>
<tr>
<td></td>
<td>Al</td>
<td>150</td>
<td>6.7</td>
<td>21</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td>He</td>
<td>300</td>
<td>3.2</td>
<td>10</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>Ar</td>
<td>300</td>
<td>5.0</td>
<td>16</td>
<td>110</td>
</tr>
<tr>
<td></td>
<td>Ar</td>
<td>150</td>
<td>1.6</td>
<td>5</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>Al</td>
<td>300</td>
<td>3.2</td>
<td>10</td>
<td>69</td>
</tr>
<tr>
<td>GTAW</td>
<td>Ar</td>
<td>50</td>
<td>0.32</td>
<td>1</td>
<td>6.9</td>
</tr>
<tr>
<td></td>
<td>Hé</td>
<td>150</td>
<td>1.7</td>
<td>5.5</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>Ar</td>
<td>300</td>
<td>3.0</td>
<td>9.5</td>
<td>66</td>
</tr>
<tr>
<td></td>
<td>Hé</td>
<td>150</td>
<td>1.6</td>
<td>5</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>He</td>
<td>300</td>
<td>3.2</td>
<td>10</td>
<td>69</td>
</tr>
<tr>
<td>PAW</td>
<td>Ar</td>
<td>200-260</td>
<td>1.5</td>
<td>4.9</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>Ar</td>
<td>100-275</td>
<td>1.7</td>
<td>5.5</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>He</td>
<td>150</td>
<td>0.94</td>
<td>3</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>He</td>
<td>400</td>
<td>1.4</td>
<td>4.4</td>
<td>31</td>
</tr>
<tr>
<td>PAC (dry)</td>
<td>N₂</td>
<td>300</td>
<td>3.3</td>
<td>7.5</td>
<td>52</td>
</tr>
<tr>
<td>PAC (H₂O)</td>
<td>N₂</td>
<td>750</td>
<td>1.7</td>
<td>5.5</td>
<td>38</td>
</tr>
</tbody>
</table>

(a) These distances are approximate. To convert to feet, multiply the distance in meters by 3.3.
(b) The distances are based upon the worst-case exposure conditions: maximum UVR for exposure angle, arc gap, and electrode distance.
(c) Invisible actinic UVR poses a potential hazard to cornea (called welder's flash) and skin (much like sunburn) and exposure is cumulative with each exposure over an 8-h workday per 24-h period.
(d) TLVs are published by the ACGIH, Cincinnati, Ohio.
(e) These distances were based upon data from Lyon, T. L. et al, 1976, Evaluation of the Potential Hazards for Actinic Ultraviolet Radiation Generated by Electric Welding and Cutting Arcs. U.S. Army Environmental Hygiene Agency.

Exposure Effects

Since the beginning of arc welding, welders have known welding and cutting operations can cause acute effects such as severe "sunburn" (erythema) of the skin and painful "welder's flash" (photokeratitis) of the cornea of the eye. Consequently, early welders empirically selected protective clothing and eyewear for comfortable viewing. Also, the U.S. Army adopted a measure to prevent eye injuries in industrial areas. Ordinary safety glasses were prescribed for all Army personnel, including welders and their helpers. As a by-product of physical injury prevention, the eyewear resulted in a dramatic drop in the incidence of welder's flash. Any stray invisible actinic UVR was also blocked by the transparent lenses.

Exposure Limits

The first actinic UVR exposure guidelines were published by the American Conference of Governmental Industrial Hygienists (ACGIH) in 1972 (Ref. 1). These guidelines were intended to prevent the acute effects of actinic UVR. The International Non-Ionizing Radiation Committee (INIRC) of the International Radiation Protection Association (IRPA) (Ref. 2) proposed similar guidelines in 1985. After considerable review, the International Commission on Non-Ionizing Radiation Protection (ICNIRP) (Ref. 3) revalidated and endorsed those limits. Besides being concerned about acute effects, these standards have also been shown to minimize any adverse effects and pose an extremely small risk for delayed effects.

Instrumentation

By the early 1970s, several instruments were available to measure actinic UVR but many simpler instruments presented significant measurement errors primarily from a flaw called "stray light." The actinic UVR resulting in an acute injury followed a narrow range of wavelengths (from around 200-315 nm) with a varying "action spectrum" (peaking sharply at 270 nm). Producing an instrument with this wavelength response was difficult with known filters at that time. The better instruments were the traditional ultraviolet spectrometers that could manually scan UVR wavelengths, weigh the results against the exposure standard for each wavelength, then sum them for the net result.

Joint Effort

In 1974, a joint effort was planned to determine the optical radiation hazards from electric arc welding and cutting operations. Testing was planned for six processes: gas tungsten arc welding (GTAW), gas metal arc welding (GMAW), flux cored arc welding (FCAW), plasma arc cutting (PAC), plasma arc welding (PAW), and shielded metal arc welding (SMAW). Organizations that provided personnel and equipment for the effort included Union Carbide Corp., the American Welding Society (AWS), Battelle Memorial Institute, National Institute of Occupational Safety and Health (NIOSH), and the U.S. Army Environmental Hygiene Agency (USAEHA, now U.S. Army Center for Health Promotion and Preventive Medicine [USACHPPM]).
Joint Effort Results

Arc measurements were conducted in 1975 at Union Carbide Corp. in Florence, S.C., and later at Plasma in Lebanon, N.H., and Caterpillar in Peoria, Ill. A variety of detectors were employed but the final results of the first study were based upon traditional UVR spectrometer results. The arc location and root opening were stabilized for measurements by employing a rotating pipe fixture, and all measurements were made at a measurement distance of one meter and at the worst-case angle for emissions. The results of that study were published as a USAEHA report (Ref. 4) in 1976 employing the ACGIH threshold limit value. That study contained results for more than 100 different conditions and processes and yielded the relationships between arc current, arc length, shielding gas, base metal, and actinic UVR that resulted in the derivation of formulas for those relationships.

Table Summary

A summary of actinic UVR hazards posed to persons working around electric arc welding and cutting operations are contained in Table 1 and are summarized as follows.

Hazardous Exposure. The level of hazardous exposure affecting welders' helpers and other personnel (forklift and overhead crane operators, for example) located in the vicinity of open arc welding and cutting operations can now be determined. The intensity and wavelengths of nonionizing radiant energy produced depend on many factors such as the process type, welding parameters, electrode and base metal composition, fluxes, and any coating or plating on the base material. Some processes such as resistance welding, cold-pressure welding, and submerged arc welding produce negligible quantities of radiant energy. Later, Europeans conducted UVR measurements on pulsed welding.

Exposure Time. Exposure to actinic UVR is considered to be cumulative with each exposure over an 8-h workday and within a 24-h period. Therefore, two 5-min exposures during a workday could be considered as a single 10-min exposure.

Retinal Exposure

In addition to actinic UVR measurements, another study was published as a USAEHA report (Ref. 7) in 1977 containing an evaluation of potential retinal exposure hazards. The eye can focus an open arc onto the retina where an injury might result that was photochemical or thermal in nature. Photodynamic injury is the result of exposure to intense blue light sources, whereas thermal injury can result from all visible and some near-infrared radiation, which is largely invisible. Measurements of blue light and other retinal-thermal emissions suggest momentary viewing of electric welding and cutting arcs does not exceed retinal exposure limits; however, staring at an open arc can readily exceed these standards. While staring at the arc should never be permitted, actual retinal injuries are rare (Ref. 8) and would likely result only from chronic staring.

References

1. American Conference of Governmental Industrial Hygienists (ACGIH), 2001. TLVs and BEIs. Threshold Limit Values for Chemical Substances and Physical Agents. Cincinnati, Ohio: ACGIH.


FOCUS: The AWS WELDING SHOW is your answer to gaining the most exposure for your industry.

Exhibit at the AWS WELDING SHOW:
The right audience.
The perfect forum for opportunity.

The AWS Welding Show offers everything from basic arc welding systems to robotic, laser, resistance, and electron beam technologies. The AWS Welding Show covers it all. This is the definitive, core event for welding technology and applications.

Did you know that most AWS Welding Show attendees make significant purchases within six months of visiting the show?

The AWS Welding Show attracts more professionals in engineering, manufacturing, corporate and production management, purchasing, design, welding, and production. It attracts more exhibitors, allocates more exhibit space, and influences more purchasing decisions.

WELDING SHOW 2003
Celebrating 50 years of Service
April 8-10, 2003
Detroit, Michigan USA
By eliminating traditional backing gas protection, stainless steel piping and fabrication costs for heavy-process construction and manufacturing industries were reduced.

BY BARRY MESSER, GREG LAWRENCE, VASILE OREA, CHARLES PATRICK, AND TERRY PHILLIPS

The Fluor Corp.'s desire to improve quality and efficiency led to the development of a stainless steel pipe welding process that needed no backing methods to prevent root bead oxidation. Since there was a limited number of qualified and experienced welders available at the site, the project team investigated methods that would not only improve weld quality and efficiency, but also improve production processes. To streamline production efforts, the team explored methods using flux paste, flux coated, and flux cored filler metals with the gas tungsten arc welding (GTAW) process as well as alternative consumable combinations.

BARRY MESSER (Barry.Messer@fluor.com), GREG LAWRENCE, and VASILE OREA are with Fluor Corp., Calgary, Alberta. CHARLES PATRICK and TERRY PHILLIPS are with Fluor Corp., Sugar Land, Tex.
**Table 1 — Weld Progression**

<table>
<thead>
<tr>
<th>Weld Progression</th>
<th>Root</th>
<th>Fill/Cap</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Downhill</td>
<td>Uphill</td>
</tr>
<tr>
<td>Joint Design</td>
<td>60-deg V, 1.6-mm land, 4-mm root opening</td>
<td></td>
</tr>
</tbody>
</table>

**Table 2 — Welding Variables**

<table>
<thead>
<tr>
<th></th>
<th>With Backing Gas</th>
<th>Without Backing Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Root</td>
<td>Fill/Cap</td>
</tr>
<tr>
<td>Volts</td>
<td>16–17</td>
<td>17–18</td>
</tr>
<tr>
<td>Amps</td>
<td>120–130</td>
<td>120–140</td>
</tr>
<tr>
<td>Heat Input (max)</td>
<td>0.6 kJ/mm</td>
<td>2.5 kJ/mm</td>
</tr>
</tbody>
</table>

The mechanical and NDE results are given in Tables 3 and 4. The final results were all acceptable to ASME IX.

**Table 3 — Representative Test Results for 304/304L Material**

<table>
<thead>
<tr>
<th></th>
<th>With Backing Gas</th>
<th>Without Backing Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guided Bend</td>
<td>Passed ASME IX</td>
<td>Passed ASME IX</td>
</tr>
<tr>
<td>Tensile Test</td>
<td>570 MPa, failure in BM</td>
<td>364 MPa, failure in BM</td>
</tr>
<tr>
<td>Charpy V-Notch</td>
<td>142 J @ -46°C</td>
<td>156 J @ -46°C</td>
</tr>
<tr>
<td>Vickers Hardness</td>
<td>207 HV&lt;sub&gt;0.02&lt;/sub&gt; max</td>
<td>209 HV&lt;sub&gt;0.02&lt;/sub&gt; max</td>
</tr>
<tr>
<td>Grain Size for</td>
<td>ASTM Grain size 5</td>
<td>ASTM Grain Size 4</td>
</tr>
<tr>
<td>Base Metal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HAZ ID</td>
<td>ASTM Grain Size 4</td>
<td>ASTM Grain Size 4</td>
</tr>
<tr>
<td>Final Result</td>
<td>Passed ASME IX</td>
<td>Passed ASME IX</td>
</tr>
</tbody>
</table>

**Table 4 — Representative Test Results for 316/316L Material**

<table>
<thead>
<tr>
<th></th>
<th>With Backing Gas</th>
<th>Without Backing Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guided Bend</td>
<td>Passed ASME IX</td>
<td>Passed ASME IX</td>
</tr>
<tr>
<td>Tensile Test</td>
<td>524 MPa, failure in BM</td>
<td>527 MPa, failure in BM</td>
</tr>
<tr>
<td>Charpy V-Notch</td>
<td>126 J @ -46°C</td>
<td>128 J @ -46°C</td>
</tr>
<tr>
<td>Vickers Hardness</td>
<td>212 HV&lt;sub&gt;0.02&lt;/sub&gt; max</td>
<td>212 HV&lt;sub&gt;0.02&lt;/sub&gt; max</td>
</tr>
<tr>
<td>Grain Size for</td>
<td>ASTM Grain size 4</td>
<td>ASTM Grain Size 3–4</td>
</tr>
<tr>
<td>Base Metal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HAZ ID</td>
<td>ASTM Grain Size 3–4</td>
<td>ASTM Grain Size 4</td>
</tr>
<tr>
<td>Final Result</td>
<td>Passed ASME IX</td>
<td>Passed ASME IX</td>
</tr>
</tbody>
</table>

**Table 5 — Corrosion and Pitting Test Results**

<table>
<thead>
<tr>
<th></th>
<th>316/316L Stainless Steel Welded Coupon with Backing Gas</th>
<th>316/316L Stainless Steel Welded Coupon without Backing Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strauss Corrosion Test (ASTM A-262)</td>
<td>Pass</td>
<td>Pass</td>
</tr>
<tr>
<td>*ASTM G 48 (ferric chloride)</td>
<td>No significant pitting</td>
<td>No significant pitting</td>
</tr>
<tr>
<td>*Electrolytic Test (simulated seawater solution ASTMD-1141, pH 8.2)</td>
<td>Slight pitting in HAZ</td>
<td>Slight pitting in weld</td>
</tr>
<tr>
<td>*Electrolytic Test (100 ppm chloride solution, pH 5)</td>
<td>No significant pitting</td>
<td>No significant pitting</td>
</tr>
</tbody>
</table>

*Pitting noted was not more severe than pitting from normal weld heat tint.

**A Technological Breakthrough**

No backing gas (NBG) in stainless steel welding technology was initiated more than two years ago at the Suncor Millennium project and the Shell Athabasca Oil Sands Development project, two major refinery projects in Alberta, Canada. NBG welding was achieved by combining solid, silicon-rich welding wire and a tri-mix shielding gas mixture using an inverter power source. The combination provided a new method to streamline stainless steel production and improve oxidation resistance of the root bead’s inner surface.

Work with shielding gases revealed implementing a higher than normal volume of tri-mix shielding gas containing 90% helium, 7.5% argon, and 2.5% carbon dioxide resulted in a reduction in oxidation of the root. Optimized shielding gas flow rates were used to “flood” the weld root area during welding. The consumables that proved to be most effective were ER308L-Si and ER316L-Si. Although these electrodes are in the same classification as the commonly used ER308L and ER316L materials, they possess a high silicon content that improves the oxidation immunity and fluidity of the weld metal. The chemical combination of the electrodes further protects the inner surface of the weld bead from damaging oxidation that traditionally required the use of an inert backing gas on stainless steel pipe welds. Work on the projects optimized and tested the welding parameters to confirm corrosion resistance, mechanical properties, and production statistics.

After extensive testing revealed positive production results, Fluor gained approval from the Alberta Boiler Safety Association (ABS) to implement NBG welding of stainless steel piping on subsequent projects. The welding procedures were approved to ASME IX.
Test Results

The team knew they had achieved a visually acceptable weld, but further corrosion testing was required before this development could be applied to production welding. An extensive oxide scale testing program was implemented on the Shell project whereby a series of welding coupons was prepared and welded with no backing gas in the shop with production welders using A 312 Types 304/304L and 316/16L materials. Matched control samples were also prepared with the same welding parameters but with the use of backing gas for comparison.

The welding parameters used to prepare the sample and matched control test coupons are described in Tables 1 and 2. The mechanical and NDE test results are given in Tables 3 and 4. The final results were all acceptable to ASME IX.

The team’s main concern was the weldment’s ability to withstand corrosive field environments. To resolve this issue, an extensive corrosion testing program was implemented. Tests conducted were the Strauss corrosion test to determine the susceptibility of the weldment to intergranular attack; the ASTM G48 (ferric chloride) test to determine pitting/crevice corrosion by measuring weight loss; an electrolytic test with simulated seawater of pH 8.2; and an electrolytic test of 100 ppm chloride solution of pH 5. The electrolytic pitting tests (based on the Avesta method) determined corrosion potential by isolating samples and matched control welds in a cell containing chloride solution or saltwater medium, then implementing accelerated electrolytic stimulation. An electrode connection exhibited the resulting electrochemical measurement of weld corrosion potential.

An analysis of the sample and the matched control welds exhibited no significant difference, and all samples passed the subject tests detailed in Table 5.

Typical root heads in A312 Type 304/304L materials welded with ER308L-1Si are pictured in Fig. 2. The root of the sample weld without a backing gas does indicate some discoloration and evidence of minor oxidation; however, all samples successfully passed the Strauss corrosion test.

The extensive testing of the oxide scale conducted by energy dispersive spectroscopy (EDS) revealed no indication of sugaring, significant oxidation, or nitrogen absorption. Radiography and penetrant testing of the welds were determined to be acceptable to ASME requirements.

A chemical analysis of the root surface was conducted using a scanning electron microscope equipped with EDS. The results confirmed there was some oxidation of the surface, but the oxidation was sporadic and typically only 0.003 mm thick. After removing the oxide layer by machining the root, the chemical analysis of the sample’s root weld metal returned to within acceptable limits.

Welder Training

The ABSA approved the welding procedures to ASME IX. The successful test results gave the team confidence to implement the new welding procedure in construction. A three-day training course was prepared for existing welders on the job site. Welders with little or no experience in short circuit gas metal arc welding were able to make quality, code-worthy NBG welds at the end of the training session.

Field NBG Welding Results

In the field, increased productivity and welding efficiency were gained from reduced setup times attributed to elimination of the necessity to install and remove inert gas purge dams inside the pipe. The overall repair rate of the welds was about 2% on the Suncor project with the major discontinuity being porosity, not incomplete fusion as one might expect, by using a short arc gas metal arc welding process. However, with the additional optimization work conducted on the Shell project, the repair rate was further reduced to less than 1%.

To date, several thousand welds on 38- to 762-mm-diameter stainless steel piping with 25 mm thickness have been successfully completed with this welding procedure.

Applications

Fluor currently conducts NBG welds in the field on 304/304L and 316/316L stainless steel utility and process piping with design temperatures up to 450°C with a typical deposition rate of 3.5 lb/h. Further testing protocols are planned for applications involving oxygenated water containing chlorides and for design temperatures above 450°C.

In addition to welding stainless steel, NBG welds coupled with variant gas mixtures, including low-temperature gas mixtures down to -46°C, have been successfully and extensively implemented on P-No. 1 Group 1 and 2 materials (carbon steel) using ER70S-6 filler metal. Similar results have also been achieved for 9Cr%Mo (P5), 9Cr-1Mo (P9), and 9Cr-1MoV (P91) materials.

Conclusions

NBG code welds on stainless steel are user friendly and contribute to reducing overall welding and setup costs. The results are substantial productivity gains on existing projects and repair rates of less than 1%.

As a result of the testing program and favorable production results, Fluor has also gained approval to implement NBG welds on subsequent major projects. The company is now using NBG welds in full production at selected refinery and chemical plants for all welding positions on all classes of carbon and low-alloy steel and Types 304/304L and 316/316L piping.
International Brazing & Soldering Conference

February 16-19, 2003
Four Points Sheraton Hotel
San Diego, California

Benefits:
- A focused technical meeting provides more interaction with your technical peers.
- A venue to discuss technical problems, solutions and opportunities.
- Discover emerging braze and solder joining technology from around the world.
- Evaluate and review joining process solutions.
- Evaluate competitive and/or complementary braze and solder technologies.
- Participate in the educational and exhibit opportunities.
- Meet suppliers and service providers at the tabletop exhibit.
- Find and meet the experts who may provide answers to your braze or solder joining problems.

Who Should Attend:
- Researchers dedicated to advances in braze and solder joining.
- Process engineers looking for solutions.
- Development personnel responsible for evaluating new applications and markets.
- Engineers seeking an introduction to advances in braze and solder joining technology.
- Students seeking emerging technology and who wish to meet prospective employers.
- Technical management seeking potential strategic partners and the latest trends and emerging technologies in the field of braze and solder joining.
- Exhibitors seeking to gain exposure for their products and/or services to potential buyers from throughout the global brazing and soldering community.

Sponsored by:
American Welding Society
ASM

Endorsed by:
EABS
DVS

Hotel Information
Four Points Sheraton
Tel: 858-277-9555
Web: http://www.sdp-points.com

For more information, or to register, contact the AWS Conference Department at (800) 443-9353, ext. 449, or visit the AWS webpage at: www.aws.org, and go to “Conferences.”

Photograph courtesy of Gasflux
Tips for Avoiding Neck Pain

Understanding the biomechanics of the neck region can help welders alleviate the stresses welding posture places on their necks.

J. WAYNE WESTERN (western@uwatec.edu) is an AWS Certified Welder, Inspector, and Certified Welding Educator. He is a Welding Instructor at Ogden Weber Applied Technology College, Ogden, Utah. JON RHODES holds a Master of Science in Physical Therapy and is with HealthSouth Rehab Center—Salem, O. H. KAREN STEVENSON is a Student Physical Therapist, University of Colorado, Health Sciences Center, Denver, Colo.
A few months ago, I was making weekly visits to a physical therapist following surgery for a ruptured disc. As part of the rehabilitation, we discussed a welder’s working conditions and the possible impact those conditions have on the welder’s neck and back. After one of these appointments, I returned home to find my son, who is also a welder, complaining of a sore neck and shoulders. I began wondering how widespread “welder’s neck” is and what could be done about it. After discussing my concerns with Jon, he and Karen began analyzing cause and effect as well as treatment. It is our hope the following information will help welders protect the health of their spine.

Fig. 1 — Three views of the human spinal column — front (left), side (middle), back (right).
A Welder's Posture

Production of quality welding in a timely and safe manner requires focus and concentration. This may be at the expense of healthy body mechanics and can result in faulty posture (rounded shoulders and forward head position) for sustained periods. A production welder could be on a single project for up to eight hours a day. Welding helmets, worn for protection and weighing as much as 3 lb in some cases, place an additional load on the neck and cervical spine. Even when not welding, the welder may still wear the helmet but with the mask in the up position. A general understanding of the structure and function of the cervical spine will help you understand what positions are harmful to the neck.

General Structure of the Spinal Column

Through a system of links, the interrelationship of the spinal column and other aspects of the human structure allow the spinal column to provide:

- A base of support for the head (and internal organs)
- A stable base of attachment for ligaments, bones, and muscles of extremities, rib cage, and pelvis
- A link between the upper and lower extremities
- Mobility for the trunk
- Protection of the spinal cord.

Some body functions require stability while others require mobility. Therefore, a structure such as the spinal column, which provides both, is complex. Anatomically, it is composed of 33 vertebrae and 23 intervertebral disks (Fig. 1) and consists of the following five regions:

- Cervical (neck)
- Thoracic (upper back)
- Lumbar (lower back)
- Sacral (pelvis)
- Coccygeal (tailbone).

(Both the sacral and coccygeal areas are fused.)

Primary and Secondary Curves

When viewed from the side and in ideal postural alignment, the adult vertebral column has four distinct curves. The thoracic and sacral regions retain the primary posterior convex curves. Two regions — cervical and lumbar — develop secondary curves as a result of accommodation of the skeleton to an upright posture.

Each curve is interdependent on each other so that movement of one curve above or below another acts to balance the head.

The joints of the vertebrae are connected with cartilage and provide weight-bearing ability and strength to the vertebral column. Intervertebral discs and ligaments connect these articulating surfaces to each other. The discs, which function as shock absorbers, consist of an outer fibrous part called the annulus fibrosus and an inner gelatinous central mass termed the nucleus pulposus. Their shapes vary depending on the region of the spine, thereby producing the secondary curvatures of the vertebral column. When weight is applied to the discs as in standing, lifting, or carrying the load of a welding helmet in addition to the weight of the head, the nucleus flattenas and the annulus bulges.

Dysfunction or poor alignment at the joints where the spinal nerves leave the vertebral column because of degenerative discs, injury, and/or osteoarthritis may impinge spinal nerve roots, causing pain and possibly muscle spasm and weakness.

Motion at the joints of any two vertebrae is limited to a small amount of translation and rotation. However, the additive effect of these small movements within a number of vertebra allow a large range of motion including forward flexion, backward extension, and lateral flexion to either side and/or rotation.

Ligaments and Muscles

In general, there are two ligamentous systems. The intrasegmental system connects adjacent vertebrae to each other. The intersegmental system connects several vertebrae together so that the vertebral column or sections of it may function as a unit.

While the overall ligamentous system of the vertebral column is extensive, the cervical (neck) region has additional reinforcing ligaments. This is due to the atypical structure of the first two cervical vertebra and their relationship and attachment to the skull. The importance of the reinforcing ligaments may be best appreciated if you picture the head as a 10-lb ball balanced on the end of a chain, the cervical spine.

Cervical Spine Flexion (looking down — Fig. 2A). During normal forward movement of the cervical spine, the vertebra above tilts and glides forward over the vertebra below, causing compression and bulging of the anterior annulus fibrosus (front of the outer disc) and stretching of the posterior annulus (back of the outer disc). This causes the intervertebral foramen to widen and the spinous processes to separate. This motion is limited due to tension in the posterior ligaments.

Cervical Spine Extension (looking up — Fig. 2B). When you look up, the superior vertebra tilts and glides posteriorly over the inferior vertebra causing the anterior annulus fibrosus to stretch while compressing and...
bulging the posterior anulus. Only the anterior longitudinal ligament limits extension; however, the bony processes of the posterior vertebrae also serve to restrict cervical extension. The posterior anulus tends to be thinner and weaker than the anterior anulus and is therefore more vulnerable to tearing and rupture.

Repetitive faulty posture and body mechanics can cause protrusion or herniation of the disc, which may compress the spinal cord and nerve roots, causing pain and dysfunction.

**The Effects of Space or Distance**

Extension or hyperextension of the cervical spine is present in faulty posture with a rounded upper back and forward head. The further outside the base of support the external force is held and the heavier the welding helmet, the greater the strain on the neck extensor muscles and intervertebral discs. If this force is held that way for long periods of time, the intervertebral disc can tear and lead to a herniation of the nuclear material.

Figure 3 shows the effect of gravity on general forward head posture by demonstrating the external forces the neck and spine must work against relative to a simple lever system. The weight and forward extension of the welding helmet compounds the force.

In the equation W X X = M x Y, W is the weight of the head, which remains constant; X is the distance of head weight (W) from center of gravity (G); Y is the distance of spinal musculature from center of gravity (G); and M is the tension developed by the musculature to sustain the weight of the head (W).

As seen in Fig. 3A, the weight supported by the fulcrum G is the sum of the weights acting at each end of the lever. If the length of the lever bar changes, this must be compensated for by a change in weight or force to maintain balance. For instance, if W is 10 lb and the distance X is 6 in., the force M must supply through the lever arm Y of 4 in. is 15 lb.

As seen in Fig. 3B, if the lever arm X is extended forward to 8 in. with the weight of the head remaining constant, the posterior lever arm Y decreases to 2 in. and the muscle tension must increase to 40 lb. If, additionally, the weight of a 3-lb welding helmet is added to W, increasing it to a total of 13 lb, the internal force increases to 52 lb.

Although this analysis is not completely accurate, it does illustrate how the effect of gravity on forward head posture along with the added weight of a welding helmet would not only cause fatigue but also acts to compress intervertebral discs, soft tissues, and the cervical spine itself. Figures 4–6 further illustrate the effects of gravity.

**Fig. 6 — Wearing a helmet down and standing in a common position for welding generates a lot of stress on the neck and back. A welder in this position may be generating more than 50 lb of internal force on his or her neck and back.**

**Recommendations**

As long as welding necessitates the wearing of helmets, hard hats, and, on occasion, breathing filtration equipment, welders will be subjected to additional stresses to their backs and necks. Being aware of what even small changes in weight and position may do can greatly reduce their impact. Use of lighter weight welding helmets and adopting the practice of never nodding a helmet down may help to prevent neck fatigue, strain, and degenerative disc disease. Evaluation and revision of workplace ergonomics may also play an important role and help to reduce time lost from work due to neck pain and dysfunction. Good posture helps minimize stress. Whenever a job keeps you in a looking down posture for very long, use time during slow periods or work breaks to stretch your head and neck and to each side to help counter the forward extension. A regular exercise program and daily stretching of the neck and back should make long days under the helmet more comfortable (see item at right). If chronic pain persists, have your doctor evaluate you for appropriate treatment.

**Works Consulted**

Here are the answers to some frequently asked questions

No matter what branch of the welding industry you’re in, no doubt there are questions that come up time and time again. The Welding Journal recently asked three active members of the welding community to provide answers to some of the questions they are most often asked. The questions and answers from each contributor follow some short biographical information.
DUANE K. MILLER, Sc.D., P.E., is manager, Welding Technology Center, and welding design consultant, The Lincoln Electric Co., Cleveland, Ohio. Miller is a recognized authority on the design of welded connections. In 1994, he was selected to chair the American Welding Society's Presidential Task Group on Northridge earthquake issues. He also served on the Project Oversight Committee of SAC, a consortium sponsored by the Federal Emergency Management Agency (FEMA) to provide understanding of connection behavior in the wake of Northridge. Miller currently serves as first vice chair of the AWS D1 Committee on Structural Welding and chairs the Seismic Welding Subcommittee.

Q: What is undermatched weld metal? Where can I use it? What are the advantages of undermatched weld metal?

A: When weld metal strength is compared to the base metal strength, one of three relationships may exist: the weld metal may be stronger than the base metal ("overmatched"), generally equivalent to the base metal ("matching"), or lower than the base metal ("undermatched"). AWS D1.1, Structural Welding Code — Steel, defines matching and undermatching in the table in Section 3.3.

In D1.1, overmatching is never required. Matching strength is required for some connections and loading types: complete joint penetration (CJP) groove welds in tension are the most common example. All partial joint penetration (PJP) groove welds, all fillet welds, and all plug and slot welds can be made with undermatching weld metal. D1.1 Table 2.3 defines where matching and undermatching weld metal is required or permitted.

When undermatching weld metal can be used, the weld is typically more resistant to fabrication-related cracking. The increased ductility of the lower strength weld metal and the reduction in residual stresses can reduce lanamellar tearing tendencies as well. Undermatching is typically considered only when the base metal yield strength is 70 ksi (485 MPa) or greater. A typical application where undermatching may be considered is when fillet welds are used to join A514 or A517 steel (minimum specified yield strength of 100 ksi [690 MPa]).

It is important the weld size reflect the use of undermatching weld metal. Depending on the particular loads involved, it may be necessary to increase the specified weld size when undermatching welds, as opposed to matching strength welds, are used.

Q: Why is aluminum alloy 7075 not listed in AWS D1.2, Structural Welding Code — Aluminum?

A: Most aluminum alloys are weldable, but a fair number of them are not, including 7075 aluminum. When designers and welders look for an aluminum alloy to use, many will start by reviewing a table that lists all of the aluminum alloys and their strengths. Alloy 7075 is often selected because it is one of the highest strength aluminum alloys. But, few of the higher strength aluminum alloys are weldable, especially those in the 7000 and 2000 series, and they should not be used.

The one exception to the rule of never using 7075 for welded applications is in the injection molding industry, which uses 7075 dies and will repair them with welding. However, 7075 should not be used for structural work.

When you need to design something of high-strength aluminum, look to a 5000 series high-magnesium alloy instead of a 2000 or 7000 series. The 5000 series alloys are weldable and will produce the best results.

Q: Why is my aluminum welded connection so much weaker than the base material?

A: In steel weldments, a welded connection can be made as strong as the base material, but this is typically not the case with aluminum. In almost all instances, the welded connection will be weaker than the base material.

To understand why this occurs, consider the two classifications of aluminum alloys: heat treatable and nonheat treatable. The latter category is hardened only by cold working, which causes physical changes in the metal. The more the alloy is cold worked, the stronger it gets. When you weld an alloy that has been cold worked, you locally anneal the material around the weld so it goes back to its zero-tempered (or annealed) condition and it becomes "soft." Therefore, the only time you can make a weld as strong as the base material with a nonheat-treatable alloy is when you start with zero-tempered material.

With heat-treatable aluminum alloys, the last heat treatment step heats the metal to approximately 400°F (200°C). When welding, the material around the weld (the heat-affected zone) becomes much hotter than 400°F so the material tends to lose some of its strength. Unless a postweld heat treatment is applied, the area around the weld will become significantly weaker than the rest of the aluminum — by as much as 30 to 40%. Postweld heat treatment can restore this loss in strength if a heat-treatable aluminum is used.

Table 1 is a guide as to which series of aluminum alloys are heat treatable and which are not.

<table>
<thead>
<tr>
<th>Heat Treatable</th>
<th>Nonheat Treatable</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>1000</td>
</tr>
<tr>
<td>6000</td>
<td>3000</td>
</tr>
<tr>
<td>7000</td>
<td>4000</td>
</tr>
<tr>
<td>7001</td>
<td>5000</td>
</tr>
</tbody>
</table>

Q: Section 12 of AWS D1.5, Bridge Welding Code, addresses fracture control. Shouldn't this apply to all structures since fracture avoidance is so important?
A: The Engineer responsible for a product or structure must determine what codes apply to a project. Further, the Engineer must develop job specifications that address the specific requirement for specific projects. The Engineer must also determine whether D1.5 Section 12 is appropriate or not.

The scope and intent of Section 12 should be understood before it is invoked on a project. It is intended to apply to "fracture critical members" (FCMs), which are defined in D1.5, paragraph 12.2.2. It states: "Fracture critical members or member components are tension members or tension components of bending members (including those subject to reversal of stress), the failure of which would be expected to result in collapse of the bridge." Two elements are important in this definition: tension and collapse. FCMs must be tension members or tension components. Columns that see only compressional loading cannot be FCMs.

The collapse component of this definition has to do with the overall performance of the bridge should a FCM fracture. Most bridges are redundant, that is, there are multiple load paths available should a single member fail. However, a twogirder bridge is likely to be fracture critical in that the fracture of a single member will likely cause the collapse of the bridge.

Bridge designers need to determine whether the bridge member is fracture critical or not, and specify such on design drawings (see D1.5, paragraph 12.3.1). For nonbridge applications, the Engineer responsible for the project needs to determine whether D1.5 Section 12 is applicable. The Engineer should know it was not the intent of D1.5 to cover nonbridge applications (see D1.5, paragraph 1.1), although it may be appropriate for certain situations. When applied to nonbridge applications, the Engineer should realize the materials and product forms (plate, sheet, shapes, tubes) that will be employed on the nonbridge project may not be covered by D1.5. Job specifications must address these situations.

Q: Now wording has been added to AWS D1.1, Structural Welding Code — Steel, that addresses "original equipment manufacturers" (OEMs). Why was this done and what does this mean?

A: The section to which you refer is 1.3.4, which states: "OEM shall be defined as the single Contractor that assumes some or all of the responsibilities assigned by this code to the Engineer." Historically, D1.1 has outlined the responsibilities of the parties involved with the typical building construction process: the Engineer, who acts on behalf of the owner; the Contractor, the entity that performs the welding; and the various types of Inspectors. In the typical building construction process, the Engineer and the Contractor are separate entities. Thus, code responsibilities assigned to the Engineer are intended to be executed by a different party than the one doing the fabrication.

Many users of the D1.1 Code do not fit into this traditional building construction pattern. For example, the purchaser (owner) of a piece of construction equipment may require the product be built to D1.1. The manufacturer of this equipment may have a whole staff of engineers, but in D1.1 terms, these "engineers" are not the same as the D1.1 "Engineer" who represents the owner. In this situation, the engineers represent the manufacturer of the equipment. Thus, application of D1.1 to these situations can cause a variety of points of confusion.

To address this situation, the D1 Committee has introduced the OEM concept. The commentary to D1.1-2002, paragraph 1.3.4, describes this situation in more detail. Provision 1.4(8) requires contract documents outline the responsibilities of all the parties involved for OEM applications. The commentary provides some examples of possible relationships for these applications.

By providing these new code provisions, it is hoped implementation of D1.1 for applications other than the typical building construction practice will be simplified.

Q: AWS D1.3, Structural Welding Code — Steel Sheet, says in its scope that it covers sheet metal applications "which are equal to or less than 3/8 in. (0.188 in./4.8 mm) in nominal thickness" (para. 1.1). AWS D1.1, Structural Welding Code — Steel, says it is not intended to be used for applications involving "steels less than 3/8 in. (3 mm) thick." This leaves an overlap between 3/8 in. (3 mm) and 3/8 in. (4.8 mm) where (apparently) both codes apply. Which one should I use for applications where the steel is in this thickness range?

A: The Engineer responsible for the project must determine which code is applicable. Applicable codes may be spelled out in contract documents or in building codes.

The overlap in thickness between the two codes has several advantages, despite the confusion created with such overlap. If a project primarily involves structural steel, and some of those thicknesses drop below 3/8 in. (4.8 mm), D1.1 can be used to address all aspects of the project, providing no materials are less than 3/8 in. (3 mm). Conversely, if a project involves primarily sheet steel, and some materials are heavier than 3/8 in. (3 mm), D1.3 can be used to govern all the project, provided no materials are thicker than 3/8 in. (4.8 mm).

One applicable code on a project has several advantages. Welders need to be qualified to only one code. Welding Procedure Specifications need only comply with one code. Inspectors need to refer to only one code. By creating an overlap in the scope of the two documents, the D1 Committee has eliminated some of the duplication that would have necessarily resulted if there were no overlap in coverage.

Consider, for example, the implications of no overlap. Assume the cut-off point was 3/8 in. (3 mm). Assume D1.1 governed 3/8 in. and greater, and D1.3 addressed less than 3/8 in. Gauge material number 10 or thicker (0.1345 in. [3.416 mm]) would need to be welded to D1.1, but number 11 (0.1196 in. [3.038 mm]) would be governed by D1.3. Two applicable codes would create unnecessary confusion. By creating the overlap, the Engineer can select the most applicable code and, in many situations, one code can be used to govern all the work being performed.

Jeff Hietpas has been involved with the welding industry for 29 years. Currently, he is Product Manager for the Three-Phase Industrial Product Group at Miller Electric Mfg. Co., Appleton, Wis.

Q: How does a wire feeder with a four drive roll system affect wire feedability compared to two drive roll systems?

A: If you're running your wire feeder on a full-time basis and are using a variety of wire diameters, it's important to consider a wire feeder with a four drive roll system. Feeders featuring a two drive roll system have proven effective, but on anything above 0.045 (and ideally 0.035 and above),
a four drive roll system will assist with a smoother feed. With larger diameter wires, there is often a great deal of cast that causes stiffening in the wire. The four drive roll system grips and straightens the wire, making for an easier feed.

However, in high fabrication shops where you’re set up to run one type of wire all day and you don’t need a lot of flexibility or range in wire (anything 0.035 and below), a two drive roll system will suffice.

Q: What’s being done with wire feeders today to help improve productivity, weld quality, and overall ease of use?

A: In recent years, wire feeders have evolved so that they provide a great number of options that either didn’t exist in the past or were not as easy to use. Some of these options include the following:

- Autodetection systems are being implemented that can tell if a feeder is hooked up to a power source with a 14-pin connection for current and voltage feedback. Newer feeders can now disregard the run-in sequence when attached to power sources without feedback, eliminating the need to remove covers and manipulate dip switches, making them ready to use out of the box, even with older power sources.

- New auxiliary menus on some machines allow welding supervisors to set locks without having to toggle dip switches. Locks are protected by codes, making it nearly impossible for individual operators to toy with settings and weld at levels not recommended or forbidden on certain applications. This is a common problem in shops where operators are welding three shifts a day and you have different welders with different tastes operating on each machine.

- Today’s wire feeder can be a source of remote amperage and voltage control that can clear your work space, allowing closer work cells, added productivity, and less clutter.

We see a lot of shops still relying on older wire feeders, mostly because they don’t know this technology exists and can greatly improve their productivity and weld quality. By simply upgrading your wire feeder, you can turn an older power source into a more productive welding unit.

Q: Why should I upgrade my wire feeder and when?

A: Wire feeders are designed to push wire. If they’re not pushing wire, it’s time to change to a newer model. It’s time to upgrade when weld quality begins to deteriorate and you begin to have other performance issues (feeding, for example). That’s the simple answer.

In reality, the evolution of wire feeding technology over the past few years has been such that a feeder implemented today can drastically outperform a feeder you purchased five years ago. Newer models allow for a greater number of programs to be stored and to be regulated within a matter of ±0 to 10 volts or 0 to 150 in./min. The enhancement of pre-flow/postflow conditions (the shielding gas dispersed before and after a welding sequence) ensures a stronger weld and drastically reduces instances of crater cracking. Remote control capabilities, locks, connection systems, and simplified menus greatly improve productivity, weld quality, and consistency. New options make many older models obsolete.

If you are in a situation where you run one wire every day, all day, upgrading is not as critical. If you’re comfortable with that feeder and don’t need it to be more flexible, by all means continue to use what works — there’s no need to complicate proven practices by adding features beyond your required functions.

Q: Why am I being told my current engine drive may not be sufficient for flux cored welding on structural steel?

A: In the past, engine-driven welding generators with a constant current (CC) output have dominated the rental and construction markets. Many contractors outfit these engine drives with a voltage-sensing wire feeder to enable flux cored welding. If you’re looking to buy a new engine drive, save the future headache and go straight for an engine drive that also features constant voltage (CV).

Many engineering firms, construction companies, and building codes no longer allow flux cored welding with a CC power source. It does not provide adequate assurance the weld is being made with the proper voltage. For this reason, CV power sources are being required, especially for nickel-alloy flux cored wires used for structural welds on buildings and bridges. Some of the self-shielded wires are particularly voltage sensitive. A wide variety of multiprocess machines are available that feature both CC and CV capabilities.

Q: How do I combat “Dirty power” [the voltage fluctuations that hamper my arc stability and weld quality]?

A: Whether it be other workers running tools and equipment off of the same primary power line, brownouts, power spikes, or generators that don’t regulate auxiliary power voltage, voltage fluctuations can cause havoc with welding parameters.

New technologies are ensuring that operators never experience a fluctuation in the welding arc. Line voltage compensation devices have been implemented on units to help curtail such fluctuations. Manufacturers are also creating new technology that makes sure the primary power remains within certain parameters. One of the newest multiprocess units available promises no arc fluctuation or wandering as long as the primary power remains within a 185 to 635-V range. That covers a “low line” 208-V primary all the way through a “high line” 575-V primary. This system takes primary power and converts it to a buss voltage, then using that buss voltage to drive the control part of the inverter mechanism.

This technology is ideal for job sites where many workers run tools off of the same power and where line transients cause voltage fluctuations.

Q: Why do I care about circuit boards in my engine drive?

A: Because they can be a giant hassle when not protected. The reality of all work areas is that they’re dirty. Between dirt, dust, humidity, and other intrusive elements of construction work, there are many things that can cause circuit board failure. While you’ll find some constant current (CC) machines that completely eliminate circuit boards, you can’t escape them entirely.

Constant voltage (CV) engine drives require at least one circuit board to control the arc and are necessary for many flux cored and gas metal arc welding (GMAW) jobs. Many new engine-drive models are implementing a single circuit board and encasing it in a “vault” of sorts. Since this practice has been implemented, circuit boards with that added protection have had a 99.71% durability rating, which is important because repairing circuit boards can cost upward of $1,000. Tip one would be to look for a machine with the fewest amount of circuit boards that still offers the welding processes you require. Since you can’t entirely get rid of them,
Rich DePue has more than 21 years' experience in the welding industry beginning with 11 years as a welder specialist at West Valley Nuclear Services. He is currently a Weld Inspection/NDE Manager for Industrial Training Consultants, Wellsville, N.Y. He is an AWS Certified Welding Inspector (CWI) and Certified Welding Educator and a New York State Department of Education Certified Welding Instructor. He also holds ASNT NDE Level III certification.

Q: I have a dependable GMAW unit and need to weld aluminum. Can I do that or should I look into other options?

A: The aluminum material thicknesses that can be welded with the GMAW process are 14 gauge and heavier. How heavy depends on the output capacity of the welding machine being used. To GMAW weld aluminum thinner than 14 gauge (0.074 in.), either specialized pulsed gas metal arc or AC gas tungsten arc welding equipment may be necessary.

Q: What is the most dependable method for welding aluminum with a GMAW machine?

A: Spray transfer is the desired mode of metal transfer for welding aluminum. Spray transfer offers a smooth transfer of molten metal droplets from the end of the electrode to the molten pool. The droplets crossing the arc are smaller in diameter than the electrode. There is no short circuiting. The deposition rate and efficiency are relatively high and the arc is smooth, stable, and stiff. The weld bead has a nice appearance and a good wash into the sides. In spray transfer mode, a large amount of heat is involved, which creates a large weld pool with good penetration that can be difficult to control and cannot be used on materials thinner than 14 gauge. This transfer will produce a hissing sound and no spatter.

Q: I'm getting a lot of melt-through. What am I doing wrong?

A: There are a number of remedies for this, one of which might be switching to the gas tungsten arc welding (GTAW) process. You're getting the melt-through due to excessive heating of the base material. This can be dealt with by increasing the travel speed and making shorter welds. Moving the arc around on the part and spreading the heat will also help. Eliminating and reducing any gaps will also prove effective, but you may have to consider switching to a thicker material or going with an AC GTAW or pulsed GMAW machine.

Q: How can I obtain welder certification?

A: In general, a welder can get certified in three ways.

1) Company certification. A welder can get certified by his or her company's procedures. Welding Procedure Specifications (WPSs) can be developed by a company in accordance with the requirements of codes, standards, or house contract requirements. With the development and qualification of a WPS, an individual can be administered a test that will qualify his or her welding skills.

2) National certification by exam. A welder can enroll in a school or attend an institution that is an approved or certified testing facility. At this facility, a test will be administered and the welder's skills evaluated and certified.

3) National, state, or municipal certification. Welder certification can be obtained by the issuance of a test by a national-, state-, or municipal-affiliated entity. A state department of transportation, utility, or public works can issue certification to national, building, or municipal codes. The military also offers certification to its codes and standards.

To summarize, to be certified means, in the eye of a qualified entity, an individual has met the requirements of a recognized code or standard. There is also up-to-date, written documentation to represent this activity.

Q: How concerned should I be about the long-term risk of illness caused by welding fumes?

A: It is best to treat all welding smoke and fumes as potentially harmful and utilize the best possible techniques and equipment to reduce exposure. Because of the melting of base and filler metal, the fumes from welding contain solid particles that can cause temporary dizziness, eye irritation, nausea, and fever. Fumes can be more serious with the welding of alloy metals such as stainless steel, manganese, and zinc, and exposure to these fumes should be kept to a minimum.

Many of the gases used in welding such as argon, helium, and carbon dioxide are nontoxic; however, their release during welding displaces oxygen. This displacement, especially in confined and poorly ventilated areas, can cause dizziness, unconsciousness, and death.

The long-term risk of health conditions because of welding has to be taken seriously. Any injurious conditions encountered will be the result of a lifetime of exposure to smoke and fumes without adequate air filtration or ventilation. Therefore, a welder must be cognizant of air quality every working day. Some tips to reduce exposure to fumes include keeping your head out of the fume plume, getting as close to the source of fume as possible with ventilation or making sure there is adequate air movement throughout the room, and properly cleaning metals prior to welding.

Q: What is a PQR?

A: PQR is an abbreviation for Procedure...
Qualification Record. A PQR is a document that represents the qualification of a welding procedure. Three ways a Welding Procedure Specification (WPS) can be qualified include:

1) Utilizing a prequalified welding procedure. Some AWS codes offer prequalified welding procedure specification data to be used for the development of a welding procedure specification that does not require testing.

2) Qualify a welding procedure by testing. Welding codes and standards usually have a specific chapter or section that addresses welding procedure qualification testing. Testing can include tensile, guided bend, radiography, ultrasonic, impact, or any combination of these.

3) Utilize noncode company procedural qualification testing. When acceptable in contract documents, a procedure can be qualified by unconventional means as required by individual company requirements providing that good engineering judgment is not compromised. Testing should be compatible with product design and intended service.

Regardless of the type of testing used to qualify a procedure, the development of a WPS and PQR should always be performed by qualified personnel such as a welding engineer or CWI.

Q: What causes porosity during welding?

A: In any welding process, porosity can be caused by the presence of contaminants or moisture in the welding zone, which includes the base metal, filler metal, shielding gas, and the surrounding atmosphere. Contaminants can include oil, dirt, grease, or cutting fluids. Concurrently, moisture can collect in the flux, shielding gas, or on the base metal, or come from the atmosphere. Porosity occurring in a welding process that utilizes an external shielding gas can occur from using too much or too little gas flow, poor gas quality, or a defective welding torch, gun, or hose.

Operator technique can also cause porosity. Electrode, torch, or gun angle can lead to porosity, as can excessive arc length, electrode extension, or travel speeds.

Q: How can I obtain NDE certification?

A: The certification of personnel performing nondestructive inspection can be accomplished by the following methods:

1) Obtain certification through training and testing by the American Society of Nondestructive Testing (ASNT). Providing the candidate has the required experience and training, ASNT has exams for all levels and all NDE methods. An inspector can participate in NDE training and testing at several schools and institutions nationwide in order to obtain ASNT certification as an NDE trainee or levels I, II, or III.

2) Utilize the requirements of ASNT-SNT-TC-1A. A company can certify its own personnel using the requirements set forth in the Recommended Practice SNT-TC-1A. These requirements include the proper number of training hours, experience hours, and written and practical testing. Such training and testing should be performed by a Level III or duly designated company party or approved third party.

Wilson Weld-O-Glass blanket.

The right curtain and blanket for every welding need.

WELDING CURTAINS - Spectra Curtain (pictured above) is Wilson's versatile and all-purpose orange transparent curtain. Other curtains which meet special needs are transparent yellow, green and gray See-Thrus. Combinations of these fabrics can be custom-made for even more specialized situations. Opaque curtains are durable Rip-Stop and quality canvas.

WELDING BLANKETS - Manufactured of high-temperature yarns. Weld-O-Glass (pictured above) replaces asbestos and does a better job. Environmentally safe, it is an excellent barrier against heat and molten metal spray. Wilson designs it in many different fabrics to fit different welding and other thermal barrier needs.

Call us at (909) 468-3636 with your welding needs and for a Wilson catalog.
Fume Filtration

In welding operations, the air that is exhausted often passes through a fume/dust collector. Most collectors remove only solid matter (fume) and not gases. The three major types of collectors for welding fume control are cartridge collectors, electrostatic precipitators, and fabric collectors.

Cartridge collectors use pleated filters made of paper or synthetic filter media. This type of collector (Figs. 1, 2) has a large media per cubic foot area for collection. It is usually efficient in collecting submicron-sized particles, but performance depends on the filter media used. Specifications should define the filtration efficiency desired. Some collectors have noncleanable cartridges, but many cartridge collectors can be cleaned on-line with a pulse of compressed air. Most cartridges are easy to handle and can be changed from outside the collector.

Electrostatic precipitators electrically charge dust and fume particles and then collect the particles on plates that are oppositely charged. This type of filter (Fig. 3) is effective on submicron-sized particles, but it must be cleaned frequently to maintain filter efficiency. Cleaning can be accomplished manually, mechanically, or with a water wash. They are not well suited for collecting high concentrations of dust or fume.

Fabric collectors are barrier-type collectors, which means the fabric and the dust collected on it act as a barrier to trap dust. These filters (Fig. 4) are typically in bag or pocket form. They are cleanable through a mechanical shaking action or through the use of compressed air. Typically, fabric collectors are not used on welding fumes because of their low efficiency in collecting submicron-sized particles. Efficiency can be improved by pre-coating the fabric, or by using more efficient filter materials.

Collectors may be contaminated with potentially hazardous materials and should be handled with care to minimize exposure. Follow the manufacturer's recommendations and instructions.

Excerpted from Ventilation Guide for Weld Fume, AWS F3.2M/F3.2:2001
Get the latest facts and code requirements for bridge building with carbon and low-alloy construction steels.

The American Welding Society has released the latest version of the D1.5 Bridge Welding Code, outlining requirements of the American Association of State Highway and Transportation Officials (AASHTO) for building highway bridges made from carbon and low-alloy construction steels. Chapters cover inspection, qualification, structural details, stud welding, welded joint details, workmanship and more. This new edition features the latest AASHTO revisions and NDE requirements, as well as a section providing a "Fracture Control Plan for Nonredundant Bridge Members." The 250-page ANSI-approved document contains 35 tables, 77 figures, and several annexes. Welding and construction professionals and designers will find this book essential for all forms of bridge work.

NEW EDITION HIGHLIGHTS:
- Implementation of U.S. Customary Units
- Provisions for undermatching electrode usage
- Added commentary section
- New requirements for the modified WPS qualification tests

AWS Bridge Welding Code (D1.5M/D1.5:2002):
List Price ................................ $180.00
AWS Members.......................... $135.00

To order your copy of the D1.5:2002 Bridge Welding Code, phone Global Engineering Documents at (800) 854-7179, or visit their webpage at: www.global.ihs.com.

An industry authority since 1928, the Structural Welding Code—Steel has been updated with information and requirements to make it an even stronger tool.

Don't wait, order your copy now!

To ORDER call 800-854-7179, fax 303-397-2740, email global@ihs.com or order via the Internet at www.global.ihs.com (mention Priority Code 936)
Photogrammetry for Dimensional Accuracy Control in Shipbuilding

The Navy Joining Center (NJC) is working with Bath Iron Works, a General Dynamics company, and Midcoast Metrology to develop and demonstrate a digital close-range photogrammetry (DCRP) metrology system to improve a shipyard's ability to measure and control cutting, welding, and fabrication operations. This project is being performed for the Office of Naval Research as a part of the Navy MANTECH’s DD(X) shipbuilding initiative. DCRP systems are capable of providing information that can improve the dimensional accuracy of components, subsequently improving part fitup and thereby improving construction efficiency, decreasing acquisition costs, and, ultimately, enhancing U.S. Naval shipyard competitiveness.

Shipbuilders report up to 30% of a total ship's welding labor costs are attributed to additional operations and rework due to improper fitup of adjacent components. Improved accuracy control is key to "neat construction" practices. In neat construction, units and blocks are designed and constructed to account for shrinkage and distortion. This minimizes the need for excessive material stock being built into components and trimmed during erection. The use of neat construction techniques improves the quality and efficiency of ship erection, fitting, and welding operations. In addition to the potential economic benefits of reduced labor and material costs, fewer schedule disruptions are also realized.

A critical component of accuracy control is the ability to identify dimensional variations normally present in the fabrication process. For neat construction, it is necessary to make corrections to fabrication and design processes to prevent future variances. Improved analysis techniques include measuring dimensional shrinkage during cutting and welding. Currently, due to the wide variation in structures and welding conditions, shrinkage estimates are based on empirical data developed by trial and error. Digital close-range photography can rapidly measure ship components and provide highly accurate dimensional data. When coupled with photogrammetry measurements and process control information, current computer models can be incorporated to aid in predicting fabrication dimensional changes.

Phase One Completed

The first phase of the project is complete. This phase demonstrated the use of photogrammetric dimensional data acquisition and control during plasma cutting of large steel plates for ship construction. A prototype photogrammetric system was developed and demonstrated at Bath Iron Works. The system was installed on a cutting machine — Fig. 1. Using a personal computer, data was successfully collected and analyzed on the shop floor. Cameras and other peripheral equipment have been identified for future use.

The work to date has indicated photogrammetry technology has great potential to make improvements in shipyard accuracy control, which will allow the U.S. shipbuilder to achieve neat construction. The team has recently launched the next phase of the project, which is to permanently install a photogrammetry system in the Bath Iron Works cutting operations and conduct proof-of-concept testing to develop and demonstrate the system during ship panel assembly operations.

For more information on the digital close-range photogrammetry metrology system, please contact Jim Dydo at (614) 688-5116, e-mail Jim_Dydo@ewi.org, or Nancy Porter at (614) 688-5194, e-mail nancy_porter@ewi.org.

Navy Joining Center Will be Presenting at DMC 2002

Visit the Navy Joining Center at the Defense Manufacturing Conference (DMC 2002) "ManTech: Strategic Edge for Transformation." The conference will be held December 2-5 at the Wyndham Anatole Hotel in Dallas, Tex. NJC will be located at Booth #205.

Information on NJC projects will be given in poster and presentation sessions.

THE ANSWER FOR INDEPENDENT WELDING SHOPS!

AWS AFFILIATE COMPANY MEMBERSHIP

MEMBER BENEFITS:

- Priceless exposure of your shop with free publicity on AWS's 40,000-visitor-a-month website.
- $50 OFF a job posting on AWS JobFind
- An AWS Individual Membership ($75 value), which includes need-to-know technical information through a FREE monthly subscription to the Welding Journal. WJ covers the latest trends, events, news and products guaranteed to make your job easier.
- Quick access to welding information through a personal library of AWS Pocket Handbooks:
  1. Everyday Pocket Handbook for Arc Welding Steel
  3. Everyday Pocket Handbook for Gas Metal Arc and Flux-Cored Arc Welding
- A 62% discount on freight shipments with Yellow Transportation, Inc.
- Practical information through The American Welder, a special section of the Welding Journal geared toward front-line welders.
- Exclusive usage of the AWS Affiliate Company Member logo on your business card and promotional material for a competitive edge.
- Wall plaque to show your company's affiliation with the world's premier welding association.
- Window decal to display on your shop's storefront.
- Free passes to the AWS Welding Show for you and your shop's best employees.
- Unmatched networking opportunities at local Section Meetings, the annual AWS Welding Show, as well as at AWS-sponsored educational events.
- Professional development via discounts on world-renowned and industry-wide AWS Certification programs, conferences and workshops.
- Technical information through a 25% Members'-only discount on 300+ industry-specific AWS Publications and technical standards.

To join, or for more information call: (800) 443-9353, ext. 480 or (305) 443-9353, ext. 480 Visit us on-line at www.aws.org

Real-world business solutions for welding and fabricating shops

AWS CORPORATE MEMBERSHIP... helping Companies (large and small) and Educational Institutions stay at the cutting edge of the materials joining industry!

AWS SUSTAINING COMPANY MEMBERSHIP

Join an elite group of over 400 AWS Sustaining Company Members and enjoy:

- Your choice of one of these money-saving benefits:
  1. AWS Standards Library ($6,500 value)
  2. Discount Promotional Package – save on Welding Journal advertising and booth space at the AWS WELDING SHOW (save thousands)
  3. 10 additional AWS Individual Memberships ($870 value)

Plus...

- 10 AWS Individual Memberships ($870 value); each Individual Membership includes a FREE subscription to the Welding Journal, a FREE AWS publication (up to a $188 value), Members'-only discounts and much more
- Free company publicity – give your company a global presence in the Welding Journal, on the AWS Website, and at the AWS WELDING SHOW
- Exclusive usage of the AWS Sustaining Company logo on your company's letterhead and on promotional materials for a competitive edge
- An attractive AWS Sustaining Company wall plaque
- Free hyperlink from AWS's 40,000-visitor-a-month website to your company's website
- 200 complimentary VIP passes to the AWS WELDING SHOW
- An additional 5% discount off the already-reduced member price of any AWS conference or seminar registration
- Up to 62% off Yellow Freight shipping charges, outbound or inbound, short or long haul

AND MUCH MORE...

Also available AWS Supporting Company Membership and AWS Educational Institution Membership

For more information on AWS Corporate Membership, call (800) 443-9353, ext. 253 or 260. E-mail: service@aws.org for an application.

AmericanWelding Society
550 N.W. LeJeune Rd.
Miami, Florida 33126
Visit our website at www.aws.org

Your organization needs solutions. AWS means answers.
Q: We have aircraft parts to be brazed to AMS 2664F, silver brazing, for use up to 800°F (427°C). The specification lists the filler metals to be used as AMS 4765 (BaG-13a), AMS 4772 (BaG-13), or, when specified, AMS 4774 (BaG-21). It further states AMS 4765 is recommended for brazing in a protective atmosphere, and AMS 4772 is recommended for use with flux. It is not indicated whether AMS 4774 (BaG-21) is to be brazed with flux or in a protective atmosphere. For AMS 2665F, silver brazing for use up to 400°F (204°C), the filler metals specified are AMS 4763 (BaG-7), AMS 4770 (BaG-1a), AMS 4771 (BaG-3), AMS 4773 (BaG-18), and AMS 4774 (BaG-21). AMS 4788 (BaG-24) may also be used when permitted by the purchaser. In this specification, flux or protective atmosphere are not specified. My question is, are all these filler metals designed for flux and can some of them be used in a protective atmosphere, which, in my case, is vacuum?

A: In earlier days, all silver filler metals were brazed using a mineral flux. Currently, all silver filler metals can be brazed using flux. In recent times, protective atmosphere brazing has entered the picture. However, cadmium and zinc will heavily vaporize from filler metals containing these elements in all of the protective atmospheres, including vacuum, thus, you are paying for an expensive filler metal and only a part of the filler metal remains on the work. Therefore, filler metals with these elements are not recommended for protective atmospheres.

Filler metals that do not contain cadmium or zinc are recommended for a vacuum atmosphere. Unless a partial pressure atmosphere is used at the higher temperatures, the silver and copper and some of the other elements will vaporize.

When brazing at the lower temperatures in a protective atmosphere, it must be remembered the atmosphere is not suitably reactive from 1000 to 1700°F (538 to 926°C). Silver filler metals do not readily wet and flow on carbon steels at these temperatures, and chromium-containing stainless steel such as 304L will oxidize and prevent all wetting and flow. Thus, it is most prudent to flux braze at these temperatures. If it is necessary to silver braze at these low temperatures, the base metals can be electrolytically nickel-plated and the silver will flow very well on the surface and in the joints.

Filler metals such as AMS 4765 (BaG-13a) AgCuNi, AMS 4774 (BaG-21) AgCuSnNi, AMS 4774 (BaG-21) AgCuSnNi, and AMS 4773 (BaG-18) AuCuSn all braze extremely well at 1850°F (1008°C) in a gas atmosphere, but they require a partial pressure in vacuum to flow well without vaporizing part of the filler metal. Note that the very volatile cadmium and zinc are missing from these filler metals.

When specifications indicate “recommend,” this is not mandatory and some judgment can be used. In reference to the...
specification not recommending either flux or a protective atmosphere, it is your option if the purchaser has not specified the brazing filler metal on the print or the purchase order. It is good to remember all of these filler metals can be brazed using flux, but it is not good to use cadmium- and zinc-containing filler metals in a protective atmosphere.

Furthermore, cadmium is a poison and a health hazard, thus it is not good to outgas the cadmium into the room or the furnace, which will create a health hazard. •

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. Readers may send questions to Mr. Peaslee c/o The Welding Journal, 550 NW LeJeune Rd., Miami, FL 33126 or via e-mail to bobpeaslee@wallcolmonoy.com.
**CONFERENCES AND EXHIBITIONS**

**23rd Army Science Conference: Transformational Science and Technology for the Army... A Race for Speed and Precision.** December 2-5, Renaissance Orlando Resort, Orlando, Fla. For conference details and registration, visit www.asc2002.com.


**NOTE: A DIAMOND (♦) DENOTES AN AWS-SPONSORED EVENT.**
aluminum usa 2003, the north american event for production, processing, and applications. september 30–october 2, 2003. navy pier, chicago, ill. for registration and complimentary tickets, e-mail: tickets@uk.dmgworldmedia.com. for conference details, contact: group managing editor ken stanford, 44 (0) 1737 855156, fax: (44) 1737 855469, e-mail: kenstanford@uk.dmgworldmedia.com; www.dmgworldmedia.com.

educational opportunities

structural welding: design and specification and steel connections: seismic applications. december 2-3, phoenix, ariz.; december 5-6, las vegas, nev. contact: steel structures technology center, 24110 meadowbrook rd., ste. 104, novi, mi 48375-3406; (248) 893-0132, fax: (248) 893-0134; www.steelstructures.com.

asme continuing education institute short courses on welding. asme section ix, welding and brazing qualifications. march 10-12, 2003, las vegas, nev.; may 5-7, 2003, houston, tex. practical welding technology. march 10-12, 2003, las vegas, nev.; june 2-4, pittsburgh, pa. contact: (800) the-asme.
The Total Welding Rod Protection System: Airtight storage and inventory control for welding electrodes and filler metals with genuine Rod Guard® welding accessories.

- Airtight
  Threaded cap with long-lasting neoprene seal.
- Reusable
  Constructed of high-impact polyethylene.
- Hi-Temp Models
  Steel-lined, heat resistant to 450°F.
- Belt Loop
  Prevents loss of contents.
- Chloride-Free
- Quality guaranteed

Available through your welding supply distributor; or contact us for more information:

K.I.W.O.T.O, Inc.
P.O. Box 1526 - WJ
Benton Harbor, MI 49022-1526
Phone: 616-926-4444
Fax: 616-926-8308
e-mail: kwoto@rodguard.com
http://www.rodguard.com


The Fabricators & Manufacturers Association, International (FMA), and the Tubular and Pipe Association, International (TPI) Courses. A course schedule is available by calling (815) 877-8775; e-mail: info@fmametalfab.org; www.fmametalfab.org.

Malcom Plastic Welding School. A comprehensive two-day, hands-on course that leads to certification in accordance with the latest European DVS-approved plastic welding standards for hot gas and extrusion welding techniques. Contact: Sheila Carpenter, Administration, Malcom Hot Air Systems, 1676 E. Main Rd., Portsmouth, RI 02871, (888) 807-4030, FAX: (401) 682-1904, e-mail: info@malcom.com; www.plasticweldingtools.com.

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

TRIANGLE ENGINEERING, INC.

Services for the Welding Industry

- Weld engineering and consulting - WPS, PQR
- Welder training and qualification coupons
- Destructive test equipment
- Full testing services

P.O. Box 1205, 6 Industrial Way
West Hanover, MA 02339
(781)878-1500 • (617)471-1762 • Fax(781)878-2547
www.trieng.com

Circle No. 37 on Reader Info-Card

YOUR NEW PLUG & WORK ROBOT CELL

Ready equipped for all kind of welding, cutting, assembling, or...

Dealers / Service-Partners wanted
M. Taddiken (Germany)
E-Mail: m.taddiken@gmx.de
Phone: +49-4241-9210444
Fax: +49-4241-9210445

SMT Systems www.smt-systeme.de

Circle No. 15 on Reader Info-Card
### Educational Opportunities

**AWS Schedule — CWI/CWE Prep Courses and Exams**

Exam application must be submitted six weeks before exam date. For exam information and an 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.

<table>
<thead>
<tr>
<th>Cities</th>
<th>Exam Prep Courses</th>
<th>CWI/CWE Exams</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
<td></td>
</tr>
<tr>
<td>Columbus, Ohio</td>
<td>February 3-7, 2003</td>
<td>February 8, 2003</td>
</tr>
<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
<td></td>
</tr>
<tr>
<td>Corpus Christi, Tex.</td>
<td>February 9-14, 2003</td>
<td>February 15, 2003</td>
</tr>
<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>9-YEAR RECERTIFICATION COURSE</td>
<td></td>
</tr>
<tr>
<td>Detroit, Mich.</td>
<td>March 31-April 5, 2003</td>
<td>March 6, 2003</td>
</tr>
<tr>
<td></td>
<td>9-YEAR RECERTIFICATION COURSE</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
<td></td>
</tr>
<tr>
<td>Knoxville, Tenn.</td>
<td>EXAM ONLY</td>
<td>January 18, 2003</td>
</tr>
<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
<td></td>
</tr>
<tr>
<td>Miami, Fla.</td>
<td>December 1-6, 2003</td>
<td>December 7, 2003</td>
</tr>
<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>9-YEAR RECERTIFICATION COURSE</td>
<td></td>
</tr>
<tr>
<td></td>
<td>9-YEAR RECERTIFICATION COURSE</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
<td></td>
</tr>
<tr>
<td>Minneapolis, Minn.</td>
<td>March 30-April 4, 2003</td>
<td>April 5, 2003</td>
</tr>
<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
<td></td>
</tr>
<tr>
<td>Mobile, Ala.</td>
<td>EXAM ONLY</td>
<td>March 29, 2003</td>
</tr>
<tr>
<td>Newark, N.J.</td>
<td>March 16-21, 2003</td>
<td>March 22, 2003</td>
</tr>
<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
<td></td>
</tr>
<tr>
<td>Norfolk, Va.</td>
<td>February 2-7, 2003</td>
<td>February 8, 2003</td>
</tr>
<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
<td></td>
</tr>
<tr>
<td>Perrysburg, Ohio</td>
<td>EXAM ONLY</td>
<td>March 15, 2003</td>
</tr>
<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
<td></td>
</tr>
<tr>
<td>Rochester, N.Y.</td>
<td>EXAM ONLY</td>
<td>March 22, 2003</td>
</tr>
<tr>
<td>St. Louis</td>
<td>EXAM ONLY</td>
<td>December 7, 2003</td>
</tr>
<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
<td></td>
</tr>
<tr>
<td>Tampa, Fla.</td>
<td>February 2-7, 2003</td>
<td>February 8, 2003</td>
</tr>
<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
<td></td>
</tr>
</tbody>
</table>

### AWS International Certification Events

**CHENNAI, INDIA**

Location: Industrial Quality Concepts

CWI Training: December 6-10; Examination: December 12

CWI Training: December 11-17; Examination: December 19

Contact: V. Raghavendran

Telephone: 44-499-3826, FAX: 44-499-3826

**SINGAPORE**

Location: Setsco Services Pte Ltd.

CWI Training: December 2-6; Examination: December 9

Telephone: 65-566-7777, FAX: 65-566-7718

**AL-KHOBAR, SAUDI ARABIA**

Location: Nondestructive Technology Testing Center (NDTTC), Damman facility

CWI Training: December 21-25; Examination: December 26

Contact: Sudhir Phansalkar

Telephone: 966-3-882-7522, FAX: 966-3-882-8417

**VENEZUELA**

Location: PDVSA/CIED, Caracas, Venezuela

Contact: Carlos Quintini

Telephone: 58212-906-4694

e-mail: quintini@pdvsa.com

---

### The NEW Watts Specialties

**CL-124 Computer-Controlled Pipe Cutting System**

**Productive** - Double or triple your pipe-cutting output.

**Economical** - The best value on the market today!

**Flexible** - Automatically cut mitered, saddle-mitered, straight-outs and multiple holes.

**Versatile** - Handle 24 inch diameters and any length with modular extensions. Use plasma or oxy-fuel as needed.

**Simple** - Easy menu-based set-up creates almost any branch angle and trunk/branch size combination in seconds!


www.watts-specialties.com email: sales@watts-specialties.com

Circle No. 39 on Reader Info-Card
Friends and Colleagues:

We're into the tenth year of the program, and 98 individuals have now entered into the fraternity of Fellows. Again, I encourage you to submit nomination packages for those individuals whom you feel have a history of accomplishments and contributions to our profession consistent with the standards set by the existing Fellows. In particular, I would make a special request that you look to the most senior members of your Section or District in considering members for nomination. In many cases, the colleagues and peers of these individuals who are the most familiar with their contributions, and who would normally nominate the candidate, are no longer with us. I want to be sure that we take the extra effort required to make sure that those truly worthy are not overlooked because no obvious individual was available to start the nomination process.

For specifics on the nomination requirements, please contact Wendy Sue Reeve, at AWS headquarters in Miami, or simply follow the instructions on the Fellows nomination form in this issue of the *Welding Journal*. Please remember, we all benefit in the honoring of those who have made major contributions to our chosen profession and livelihood. The deadline for submission is February 1, 2003. The Committee looks forward to receiving numerous Fellow nominations for 2004 consideration.

Sincerely,

Dr. Alexander Lesnewich
Chairman, AWS Fellows Selection Committee
CLASS OF 2004
FELLOW NOMINATION FORM

DATE

NAME OF CANDIDATE

AWS MEMBER NO.

YEARS OF AWS MEMBERSHIP.

HOME ADDRESS

CITY.

STATE Zip CODE

PHONE.

PRESENT COMPANY/INSTITUTION AFFILIATION.

TITLE/POSITION.

BUSINESS ADDRESS

CITY.

STATE Zip CODE

PHONE.

ACADEMIC BACKGROUND, AS APPLICABLE:

INSTITUTION.

MAJOR & MINOR.

DEGREES OR CERTIFICATES/YEAR.

LICENSED PROFESSIONAL ENGINEER: YES NO

STATE.

SIGNIFICANT WORK EXPERIENCE:

COMPANY/CITY/STATE.

POSITION.

YEARS.

COMPANY/CITY/STATE.

POSITION.

YEARS.

SUMMARIZE MAJOR CONTRIBUTIONS IN THESE POSITIONS:

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

**MOST IMPORTANT**
The Fellows Committee selection criteria are strongly based on and extracted from the categories identified below. All information and support material provided by the candidate’s Fellow Proposer, Nominating Members and peers is considered. Provide as much detailed information as possible regarding:

The candidate’s accomplishments under areas identified below (use separate sheet for each category):

A. Research & Development
B. Education
C. Manufacturing
D. Design and Inventions
E. Other (e.g., Standards Development, National and International Liaison)

Evidence of accomplishment should include sustained service and performance in the promotion of joining technology; publication of papers, articles and books; innovative development of joining technology; service to AWS and other technical societies; and list and description of patents, awards and honors.

SUBMITTED BY: PROPOSER.

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

NOMINATING MEMBER:

NOMINATING MEMBER:

NOMINATING MEMBER:

NOMINATING MEMBER:

SUBMISSION DEADLINE FEBRUARY 1, 2003
DEFINITION AND HISTORY

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

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

RULES

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

NUMBER OF FELLOWS

Maximum of 10 Fellows selected each year, as determined by the selection committee.

AWS Fellow Application Guidelines

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

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

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

Supporting Letters

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

Return completed Fellow nomination package to:

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

Telephone: 800-443-9353, extension 215

SUBMISSION DEADLINE: February 1, 2003
I want to make my own decisions about my estate plan, rather than let the state decide.

I would like my current, or up-dated, estate plan to adequately express my desires.

I would rather make a deductible bequest to the AWS Foundation than pay estate taxes, if required.

If you agree with any of the above statements, then the AWS Foundation would like to hear from you. Please call the number listed below and request our free no-obligation Estate Planning Brochure.

AWS Foundation, Inc.
550 N.W. LeJeune Road
Miami, FL 33126
Phone: 305-443-9353, extension 293

Prepare Your Estate for the Future!
This conference is specifically of interest to welding engineers, welding specialists, and all others interested in robotic welding technology and related fields. The program will include a tutorial on robotic basics, plus discussion of robotic arc welding of steel and aluminum (with case studies), the use and role of computer simulations, and other topics.

For more information, or to register, contact the AWS Conference Department at (800) 443-9353, ext. 449, or visit the AWS webpage at: www.aws.org, and go to “Conferences”.

Hotel Information:
Grosvenor Resort in the WALT DISNEY WORLD RESORT
Tel: 407-828-4444/Fax: 407-827-6314
The 2001-2002 Nominating Committee has announced those candidates who will stand for election to American Welding Society national offices for the 2003-2004 term, which begins in June 2003.

Nominated are the following:
- For president: Thomas M. Mustaleski.
- For vice president (three to be elected): James E. Greer, Damian J. Kotecki, and Gerald D. Uttrachi.
- For director-at-large: Scott Chapple and Nancy Cole.

The National Nominating Committee was chaired by Past President William L. Myers. Serving on the committee with Myers were Claudia B. Bottenfield, John C. Bruskotter, Gerald R. Crawmer, James R. “Rusty” Franklin, Jack D. Heikkinen, Richard D. Kellum, Michael D. Kersey, Gene E. Lawson, John L. Mendoza, F. R. “Bob” Schneider, Jr., Thomas A. Siewert, and Robert J. Teuscher. John J. McLaughlin served as secretary of the Committee.

The Nominating Committees for Districts 1, 4, 7, 10, 13, 16, 19, and 22 have selected the following candidates for election or reelection as District directors for three-year terms beginning June 1, 2003. The nominees are District 1 director, Russell Norris; District 4 director, Theodore R. Alberts; District 7 director, Robert J. Tabernik; District 10 director, Victor Y. Matthews; District 13 director, Jesse L. Hunter; District 16 director, Charles F. Burg; District 19 director, Phil F. Zammit; and District 22 director, Kent S. Baucher.

The District 11 Nominating Committee elected Efthiios T. “E T.” Siradakis to fulfill the remaining term of District 11 Director and Director-at-Large Nominee Scott Chapple, commencing June 1, 2003, and ending May 31, 2004.
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 was previously a senior welding engineer at the A. O. Smith Corp. (1969-1974) and electron beam welding applications engineer (1967-1969) for the Hamilton Standard Div. of the United Aircraft Corp.

Mustaleski received his undergraduate degree in metallurgical engineering at Rensselaer Polytechnic Institute in 1967. He has done subsequent graduate work in metallurgical engineering at the University of Wisconsin-Milwaukee and the University of Tennessee.

Mustaleski, who was designated a Distinguished Member of AWS in 1989, served two terms as director-at-large on the Board of Directors for the American Welding Society. While on the board, he has served on the Education, Technical, Certification and Communications Councils and the Executive Committee. He has been a member of a number of presidential task groups, including groups addressing volunteer recognition, reorganization, the ANB, the Role & Missions Committee, and Technical Department review.

Mustaleski has served as an officer in two Sections of the American Welding Society. He relinquished his post as first vice chairman of the Milwaukee Section when he left to accept employment in Oak Ridge, Tenn. As a member of the Northeast Tennessee Section, he twice served as chairman (1982-1983 and 1983-1984). He continues to serve the Section as education chairman and Foundation representative. He received the District Meritorious Award in 1989, and he has served on the Welding Advisory Committee for Oak Ridge High School.

Mustaleski is currently a member of the Product Development Committee and the Constitution and Bylaws Committee. He is also an advisory member of the C7 Committee on High Energy Beam Welding and Cutting and the C7B Subcommittee on Electron Beam Welding and Cutting. From 1981 to 1995, he served as the chairman of the C7 Committee, of which he is a founding member, and as the first chairman of its C7B Subcommittee. He was chairman of the Technical Activities Committee (1989-1992). He has also served several terms on the Technical Papers Committee. On three occasions, he has served on the National Nominating Committee. He was also a participant at the AWS Concurro, Fastigium and Continuum and the 1994 Henniker Conference. Mustaleski has also been a contributor to the Welding Handbook.

Mustaleski is a member of the Board of Trustees of the Edison Welding Institute (EWI). He previously served on the Industrial Advisory Board (IAB) and chaired the Aerospace Industry Advisory Committee for EWI. He is also a past chairman of the Department of Energy Interagency Manufacturing Operations Groups (IMO Group) 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 Irgang 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 second year as AWS vice president. He has been employed by Moraine Valley Community College (MVCC) for 27 years and is currently a professor and coordinator of the welding program. He is also president of Techno-Weld Welding Consultants. In his more than 20 years as a consultant, Greer has had extensive experience as a welding training specialist and master welder. He 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 Certification 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 is currently completing his first year as AWS vice president. In 1989, he joined The Lincoln Electric Co., where he is now technical director for stainless and high-alloy product development. Kotecki has been active in the development of welding filler metals, particularly for stainless steels and hardfacing, since 1974. Kotecki holds a Ph.D. in mechanical engineering from the University of Wisconsin-Madison.

Kotecki 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 TC44 and its Subcommittee 3.
Nominated for Vice President
Gerald D. Uttrachi

Gerald D. Uttrachi is currently serving as AWS Director-at-Large, and has been nominated as vice president. He 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 under ESAB Welding & Cutting Products.

Throughout his 39-year career in the welding industry, Uttrachi's main concern was 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 and published numerous technical papers 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 metal 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, chairman of Metric Practices Committee, and an AWS Foundation Trustee. He was 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-at-Large
Scott Chapple

Scott Chapple has been nominated to serve as director-at-large. Chapple is a welding engineer at FlexNGate LLC, a large Tier One supplier of fabricated metal products for both domestic, and foreign auto makers, in Warren, Mich.

Currently, Chapple serves on the Detroit Executive Committee; D8 Automotive Committee; D8C Automotive Subcommittee; ISAC 5, 6, 7, and 10; Standards Council; Certification Committee; Qualification Committee; Technical Papers Committee; and as a judge/welding inspector during the SkillsUSA/VICA competition.

One of Chapple's goals during his term will be working toward uniting the research and development, industrial, and grass roots production segments of the AWS to increase R&D, funding, industrial support, and technology transfer.

Nominated for Director-at-Large
Nancy Cole

Nancy Cole is a Fellow of the American Welding Society and has been a member for more than 30 years. She was recently chair of the AWS Technical Activities Committee (1997-2001), having first joined the committee as chair of the C3 Brazing and Soldering Committee (1983-1986). She was a familiar participant at the Chattanooga Section of AWS and crisscrossed the country over the years from New York, New Jersey, and Ohio to Florida and Louisiana to visit and speak to various local AWS sections.

Since the early 1970s, Cole has presented papers, published in the Welding Journal, and has helped organize and chair sessions for AWS's Professional Program and the International Brazing Conference at the Welding Show. Through AWS, the Welding Research Council, and ASM International, she is known internationally for her pioneering work on corrosion resistance of brazed joints.

While with Combustion Engineering, Cole worked on developing and manufacturing welding electrodes, submerged arc fluxes, and flux cored wire and wrote the computer program used in that process. She has experience with nondestructive examination of welds and monitored NDE of components in the field. As program manager and contract manager, she developed budgets, then monitored and controlled costs on multimillion dollar programs.

Cole spent 11 years as a researcher at Oak Ridge National Laboratory (ORNL). While at ORNL, she managed materials research at six federal laboratories, 13 universities, and 13 industrial organizations. More recently, Cole was in management before forming her own company.
Cole has been involved with standards internationally (ISO) and has attended selected ISO meetings. She is an AWS representative to ABET and participates in accreditation audits of engineering programs of several universities.

Cole has been honored with the AWS Wasserman Award for best contribution to the progress of brazing and the AWS McKay-Helm Award for a significant contribution in the field of welding. She has published more than 35 technical papers and holds three patents.

Cole received her B.S. and M.S., both in metallurgical engineering, from the University of Tennessee and was a registered Professional Engineer in the state of Tennessee. Her professional activities include membership and previous service on the Advanced Joining Committee, National Materials Advisory Board, Materials Advisory Group, Marine Board, National Research Council, AWS Awards Committee, AWS Research and Development Committee, Welding Research Council Brazing Research Committee, Paper Selection Committee for the International Brazing Conference, Tau Beta Pi, and ASM International.

**Nominated for Director**

**District 1**

**Russell Norris**

Russell Norris began his career in the welding supply industry in 1979. He currently serves as a branch manager for Merriam Graves Corp. in Portsmouth, N.H. Norris joined the AWS Maine Section in 1992 and, as a member of the SkillsUSA/VICA Weld Skills team, assisted in planning the test and aided in the procurement of materials and equipment needed for students to take part in the competition. The following year, Norris became a judge for the competition as well.

Norris has held various offices with the Maine Section including education, certification, and scholarship chairman; secretary; and chairman. In addition to his AWS activities, Norris sits on the Craft Committee of the Seacoast School of Technology in Exeter, N.H.

**Nominated Director**

**District 4**

**Theodore R. Alberts**

Theodore R. Alberts is a 30-year member of AWS and a charter member of the Southwest Virginia Section, where he is currently serving as education chairman and has been, for two terms, Section chairman.

Alberts is an associate professor and coordinator of the welding technology program at New River Community College in Dublin, Va. He has also been a welding consultant for the past 20 years. Alberts has extensive experience as a welding training specialist. In addition, he has written and supervised the qualification of many Welding Procedure Specifications and has qualified more than one thousand welders to ASME, AWS, and API codes over a span of 20 years. Alberts worked for 3 years as a welding inspector and supervisor for Chicago Bridge and Iron in its Quality Assurance Department at its Kankakee, Ill., facility.

Alberts holds both a B.S. and an M.S. in industrial technology from Northern Illinois University, Dekalb, Ill. He has been awarded the AWS District Educator Award, the Section Meritorious Award, and was selected to represent District 4 at the first AWS Leadership Symposium in August 1999 and at the first AWS Instructor's Institute in July 2001.

**Nominated Director**

**District 7**

**Robert J. Tabernik**

Robert J. Tabernik is a 1973 graduate of Case Institute of Technology with a B.S. degree in civil engineering. While at Case, he was named Civil Engineering Student of the Year and was president of the school's chapter of the American Society of Engineers. After graduation, Tabernik was employed by The Lincoln Electric Co., Cleveland, Ohio. After one year, he was transferred to the Minneapolis office, where his responsibilities included sales, demonstrations, and training in Minnesota, North Dakota, and South Dakota. In 1989, he was promoted to his current position as district manager in Columbus, Ohio. He is responsible for sales in parts of Ohio, West Virginia, and Kentucky.

Tabernik joined the American Welding Society in 1973. In 1979, he served as chairman of the Minneapolis Section. In 1992, he was chairman of the Columbus Section. Also in 1992,
Tabernik received the Section Meritorious Award. He has spoken at Section meetings throughout the country and has been active in 4-H and VICA welding programs in Minnesota and Ohio.

Nominated for Director
District 10
Victor Y. Matthews

Victor Y. Matthews is completing his first term as District 10 Director. Matthews, who is employed at The Lincoln Electric Co., is currently assigned responsibility for Cleveland-manufactured consumable products worldwide. He attended the Lincoln Welding School and earned all of the diplomas offered. He is a certified ASME and API welder.

He is a past chairman of the Cleveland Section of AWS, was chairman of the Liaison Committee for the 1995 AWS Welding Exposition, and is a member of the national Publications, Expositions, Marketing Committee.

Matthews is listed on patents in eight countries for development work he accomplished while working in the Electrode Research and Development Lab at Lincoln.

Elected Director
District 11
Efthiios T. "F. T." Siradakis

Efthiios T. "F. T." Siradakis has been a member of AWS's Saginaw Valley Section since 1982. He has held all section chairs and is active in fund raising, advisory boards of local skill centers, and support of SkillsUSA/VICA welding competitions.

Siradakis has been employed by Airgas Great Lakes, a regional company of Airgas Inc. for 21 years. He has attended product and process training with Arc-Air, ESAB Welding & Cutting Products, The Lincoln Electric Co., Miller Electric Mfg. Co., Taylor Wharton, and Victor Equipment. Positions he has held within the company include sales representative, branch manager, and strategic account manager.

Siradakis holds a B.S. degree in business from Ferris State University.

Nominated for Director
District 13
Jesse L. Hunter

Jesse L. Hunter is an active member of the AWS Peoria Section and has served as vice chairman (1994-1995), chairman (1995-1996), nominations chairman (1996-1997), and technical chairman (1997 to present). Hunter is currently completing his first term as District 13 director.

Hunter currently serves as senior staff engineer in quality control at Mitsubishi Motors Manufacturing of America in Normal, Ill. His responsibilities include, but are not limited to, stamping inspection, assembly conformation, body appearance, fit and finish, and welding in both the production and model launch phases of quality control. Hunter also conducts training in welding and weld inspection. He recently completed ANSI RAB national accreditation as auditor/lead auditor of Quality Systems/ISO 9000, 2000.

Hunter graduated in 1980 from Illinois Central College in Peoria, Ill., with an A.A.S. in welding and certificates in welding, machinist, and drafting. During this time, he worked as a technical welder and inspector for Morton Metalcraft. He then served a four-year apprenticeship in the pipe trades and completed his training to become a Building Trades Journeyman with Local #65 in Decatur, Ill. His work in the pipe trades included nuclear, food processing, and fuel production, and he is certified to ASME Section IX.

While working in the pipe trades, Hunter began teaching welding for the Bloomington Adult Education Program. He then became a full-time instructor at Lincoln High School and Lincolnland Area Vocational Center. His next teaching position was as lead welding instructor at Illinois State University, Normal, Ill., for Mitsubishi Motors Manufacturing of America (MMMA), formally Diamond Star Motors, training program. While teaching, Hunter opened his own welding repair and fabrication shop, Hunter Welding. With this, he also did private consulting and certifications. With the conclusion of the MMMA training program, Hunter became manufacturing manager and vice president of Bransfield, Inc., in Hudson, Ill.

In 1991, he earned his B.S. in industrial technology from Illinois State University, Normal, Ill.

Nominated for Director
District 16
Charles F. Burg

Charles F. Burg, a 21-year member of the American Welding Society, is a senior research technician at Iowa State University of Science and Technology's Ames Laboratory, which is a member of the Institute for Physical Research and Technology. He began welding with his father at the age of 13 in a combination gas
Charles F. Burg

Phil F. Zammit

station, repair, and job shop.

In 1972, Burg began working at Iowa State University in the Engineering Research Institute. He worked with professors and graduate students designing research specimens and/or models, which he fabricated from the design. In 1978, he moved to Ames Laboratory, where he is involved with welding and machine work on experimental equipment and ultra-high vacuum systems from drawings and verbal consultation with chemists, physicists, and metallurgists. Burg also performs visual inspection, as well as NDE tests, on vacuum systems. He has given seminars on metals, proper joint design, and welding processes for new graduate researchers. He also gives talks and demonstrations at Des Moines Area Community College adult education welding classes and Iowa Blacksmith Continuing Education seminars at Iowa State University. In 1990, he received the Superior Service Award from his peers at Ames Laboratory.

For several years, Burg has been actively involved in welding the Iowa State team’s solar-powered car for the Sunrayce 90 races. He also advises the team on material selection, joint design, and welding processes.

Burg has served as secretary/treasurer (1981–1982), chairman (1982–1983 and 1988–1989), and a board member (1980 to present) for the AWS Iowa Section. He has supervised eight CWI examinations and has also served as a proctor.

Burg served three consecutive terms as District 16 Director (1988–1994). During his tenure, he was a member of the Technical Council, Membership Committee, Education and Certification Council, Districts Council, and Board of Directors.

Phil F. Zammit was born in Malta and began his working life in an intellectual, rather than technical, career. After graduation, he worked for three years as a customs officer. He then left Malta for London, England, and worked in the Dept. of Health and Social Security. Zammit, however, found he was unhappy with a position that relied solely on his intellect. He missed using his hands. He soon traded in his suit and tie for a pair of coveralls and workboots and plunged full time into welding school. Eight months later, Zammit was welding in a London shop using mostly the oxyacetylene and gas tungsten arc processes to weld nonferrous metals.

In 1978, Zammit moved to the United States and accepted a position as a fitter/welder for R. A. Hanson Co. (RAHCO). During that time, he continued his welding education through self-study and received his CWI certification in 1985. In 1998, he accepted an opportunity to serve as quality control inspector with Red Iron Corp. (now Brooklyn Iron Works, Inc., and Brooklyn Industrial Coatings, Inc.), a steel fabrication shop. Zammit now serves as QA manager for both Brooklyn Iron Works and Brooklyn Industrial Coatings.

Aside from AWS, Zammit is active in the National Association of Coating Engineers and the Pacific Northwest Steel Fabrication Association.

Nominated for Director
District 22
Kent S. Baucher

Kent S. Baucher graduated from California State University, Fresno, in 1975. He began his career in the welding field with U.S. Steel (American Bridge) in 1979 as a machine operator, welder, and radiographer. He has also worked with magnetic particle and liquid penetrant inspection methods. He is a Level II in magnetic particle, liquid particle, and ultrasonic testing. He also holds AWS Certified Welding Inspector accreditation and is ICBO Certified in Structural Steel and Welding.

In 1989, Baucher and his current business partner began their own testing and inspection laboratory, Technion Engineering Services, Inc. The company, which currently has 38 employees, serves central California with the largest welding inspection department in the central valley. It also provides environmental and geotechnical engineering, material testing, and inspection services.

Baucher, a member of AWS since 1988, is a Charter Member of the AWS Fresno Section. He has held most offices in the Section and is currently involved in keeping the Section active by assisting in arranging speakers and meeting locations.
People Make the Difference

By Jeffrey Noruk, Larry Gross, and Ed Bohnart

Background

Robots were first used for arc welding in production in the late 1970s, but the first real successes were not registered until the early to mid 1980s. The first systems utilized welding equipment borrowed from the manual and mechanized world. The first programmers typically came from the electrical engineering or computer departments. As time progressed and robotic arc welding became a "significant niche," the welding industry began to design and build equipment especially for this market. Likewise, the manufacturing companies themselves began to recognize that to be successful, they needed a specific type of person to manage the robotic arc welding systems they were installing.

Need(s) Identified

AWS recognized the need for standards specifically geared to the robotic and automatic arc welding field and created the D16 Committee in 1989. Since then, the D16 Committee has published standards dealing with component selection, risk assessment, and "Do's and Don'ts." In 1996, it was also recognized that the "human side" needed to be addressed to allow robotic arc welding to reach its potential. This spawned the creation of a robot operator qualification document (D16.4) and recently a certification specification (QC19) and test program called Certified Automated Process-Technician/Operator (CAP).

The story of how the Certified Automated Process-Technician/Operator program grew from an idea to reality mirrors the maturing of the robotic arc welding industry and its growing success.

Why Aren't These Robots Making Money?

The first robotic arc welding robots in the early 1980s were installed by large Tier One automotive companies such as A. O. Smith Automotive Products Co. (now Tower Automotive) and large heavy equipment manufacturers such as Caterpillar. These companies had to develop their own electrical interfaces to the welding equipment, modify mostly manual and automatic peripherals, and "grow" their own support personnel. The three biggest reasons why robots have been technically and/or financially unsuccessful in the past are 1) selection of incorrect equipment, 2) failure to introduce a consistent weld joint within the tolerances of the process, and 3) lack of qualified people to operate the systems.

The AWS D16 Committee recognized this. The members first addressed the equipment issue and then the part repeatability requirements through standards and educational seminars. It wasn't realized until the mid 1990s that the single biggest hurdle to further increasing the success rate of robotic arc welding, especially among the small- to medium-sized companies, was the people. The need for qualified personnel was also buoyed by the realization that structures previously welded manually or with mechanized equipment and certified people were now being converted to robotic welding where no operator qualification requirements existed.

AWS D16 Committee Begins Its Work

In the spring of 1995, the D16 Committee received approval of its request to begin work on the first qualification document for robotic support personnel. The model for this was an existing program being used by A. O. Smith Automotive Products Co. that supported their installed base of more than 1600 arc welding robots. Key items that needed to be established included 1) what skills were needed, 2) what prerequisite education was important, 3) how a person would progress from a beginner to an experienced operator, and 4) how this could be measured.

After more than four years of work, D16.4, Specification for the Qualification of Robotic Arc Welding Personnel, was completed. It listed four levels of support personnel.

The Next Step — Certification

While the qualification document was being developed, it became apparent to committee members that a means to certify people to this standard would also be necessary. The D16 Committee commissioned a task force to quantify the perceived need and to formalize this into a marketing study, which was completed in 1999 and presented to AWS management. This study showed an industry need for such a program and that it could be an eventual revenue generator for AWS, similar to the CWI program. Permission to proceed was given, and the Certification Committee appointed a special task force to begin work on this certification. The QC19, Standard for AWS Certification of Automated Process Operators and Technicians, was the result.

Challenges Faced

The biggest hurdles faced in developing an effective certification program were 1) how to test the hands-on ability of the individual, 2) finding an adequate amount of reference books to support the development of a written test, and 3) how to effectively differentiate and test for the four different levels identified in the qualification document.

A Weld Must Be Made

Fig. 1 — Kevan Kokkonen, a welding engineer at Miller Electric Mfg. Co., inspecting the robot gun and making adjustments during practical portion of the examination.
The task force felt it was vital to require the candidate to actually make a weld with the robot. This would demonstrate the person’s programming and welding ability. Selecting the right test coupon, to represent the greatest cross section of applications while being adequately difficult, was a challenge. Initially, a curved thin sheet metal T-fillet sample was favored, but eventually it was felt that a T-fillet sample with a round tube attached was better. It is made of thicker material that better represents the market, is simpler to make, and requires the use of programming techniques such as circular interpolation and multiple weld starts/stops.

**Multiple Robot Types and Languages**

The issue of testing multiple robot types with varying programming languages is a challenge not really experienced in the CWI or Welder Qualification programs. It was decided a variety of testing facilities needed to be established based on robot type and geography. Prime locations include technical colleges and robot companies. To date, three locations have been approved (Table 1).

**Written Test**

The written test originally consisted of both a closed- and open-book test. Due to the difficulty in finding enough reference books from which applicable questions could be developed, the written open-book test was eliminated. The makeup of the questions was developed based on two criteria—what does the person need to know to be successful, and what reference material exists to support the development of questions? While an adequate number of questions on every subject was developed, it was felt that improvement would require more robot programming and more real world questions.

**How Many Levels Are Required?**

It was recognized that the four levels of operator qualification would not be possible to differentiate through testing. For this reason, Level 1 was made into a company self-certification process, Levels 2 and 3 were combined into the CAP-O class, and Level 4 became CAP-T, which requires the person be a certified welding inspector.

### Table 1 — Facilities Testing Multiple Robot Types with Varying Programming Languages

<table>
<thead>
<tr>
<th>Facility Name</th>
<th>Location</th>
<th>Robot Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milwaukee Area Technical College</td>
<td>Milwaukee, Wis.</td>
<td>ABB</td>
</tr>
<tr>
<td>Fox Valley Technical College</td>
<td>Appleton, Wis.</td>
<td>OTC</td>
</tr>
<tr>
<td>Panasonic Factory Automation</td>
<td>Chicago, Ill.</td>
<td>Panasonic</td>
</tr>
</tbody>
</table>

### Table 2 — Written Test Categories

<table>
<thead>
<tr>
<th>Topic</th>
<th>Minimum Number</th>
<th>Approximate Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weld Equipment Setup</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>Welding Processes</td>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>Weld Examination</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>Definitions and Terminology</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>Symbols — Welding &amp; Robotics</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Safety</td>
<td>14</td>
<td>12</td>
</tr>
<tr>
<td>Destructive Testing</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>Conversion and Calculations</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Robot Programming and Logic</td>
<td>25</td>
<td>20</td>
</tr>
<tr>
<td>Welding Procedures</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>Kinematic Concepts</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Robot Arc Weld Cell Components-ID</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>136 questions</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

### Table 3 — Performance Test Criteria

<table>
<thead>
<tr>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identification of Components &amp; Demonstration of Use</td>
</tr>
<tr>
<td>Demonstrations of Safe Equipment Use</td>
</tr>
<tr>
<td>Procedure and Welding Process Setup</td>
</tr>
<tr>
<td>Robot Programming and Welding of Test Piece</td>
</tr>
<tr>
<td>Weld Quality Assessment</td>
</tr>
</tbody>
</table>

A pilot test was required to determine if the difficulty of the written and performance tests were adequate and whether they could be administered fairly and safely. It was decided to hold the pilot test in the Chicago area during the 2002 Welding Show. The test experience was broadened by having three different sites with three different robot types. The proctors were selected based on their familiarity with the test and their location. Dave Erbe administered the Chicago test, Ed Bohnart the Appleton test, and Larry Gross and Jeffrey Noruk oversaw the Milwaukee test.

A total of fourteen candidates took the free test. Requirements were a completed application form, adequate experience and educational background, and a willingness to provide constructive feedback. The written test consisted of 136 multiple-choice questions covering the subjects listed in Table 2. The performance segment of the test required the demonstration of the skills listed in Table 3. Some of the most important results and lessons learned were:

- Seven questions were either eliminated from scoring altogether or more than one correct answer was allowed.
- The test plate used worked well to properly test the programming and welding skills of the candidate. Difficulty could be increased in the future by requiring the demonstration of weaving and downhill travel.
- The range of the candidates' backgrounds and experience was purposely wide to allow the difficulty of the test to be evaluated.
- The performance methodology proved workable for the three different robots utilized in the three different locations, even though the overall cell configurations were different.
- The test produced a total of five CAP-T- and six CAP-O-qualified individuals. Those CAP-T individuals are now available to become proctors themselves.
There was a need to run a second pilot test to evaluate the changes made and to increase the number of proctors. This was held in June 2002, and the findings confirmed this test was fair and ready for a widespread rollout.

Future Plans

The first CAP test open to the general industry is slated to be held in the Midwest during spring 2003. The goal is to expand into other regions of the country as the number of proctors and test facilities become available. We hope robot companies and technical colleges will provide the backbone of this infrastructure. The CAP test will, in some cases, be made an optional part of a robot company’s arc welding training course.

The need for support materials for the test, similar to that available for the CWI program, will be needed. This includes a training guide for self-study as well as AWS-sponsored training courses. The training course is currently under development. This is an area in which the D16 Committee would welcome help.

Acknowledgments

The authors would like to thank the hardworking members of the D16 and Certification Committee task force, as well as Ed Bohnart for his guidance and AWS Deputy Executive Director Jeff Hufsey, who pulled everything together to make the pilot tests a worthwhile experience.

The American Welding Society is sponsoring the Seventh Robotic Arc Welding Conference and Exhibition February 10 and 11, 2003 in Orlando, Florida. The conference will include a tutorial on robotic basics, robotic arc welding of steel and aluminum with case studies, and computer simulations. For further information, contact the AWS Conference Business Unit at (800) 443-9353 ext. 223 or, outside the United States, (305) 443-9353 ext. 223 or via e-mail to gladys@aws.org.

Submit Your Technical Committee Reports

Committee Chairmen – We want to recognize the efforts of your committee and inform our readers of its accomplishments. Send a brief profile of its activities and recent accomplishments, along with a member roster and contact numbers, and we will publish it in the Welding Journal’s Society News section.

Send your submissions to Susan Campbell, Associate Editor, American Welding Society, 550 NW LeJeune Rd., Miami, FL 33126, Telephone, (305) 443-9353 ext. 244, FAX: (305) 443-7404, e-mail: campbell@aws.org.
AWS Welcomes New Affiliate Member Companies

Port-A-Weld, Inc.
4791 SW 83 Trr.
Davie, FL 33328

AD&D Welding & Boiler Works
33 Bleachery Ct.
Warwick, RI 02886

Big Al's Welding, Inc.
27375 Elwood Dr.
Bonita Springs, FL 34135

British Columbia Rapid Transit
6800 14 Ave.
Burnaby, British Columbia V3N 4S7
Canada

Bruce Proulx Welding
79 Guelphwood Rd.
Southbridge, MA 01550

Burnell's Welding Inc.
1231 Hayes Blvd.
Bristol, PA 19007

CWI
209 N. Fry
Yates Center, KS 66783

Heavy Iron Works, Inc.
1421 NW 65 Ave.
Plantation, FL 33313

Holston Gases
964 Hwy. 26
Corbin, KY 40701

Jenkins Machine and Welding
298 W. Bypass
Moultrie, GA 31768

Knight's Piping
335 Glen St.
Summerville, SC 29483

Maple Grove Enterprise
7075 Rte. 98 N
Arcade, NY 14009

Pottstown Metal Welding Co.
350 W. High St.
Pottstown, PA 19464

Precision Welding and Fabrication
334 Hackberry St.
Magnolia, TX 77354

Precision Welding and Tool
1035 E. 7 St.
Bloomburg, PA 17815

Schutz Carbon Electrode
43 G I D C Estate
Kalol (NG), Gujarat 38275 India

AWS Welcomes New Supporting Companies

New Educational Institutions

Arcadia Valley Career Tech
650 Park Dr.
Ironton, MO 63650

Assabet Valley Vocational Technical
215 Fitchburg St.
Marlborough, MA 01752

Cerritos College
11110 East Alondra Blvd.
Norwalk, CA 90650

College of the Mainland
1200 Amburn Rd.
Texas City, Tx 77591

Delta Career Academy
6200 East Hwy. 62, Bldg. 2533
Jeffersonville, IN 47130

Kentucky Tech Garrard Co. A.T.C.
306 W. Maple Ave.
Lancaster, KY 40444

Millstream Career and Technology Center
1200 Broad Ave.
Findlay, OH 45840

New England School of Metalwork
7 Albilston Way
Auburn, ME 04210

Nova Career Centre
214 McLeon
Chateauguay, Quebec J6J 2H4
Canada

South Vo-Tech High School
930 E. Carson St.
Pittsburgh, PA 15203

West Point Career and Technology Center
East Churchill Rd.
West Point, MS 39773

New Supporting Companies

ACCELERON, Inc.
21 Lordship Rd.
East Granby, CT 06026

ILL-MO Products Co.
400 Gardner Expressway
Quincy, IL

RCC Fabricators, Inc.
2035 Rte. 206
Southampton, NJ 08088

PT. PAL INDONESIA
P.O. Box 1134
Surabaya, Jatin 60155 Indonesia

AWS Membership

Member Grades As of November 1, 2002

Sustaining Companies ..........417
Supporting Companies ..........256
Educational Institutions ..........298
Affiliate Companies ..........16

Total Corporate Members .... 987

Individual Members ..........42,890
Student Members ..........4,427

Total Members ..........47,317
Member Dues Adjustment is Rescinded

At their most recent meeting, the AWS Board of Directors voted to rescind the proposed $5 dues increase to $80 for Individual Members scheduled to take effect January 1, 2003. An announcement of this dues increase appeared in the November 2002 issue of the Welding Journal. Any Individual Member who recently renewed their membership at the $80 dues rate will have their memberships automatically extended for one month. •

Section Events Calendar

ALASKA
JANUARY 17, 2003
Activity: Technical meeting.
Topic: To be announced.

FEBRUARY 14, 2003
Activity: Welding equipment show.
Location: UAA Welding Lab, Anchorage, Alaska.

LANCASTER
JANUARY 21, 2003
Topic: Filler metal selection.

MARCH 1, 2003
Activity: Ladies’ Night Dance (a ’50s/’60s Sock Hop held with the York-Central Pennsylvania Section).
Location: Lancaster Tennis & Yacht Club.

MARCH 5, 2003
Speaker: AWS President Ernest Levert.
Topic: Keeping cool in space.

OKLAHOMA CITY
DECEMBER 20
Activity: Holiday Party.
Location: Old Oaks.

JANUARY 2003
Activity: Bowling Tournament.
Location: Bowling Green’s.

SACRAMENTO VALLEY
DECEMBER 11
Activity: Ladies’ Night Out and gift exchange.

JANUARY
No meeting.

FEBRUARY 19, 2003
Speaker: Jack Compton, welding instructor.
Affiliation: College of the Canyons.
Topic: The future of AWS.

TIDEWATER
JANUARY 16, 2003
Activity: Joint meeting with ASNT.
Topic: Marine sonic side scan sonar.

FEBRUARY 3–7, 2003
Activity: CWI seminar.

FEBRUARY 8, 2003
Activity: CWI exam.

MARCH 13, 2003
Activity: To be announced.

YORK-CENTRAL PENNSYLVANIA
JANUARY 9, 2003
Speaker: Michael Sebergandio, the AWS Matsuo Bridge Scholarship winner and Pennsylvania State University student.

FEBRUARY 6, 2003
Topic: Fox Hot Tapping

MARCH 1, 2003
Activity: Ladies’ Night Dance (a ’50s/’60s Sock Hop held with the Lancaster Section).
Location: Lancaster Tennis & Yacht Club.

MARCH 6, 2003
Speaker: AWS President Ernest Levert.

APRIL 3, 2003
Activity: Joint meeting with ASNT.

Member Dues Adjustment is Rescinded

At their most recent meeting, the AWS Board of Directors voted to rescind the proposed $5 dues increase to $80 for Individual Members scheduled to take effect January 1, 2003. An announcement of this dues increase appeared in the November 2002 issue of the Welding Journal. Any Individual Member who recently renewed their membership at the $80 dues rate will have their memberships automatically extended for one month. •

Section Events Calendar

ALASKA
JANUARY 17, 2003
Activity: Technical meeting.
Topic: To be announced.

FEBRUARY 14, 2003
Activity: Welding equipment show.
Location: UAA Welding Lab, Anchorage, Alaska.

LANCASTER
JANUARY 21, 2003
Topic: Filler metal selection.

MARCH 1, 2003
Activity: Ladies’ Night Dance (a ’50s/’60s Sock Hop held with the York-Central Pennsylvania Section).
Location: Lancaster Tennis & Yacht Club.

MARCH 5, 2003
Speaker: AWS President Ernest Levert.
Topic: Keeping cool in space.

OKLAHOMA CITY
DECEMBER 20
Activity: Holiday Party.
Location: Old Oaks.

JANUARY 2003
Activity: Bowling Tournament.
Location: Bowling Green’s.

SACRAMENTO VALLEY
DECEMBER 11
Activity: Ladies’ Night Out and gift exchange.

JANUARY
No meeting.

FEBRUARY 19, 2003
Speaker: Jack Compton, welding instructor.
Affiliation: College of the Canyons.
Topic: The future of AWS.

TIDEWATER
JANUARY 16, 2003
Activity: Joint meeting with ASNT.
Topic: Marine sonic side scan sonar.

FEBRUARY 3–7, 2003
Activity: CWI seminar.

FEBRUARY 8, 2003
Activity: CWI exam.

MARCH 13, 2003
Activity: To be announced.

YORK-CENTRAL PENNSYLVANIA
JANUARY 9, 2003
Speaker: Michael Sebergandio, the AWS Matsuo Bridge Scholarship winner and Pennsylvania State University student.

FEBRUARY 6, 2003
Topic: Fox Hot Tapping

MARCH 1, 2003
Activity: Ladies’ Night Dance (a ’50s/’60s Sock Hop held with the Lancaster Section).
Location: Lancaster Tennis & Yacht Club.

MARCH 6, 2003
Speaker: AWS President Ernest Levert.

APRIL 3, 2003
Activity: Joint meeting with ASNT.
DISTRICT 1
Director: Geoffrey H. Putnam
Phone: (802) 439-5916

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

NEW YORK
SEPTEMBER 16
Speaker: Ana Lucia Martinex, codirector of New York First Program.
Affiliation: The Lincoln Electric Co.
Topic: The New York FIRST Program, which is for inspiration and recognition of science and technology.

Lancaster Section members observe while Gerry Mletzko, right, demonstrates pipe fitting and automated pipe cutting.

DISTRICT 3
Director: Alan J. Badeaux, Sr.
Phone: (301) 449-4800, ext. 286

LANCASTER
OCTOBER 15
Speaker: Gerry Mletzko.
Affiliation: Mathey/Dearman Co.
Topic: Laser cutting technology.
Activity: Members attended pipe fitting and pipe cutting equipment demonstrations at the Thaddeus Stevens College of Technology. Students and faculty from the school's Plumbing and Pipe Fitting Technology Departments also attended.

Southwest Virginia Section members enjoying their Annual Fall Picnic.

YORK-CENTRAL PENNSYLVANIA
OCTOBER 3
Speaker: Robert Vaughn, instructor.
Topic: Plastic Welding.

York-Central Pennsylvania Secretary Claudia Bottenfield and Chairman George Bottenfield, right, presenting Robert Vaughn with a speaker's gift.

YORK-CENTRAL PENNSYLVANIA
OCTOBER 3
Speaker: Robert Vaughn, instructor.
Topic: Plastic Welding.

Southwest Virginia Section members enjoying their Annual Fall Picnic.

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

SOUTHWEST VIRGINIA
SEPTEMBER 7
Activity: Section members enjoyed the Annual Fall Picnic at Green Hill Park in Roanoke, Va. Blacksmith Brian Fritts gave live forging demonstrations.
South Carolina Chairman Gale Mole posing with the Certificate of Appreciation he received for serving as the Section's 2001-2002 chairman.

South Carolina Section Chairman Gale Mole, right, with guest speakers Jerry Butler, left, and Duane Scott during the Section's September meeting.

District 5 Director Wayne Engeron, right, presenting Florida West Coast Section member Robert Brewington with the District 5 CWI of the Year Award.

Florida West Coast Chairman Lee Clemens, left, and District 5 Director Wayne Engeron, right, presenting Lazzara Yacht owner, Greg William, second from left, and purchasing agent Dale Pollauf with an Award of Appreciation for the Section's tour of the facilities.

South Carolina Chairman Gale Mole receiving a Certificate of Appreciation for serving as the Section's 2001-2002 chairman.

FLORIDA WEST COAST
OCTOBER 9
Speakers: Dale Pollauf, Steve Lazzara, Rick Broilliari, and Neil Chandler.
Affiliation: Lazzara Yacht, Tampa, Fla.
Activities: Members toured the Lazzara Yacht plant and shipyard. District 5 Director Wayne Engeron presented Robert Brewington with the District 5 CWI of the Year Award.

Topic: Elevator and amusement park ride inspection.
Activity: Gale Mole received a Certificate of Appreciation for serving as the Section's 2001-2002 chairman.

Affiliation: Niagara Metallurgical, Inc./Technical Institute, Inc., Buffalo, N.Y.
Topic: Interpretation of X-rays.

District 5 Director Wayne Engeron, right, presenting Florida West Coast Section member Robert Brewington with the District 5 CWI of the Year Award.

SOUTH CAROLINA
SEPTEMBER 19
Speakers: Jerry Butler, administrator, and Duane Scott, field supervisor.
Affiliation: South Carolina Dept. of Labor and Licensing, Columbia, S.C.

Kerry Sabo, in white shirt, with Pittsburgh Section members during the Open House held by Lincoln and NDT Group in September.

Niagara Frontier Section Chairman Frank Schweers, right, presenting a speaker's plaque to Jim Haynes during the Section's September meeting.

District 6
Director: Neal A. Chapman
Phone: (315) 349-6960

NIAGARA FRONTIER
SEPTEMBER 19
Speaker: Jim Haynes, president.
Dayton Section Vice Chairman Bart Goings teeing off at the Annual Golf Outing.

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

PITTSBURGH
September 24
Activity: The Lincoln Electric Company's Pittsburgh Technical Center and the Non-Destructive Testing Group (NDTG) held a Joint Open House that featured testing by NDTG and live welding demonstrations.

October 8
Speaker: Michael S. Flagg, senior applications engineer.
Affiliation: The Lincoln Electric Co.

Topic: The development of waveform outputs for equipment to create arc and weld characteristics to fit a specialized need in pulse, constant voltage, constant power, and surface tension transfer applications.

DAYTON
September 30
Activity: The Section's Annual Golf Tournament was held at the Sugar Isle Golf Course in New Carlisle, Ohio.

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

NASHVILLE
August 24
Activity: The Section sponsored a golf tournament at the Farmlakes Golf Course with awards and a luncheon immediately following.

September 19
Activity: The Section cosponsored an open house and a tour of the Kirby Welding facility.

GREATER HUNTSVILLE
September 26
Speakers: James E. Swindell and Lee Flanigan.
Affiliation: Calhoun Community College.
Activity: Members toured the Aerospace Welding Department at Calhoun Community College.

HOLSTON VALLEY
October 1
Activity: Members toured the Bush Hog plant in Jonesborough, Tenn. District 8 Director Wallace Honey presented Glenn Wade with the District Director's Certificate.
Members of the Holston Valley Section during their October tour of the Bush Hog plant.

AWS President Ernest Levert, second from right, accepting a speaker's plaque from New Orleans Section First Vice Chairman David Foster, right, and, from left, District 9 Director John Bruskotter and Chairman Lenis Doiron.

NORTHEAST
MISSISSIPPI
OCTOBER 12
Activity: Section members attended the Innovations in Modern Manufacturing 2002 conference. The two-day conference was held at the Center for Manufacturing Technology on the Golden Triangle campus of East Mississippi Community College.

DISTRICT 9
Director: John Bruskotter
Phone: (504) 363-5900
NEW ORLEANS
SEPTEMBER 17
Speaker: Ernest Levert, senior staff engineer and AWS president.
Affiliation: Lockheed Martin Missiles and Fire Control, Dallas, Tex.
Topic: Welding principles on the international space station.
Activities: Levert, District 9 Director John Bruskotter, and Section Chairman Lenis Doiron presented awards. Receiving awards were David Foster, Section Meritorious Award; Byron S. Landry, District Meritorious Award; John Pajak, Section Meritorious Award and District 9 Director's Certificate Award; Paul Hebert, Section CWI of the Year Award; Travis Moore, District CWI of the Year Award; and Tony DeMarco, and Sam Bailey, District 9 Director's Certificate Awards.

Attending the Mahoning Valley 27th Annual Jim Best Memorial Golf Outing are, from left, Kevin Kreiger, Jim Rach, and Carl Ford.

Northwestern Pennsylvania members during the Section's October meeting.

DISTRICT 10
Director: Victor Y. Matthews
Phone: (216) 383-2638
MAHONING VALLEY
AUGUST 2
Activity: The Section held the 27th Annual Jim Best Memorial Golf Outing at the Tanglewood Golf Course in Pulaski, Pa.

NORTHWESTERN PENNSYLVANIA
SEPTEMBER 19
Activity: The Section held a Golf Outing at the Culbertson Hill Golf Club in Edinboro, Pa.

OCTOBER 8
Speaker: Chet Wesley, instructor/director.
Affiliation: Tri-State Business Institute.
Topic: Vocational education and starting up a new school.
DETROIT
October
Speaker: Robert K. Cohen, president.
Affiliation: Weld Computer Corp.
Topic: Quality control of resistance welds using computers.

DISTRICT 11
Director: Scott C. Chapple
Phone: (586) 772-1514

NORTHWEST OHIO
September 24
Speaker: Richard West.
Affiliation: AWS Northwest Ohio Section chairman.
Activity: A planning meeting was held.

MILWAUKEE
September 19
Activity: The Section chartered a bus for the ride to Janesville, Wis., to tour the General Motors plant.

FOX VALLEY
October 8
Speakers: Frank Vailone, laser automation consultant; Tim Fabian, product specialist; Brian Schmidt, product manager.
Affiliations: Amada America, Inc., Tristate Machinery (OMAX Abrasive Water-Jet), and Miller Electric Mfg. Co., respectively.

Topic: Cutting technologies in industry including laser, abrasive water jet, and plasma arc.

INDIANAPOLIS
September 16
Speaker: Kurt Hoffman.
Topic: Resistance Welding Transformers.

ST. LOUIS
September 18
Speaker: Kevin Showers.
Affiliation: Victor Cutting Equipment.
Topic: Oxyfuel Safety Seminar.
Activity: Kevin Showers presented in...
Lexington Section Chairman Frank McKinley, right, and Wayne County Vo-Tech Instructor Carl Watson, left, congratulate Brandon Lester for placing as fourth runner-up in the National SkillsUSA/VICA welding competition.

Lexington Section speaker Wayne Reece, standing, during his presentation in September.

Lexington Section speaker Wayne Reece, standing, during his presentation in September.

Formation on oxyfuel safety at the Iron Workers Local #392 Training Center to 85 attendees. Don Kulesun and Bill Leonard set up and prepared the facility for the seminar.

LEXINGTON
SEPTEMBER 19
Speaker: Wayne Reece.
Topic: The Miller gas tungsten arc welding machine.
Activity: Brandon Lester was honored for placing as fourth runner-up in the National SkillsUSA/VICA welding competition.

MISSISSIPPI VALLEY
SEPTEMBER 19
Activity: The Section held its Annual Fish Fry Social and established the Section’s meeting schedule through May 2003.

EASTERN IOWA
OCTOBER 22
Speaker: Jim Donaghy, shielding gas engineer.
Affiliation: Messer MG Industries.
Topic: Shielding gases.
Activities: Trips were planned for future meetings. Section officers were introduced.

DISTRICT 15
Director: J. D. Heikkinen
Phone: (218) 741-9683

ARROWHEAD
OCTOBER 1
Activity: An Executive Committee meeting was held to discuss financial aid guidelines and limitations, Section meeting attendance, future officers and candidates, and events for the 2002-2003 year.

DISTRICT 16
Director: C. F. Burg
Phone: (515) 294-5428

OKLAHOMA CITY
SEPTEMBER 12
Speaker: Mike Klegin.
Topic: Submerged arc welding and deposition rates. Variable balance of AC squarewave technology can reduce filler metal, flux, labor time, and heat input.

OCTOBER 10
Speaker: Jim Kournay.
Affiliation: Jackson Safety Products.
Topic: Eye, head, and face safety and protection.

EAST TEXAS
SEPTEMBER 19
Speaker: Angie Hill Price, associate professor.
Activity: An Executive Committee meeting was held to discuss financial aide

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

ARROWHEAD
OCTOBER 1
Activity: An Executive Committee meeting was held to discuss financial aide

EAST TEXAS
SEPTEMBER 19
Speaker: Angie Hill Price, associate professor.

WELDING JOURNAL 79
Affiliation: Texas A&M University, College Station, Tex.
Topic: Weld training program requirements for Mexico, and cultural adjustments U.S. companies operating in Mexico must make in order to be successful.
Activity: Members of the LeTourneau University AWS Student Chapter also attended the meeting.

Activity: Members of the LeTourneau University AWS Student Chapter also attended the meeting.

North Texas Section Chairman Kirk Jordan presenting guest speaker Sylvia Farris with a Section shirt in appreciation of her September presentation.

North Texas Section Chairman Kirk Jordan presenting a Section scholarship.

NORTH TEXAS
September
Speaker: Sylvia Farris, personnel placement specialist.
Affiliation: RESOURCE.
Topic: Methods of marketing yourself to employers.
Activity: Mark Knappenberger, Jason Pack, and Nicholas Rawlings each received a $500 Section scholarship. A TurboTorch ProLine kit was given away as the evening's door prize.

DISTRIBUT 18
Director: John Mendoza
Phone: (210) 860-2592

HOUSTON
September 19
Speaker: Avery Harrell, sales consultant.
Affiliation: Swagelok.
Topic: Orbital Welding.

October 16
Speakers: Steve Rowland, Paul Tews, and Joe Scott.
Affiliations: San Jacinto College, Stolt Offshore, and Devasco International, respectively.
Topic: Each speaker gave a presentation on how welding-related professions have had positive effects on their careers and the opportunities available in the welding industry today.

SPOKANE
September 18
Activity: A meeting of the Section's incoming 2002-2003 officers was held to discuss and decide the year's agenda.

Members of the Spokane Section pose for a photograph during their September meeting.

ALASKA
September 20
Speakers: John Griffith, district manager, and Dan Rogers, sales representative.
Affiliation: Thermadyne Industries and Air Liquide, respectively.
Topic: Victor's training CD-ROMs.

September 28
The SCWI/CWI/CWE Examination took place at the University of Alaska campus.

October 23
Affiliation: Alyeska Pipeline Service Company.
Topic: The bullet strikes at Milepost 399, and the bullet hole repair that took place at Milepost 400 on the Trans-Alaska Pipeline.

DISTRICT 20
Director: Jesse A. Grantham
Phone: (303) 451-6759

DISTRICT 21
Director: Les Bennett
Phone: (805) 929-2356

LONG BEACH/ORANGE COUNTY
April
Activity: The Section held Student Night. Scholarships were presented to Amanda Kinsman, David Sean John-
Long Beach/Orange County Section officers, from left, Publicity Chairman Larry Gustafson, Ladies Representative Kathy Hutchison, Treasurer Richard Hutchison, incoming Chairman Winford Sartin, and Secretary Mike Greeley pose for a photo during the Section's May installation of officers.

Long Beach/Orange County Section outgoing Chairman Robert S. Waldron, left, receiving an Appreciation Plaque from incoming Chairman Winford Sartin.

Sacramento Valley Section Treasurer Kerry Shatell, right, thanking Denny Hollison for his presentation to the Section.

DISTRICT 22

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

SACRAMENTO VALLEY

OCTOBER 16
Speaker: Denny Hollison, QA/QC department supervisor.

INTERNATIONAL SECTION

SAUDI ARABIA

JUNE 18
Speaker: Michel S. J. Ligthart, sales manager.
Affiliation: Euromate B.V., Netherlands.
Topic: Welding fumes — hazards, solutions, and regulations.

Student Activities

DISTRICT 8

Director: Wallace E. Honey
Phone: (256) 332-3366

CROSSVILLE

STUDENT CHAPTER

OCTOBER 10
Activity: The Student Chapter held a Welding Competition at the Tennessee Technology Center at Crossville.

DISTRICT 17

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

LeTOURNEAU

UNIVERSITY

STUDENT CHAPTER

SEPTEMBER 19
Speaker: Angie Hill Price, associate professor.
Affiliation: Texas A&M University, College Station, Tex.
Topic: Weld training program requirements for Mexico, and cultural adjustments U.S. companies operating in Mexico must make in order to be successful.
Activity: Members of the AWS East Texas Section joined the Student Chapter for the meeting.

DISTRICT 20

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

UTAH STATE

UNIVERSITY

STUDENT CHAPTER

SEPTEMBER
Speaker: Stan Checketts.
Affiliation: S&S POWER.
Topic: The role welding engineers have in producing the fastest and safest thrill rides in the world.
Activity: Students were invited by Checketts to ride S&S's newest rides as they are unveiled in Logan, Utah. Checketts teamed up with Clay Rasmussen to fund a senior design project.
## 2002 District and Section Awards

### MERITORIOUS AWARDS

#### 2002 District Meritorious

<table>
<thead>
<tr>
<th>Dist. Name</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rick Moody</td>
<td>Boston</td>
</tr>
<tr>
<td>Thomas Ferri</td>
<td>Boston</td>
</tr>
<tr>
<td>Frederick Windsor</td>
<td>New Jersey</td>
</tr>
<tr>
<td>James Dolan</td>
<td>New Jersey</td>
</tr>
<tr>
<td>Michael Bannell</td>
<td>York-Central Pa.</td>
</tr>
<tr>
<td>Douglas Carpenter</td>
<td>Tidewater</td>
</tr>
<tr>
<td>Charles Hunnicutt</td>
<td>Tidewater</td>
</tr>
<tr>
<td>Heath Strickland</td>
<td>Rochester</td>
</tr>
<tr>
<td>Tom Kuntzman</td>
<td>Columbus</td>
</tr>
<tr>
<td>S. D. Dean</td>
<td>Holston Valley</td>
</tr>
<tr>
<td>Dan Mobley</td>
<td>Northeast Tennessee</td>
</tr>
<tr>
<td>Eleanor Ezzell</td>
<td>Mobile</td>
</tr>
<tr>
<td>Byron Landry</td>
<td>New Orleans</td>
</tr>
<tr>
<td>Paul Null</td>
<td>Cleveland</td>
</tr>
<tr>
<td>Harry Sadler</td>
<td>Cleveland</td>
</tr>
<tr>
<td>Michael Karagoulis</td>
<td>Detroit</td>
</tr>
<tr>
<td>Thomas Teifler</td>
<td>Fox Valley</td>
</tr>
<tr>
<td>Dan McCary</td>
<td>Blackhawk</td>
</tr>
<tr>
<td>Bernard Piotrowski</td>
<td>Illinois Valley</td>
</tr>
<tr>
<td>Tully Parker</td>
<td>St. Louis</td>
</tr>
<tr>
<td>J. R. Hollers</td>
<td>Indiana</td>
</tr>
<tr>
<td>Dan Zabel</td>
<td>Southeast Nebraska</td>
</tr>
<tr>
<td>J. A. Rufer</td>
<td>Tulsa</td>
</tr>
<tr>
<td>Ernest Levert</td>
<td>North Texas</td>
</tr>
<tr>
<td>Wilson Fuselier, Jr.</td>
<td>Lake Charles</td>
</tr>
<tr>
<td>Mark Clark</td>
<td>Sabine</td>
</tr>
<tr>
<td>Shawn McDaniel</td>
<td>Puget Sound</td>
</tr>
<tr>
<td>Art Watkins</td>
<td>Eastern Idaho/Montana</td>
</tr>
<tr>
<td>Reed Nielsen</td>
<td>Utah</td>
</tr>
</tbody>
</table>

#### 2002 Section Meritorious

<table>
<thead>
<tr>
<th>Dist. Name</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>August Manz</td>
<td>New Jersey</td>
</tr>
<tr>
<td>Michael Bunnell</td>
<td>York-Central Pa.</td>
</tr>
</tbody>
</table>

### EDUCATOR AWARDS

#### 2002 Private Sector Educator District Award

<table>
<thead>
<tr>
<th>Dist. Name</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>William Campbell</td>
<td>New York</td>
</tr>
<tr>
<td>Richard Jacobs</td>
<td>Charlotte</td>
</tr>
<tr>
<td>Walter Sperko</td>
<td>Carolina</td>
</tr>
<tr>
<td>Don Russell, Jr.</td>
<td>Chattanooga</td>
</tr>
<tr>
<td>Levon Mills</td>
<td>Mobile</td>
</tr>
<tr>
<td>Byron Darcey, Jr.</td>
<td>Acadiana</td>
</tr>
<tr>
<td>Dennis Klingman</td>
<td>Cleveland</td>
</tr>
<tr>
<td>Victor Hunter</td>
<td>Blackhawk</td>
</tr>
<tr>
<td>Mark Kerley</td>
<td>Peoria</td>
</tr>
<tr>
<td>Robert Richwine</td>
<td>Indiana</td>
</tr>
<tr>
<td>Paul Maki</td>
<td>Arrowhead</td>
</tr>
<tr>
<td>J. Jones</td>
<td>North Texas</td>
</tr>
<tr>
<td>R. W. &quot;Tec&quot; Edwards</td>
<td>Lake Charles</td>
</tr>
<tr>
<td>J. W. Ralls</td>
<td>Corpus Christi</td>
</tr>
<tr>
<td>Jesse Grantham</td>
<td>Colorado</td>
</tr>
<tr>
<td>Blair Toone</td>
<td>Utah</td>
</tr>
</tbody>
</table>

#### 2002 District Educator Awards

<table>
<thead>
<tr>
<th>Dist. Name</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steve Flowers</td>
<td>Boston</td>
</tr>
<tr>
<td>Joseph Kass</td>
<td>Long Island</td>
</tr>
<tr>
<td>Joseph Gess</td>
<td>New Jersey</td>
</tr>
<tr>
<td>Randy Owens</td>
<td>Carolina</td>
</tr>
<tr>
<td>Theodore Alberts</td>
<td>Southeast Georgia</td>
</tr>
<tr>
<td>Robert Brewington</td>
<td>Florida West Coast</td>
</tr>
<tr>
<td>Tina Buchanan</td>
<td>Mid-Ohio Valley</td>
</tr>
<tr>
<td>Richard Young</td>
<td>Northwest Ohio</td>
</tr>
<tr>
<td>Christian Hudson</td>
<td>Tri-State</td>
</tr>
<tr>
<td>Bobby Graham</td>
<td>Northeast Mississippi</td>
</tr>
<tr>
<td>Jim Thompson</td>
<td>Greater Huntsville</td>
</tr>
<tr>
<td>Anthony Blakeney</td>
<td>Baton Rouge</td>
</tr>
<tr>
<td>Art Baughman</td>
<td>Stark Central</td>
</tr>
<tr>
<td>Irving &quot;Chip&quot; Rathwell</td>
<td>Cleveland</td>
</tr>
<tr>
<td>Dave Hoffman</td>
<td>Fox Valley</td>
</tr>
<tr>
<td>Mike Spangler</td>
<td>JAK</td>
</tr>
<tr>
<td>Mike Merriman</td>
<td>Blackhawk</td>
</tr>
<tr>
<td>David Viar</td>
<td>Chicago</td>
</tr>
</tbody>
</table>
# 2002 District and Section Awards

## 2002 Section Educator

<table>
<thead>
<tr>
<th>Dist. Name</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Joseph Gess</td>
<td>New Jersey</td>
</tr>
<tr>
<td>4 Sandra Johnston</td>
<td>Southwest Virginia</td>
</tr>
<tr>
<td>7 William Eric Younkins</td>
<td>Mid-Ohio Valley</td>
</tr>
<tr>
<td>7 Charles Hardbarger</td>
<td>Mid-Ohio Valley</td>
</tr>
<tr>
<td>8 Dion Frady</td>
<td>Nashville</td>
</tr>
<tr>
<td>8 Robert Thompson, Sr.</td>
<td>Holston Valley</td>
</tr>
<tr>
<td>8 Joseph Smith</td>
<td>Greater Huntsville</td>
</tr>
<tr>
<td>9 Vernon DeLaune</td>
<td>New Orleans</td>
</tr>
<tr>
<td>9 Luther Davis</td>
<td>New Orleans</td>
</tr>
<tr>
<td>9 Marcie Jacquet</td>
<td>Acadiana</td>
</tr>
<tr>
<td>9 William Jordan</td>
<td>Pascagoula</td>
</tr>
<tr>
<td>9 Darren Haas</td>
<td>Pascagoula</td>
</tr>
<tr>
<td>9 Roger Ball</td>
<td>Baton Rouge</td>
</tr>
<tr>
<td>9 James Sullivan</td>
<td>Mobile</td>
</tr>
<tr>
<td>13 Larry Clevenger</td>
<td>Blackhawk</td>
</tr>
<tr>
<td>13 Marc Churchill</td>
<td>Peoria</td>
</tr>
<tr>
<td>13 Bill Baker</td>
<td>Peoria</td>
</tr>
<tr>
<td>13 Eric Oekerhausen</td>
<td>Peoria</td>
</tr>
<tr>
<td>13 Jim Flanigan</td>
<td>JAK</td>
</tr>
<tr>
<td>13 Art Suprenant</td>
<td>JAK</td>
</tr>
<tr>
<td>13 Eldon Lafever</td>
<td>JAK</td>
</tr>
<tr>
<td>14 Philip Bedel</td>
<td>Indiana</td>
</tr>
<tr>
<td>16 John Hopwood</td>
<td>Iowa</td>
</tr>
<tr>
<td>17 Ed Norman</td>
<td>Ozark</td>
</tr>
<tr>
<td>17 Gil Linker</td>
<td>Oklahoma City</td>
</tr>
<tr>
<td>17 Charles Credcott</td>
<td>North Texas</td>
</tr>
<tr>
<td>17 Kenneth Lynn</td>
<td>San Antonio</td>
</tr>
<tr>
<td>18 Drew Fontenot</td>
<td>Lake Charles</td>
</tr>
<tr>
<td>18 Raul Robles</td>
<td>Corpus Christi</td>
</tr>
<tr>
<td>18 Stanford Jones</td>
<td>Corpus Christi</td>
</tr>
<tr>
<td>20 Lynn Baradgard</td>
<td>Utah</td>
</tr>
<tr>
<td>20 Randee Munns</td>
<td>Utah</td>
</tr>
<tr>
<td>20 Leo Castagno</td>
<td>Eastern Idaho/Montana</td>
</tr>
<tr>
<td>20 Jeff Oliver</td>
<td>Colorado</td>
</tr>
<tr>
<td>20 Russell Rux</td>
<td>Wyoming</td>
</tr>
</tbody>
</table>

## 2002 Section CWI of the Year

<table>
<thead>
<tr>
<th>Dist. Name</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 Theodore Alberts</td>
<td>Southwest Virginia</td>
</tr>
<tr>
<td>4 Bobby Perkins, Jr.</td>
<td>Northeastern Carolina</td>
</tr>
<tr>
<td>4 Gary Stilner</td>
<td>Charlotte</td>
</tr>
<tr>
<td>4 Gregory Frederick</td>
<td>Charlotte</td>
</tr>
<tr>
<td>7 Randy Dull</td>
<td>Columbus</td>
</tr>
<tr>
<td>7 Greg Reese</td>
<td>Tri-State</td>
</tr>
<tr>
<td>7 Bill Bryant</td>
<td>Columbus</td>
</tr>
<tr>
<td>8 Walter Rose</td>
<td>Holston Valley</td>
</tr>
<tr>
<td>8 Kevin Reed</td>
<td>Northeast Mississippi</td>
</tr>
<tr>
<td>9 James Ivy</td>
<td>Pascagoula</td>
</tr>
<tr>
<td>9 Eddie Coaker</td>
<td>Mobile</td>
</tr>
<tr>
<td>9 Murphy Kim LeBlanc</td>
<td>Acadiana</td>
</tr>
<tr>
<td>9 Larry Thomas</td>
<td>New Orleans</td>
</tr>
<tr>
<td>9 Paul Hebert</td>
<td>New Orleans</td>
</tr>
<tr>
<td>9 Garry Owens</td>
<td>Baton Rouge</td>
</tr>
<tr>
<td>10 David Hughes</td>
<td>Mahoning Valley</td>
</tr>
<tr>
<td>10 David Hopkins</td>
<td>Stark Central</td>
</tr>
<tr>
<td>10 Paul Betzweiser</td>
<td>Blackhawk</td>
</tr>
<tr>
<td>13 Merle Longnecker</td>
<td>Blackhawk</td>
</tr>
<tr>
<td>13 Stan Egli</td>
<td>Peoria</td>
</tr>
<tr>
<td>13 Greg Berklund</td>
<td>JAK</td>
</tr>
<tr>
<td>13 Earl Bishop</td>
<td>Chicago</td>
</tr>
<tr>
<td>13 John Kornick</td>
<td>Chicago</td>
</tr>
<tr>
<td>14 Timothy Pinson</td>
<td>Louisville</td>
</tr>
<tr>
<td>14 Pat Perkins</td>
<td>Indiana</td>
</tr>
<tr>
<td>14 Brenda Cottrell</td>
<td>St. Louis</td>
</tr>
<tr>
<td>14 Todd Hatfield</td>
<td>St. Louis</td>
</tr>
<tr>
<td>16 Michael Burdic</td>
<td>Southeast Nebraska</td>
</tr>
<tr>
<td>16 Robert Vincent</td>
<td>Lake Charles</td>
</tr>
<tr>
<td>16 Lyle Landry</td>
<td>Lake Charles</td>
</tr>
<tr>
<td>16 J. W. Ralls</td>
<td>Corpus Christi</td>
</tr>
<tr>
<td>16 Alton Wolf</td>
<td>Sabine</td>
</tr>
<tr>
<td>18 John Mendoza</td>
<td>San Antonio</td>
</tr>
<tr>
<td>18 Paul O'Leary</td>
<td>Eastern Idaho/Montana</td>
</tr>
<tr>
<td>20 Russell Rux</td>
<td>Utah</td>
</tr>
</tbody>
</table>

---

# 2002 CWI OF THE YEAR AWARDS

## 2002 District CWI of the Year

<table>
<thead>
<tr>
<th>Dist. Name</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 Anver Classens</td>
<td>Charlotte</td>
</tr>
<tr>
<td>4 Stacy Flynn</td>
<td>Richmond</td>
</tr>
<tr>
<td>4 Randy Owens</td>
<td>Carolina</td>
</tr>
<tr>
<td>5 Robert Brewington</td>
<td>Florida West Coast</td>
</tr>
</tbody>
</table>

---

**I WELDING JOURNAL**
Standards Notices

Standards for Public Review

AWS was approved as an accredited standards-preparing organization by the American National Standards Institute (ANSI) in 1979. AWS rules, as approved by ANSI, require all standards be open to public review for comment during the approval process. This column also advises of ANSI approval of documents. The following standards are submitted for public review. A draft copy may be obtained by contacting Rosalinda O’Neill at AWS, Technical Services Business Unit, 550 NW LeJeune Rd., Miami, FL 33126; telephone: (800) 443-9353, ext. 451 or, outside the United States, (305) 443-9333, ext. 451; e-mail: ronell@aws.org.


New Standard Approved by ANSI


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 or, outside the United States, (305) 443-9333.

December 4-5, Safety and Health Committee, Miami, Fla. Standards preparation and general meeting. Staff contact: Stephen P. Hedrick, ext. 305.

Deadline Nears for AWS Foundation Scholarships

Don’t forget to submit your application for an AWS Foundation National Scholarship by January 15, the deadline for the 2002-2003 school term.

For further information on the AWS Foundation scholarship and student loan programs, visit the AWS Foundation on the Web at www.aws.org/foundation.

2002-2003 Member-Get-A-Member Campaign

Listed below are the people participating in the 2002-2003 Member-Get-A-Member Campaign. For campaign rules and a prize list, please see page 75 of this Welding Journal. If you have any questions regarding your member proposer points, please call the Membership Department at (800) 443-9353 ext. 480.

Winner’s Circle

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

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

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

President’s Guild

(AWS Members supporting 20 or more new Individual Members between June 1, 2002, and May 31, 2003.)

J. Livesay, Kentucky
W. Galvrey, Jr, Long Beach/Orange Cnty
J. Goodson, New Orleans
J. A. Glauser, Houston
D. Zabel, Southeast Nebraska

President’s Round Table

(AWS Members supporting 11-19 new Individual Members between June 1, 2002, and May 31, 2003.)

G. Fairbanks, Jr, Baton Rouge
J. Grantham, Colorado

President’s Club

(AWS members supporting 6-10 new Individual Members between June 1, 2002, and May 31, 2003.)

M. Kincheloe, Holston Valley
J. Scott, Houston
G. W. Taylor, Pascagoula

President’s Honor Roll

(AWS Members sponsoring 1-5 new Individual Members between June 1, 2002, and May 31, 2003. Only those sponsoring 2 or more AWS Individual Members are listed.)

F. Luening, Houston
J. Carney, Western Michigan

Student Sponsors

(AWS members sponsoring 3 or more new AWS Student Members between June 1, 2002, and May 31, 2003.)

D. Scott, Peoria
W. Galvrey, Jr, Long Beach/Orange Cnty
B. Huff, Sunnamon Valley
C. Wesley, Northwestern Pa.
W. Harris, Pascagoula
G. Woomer, Johnstown/Altoona
J. Hayes, Oklahoma City
R. Fulmer, Twin Tiers
E. Soto Ruiz, Puerto Rico
S. Caldera, Portland
D. Combs, Santa Clara Valley
F. Madrid, Arizona
P. Walker, Ozark
J. Boyer, Lancaster
R. Grays, Kinn
C. Jones, Houston
D. Hatfield, Tulsa
T. Strickland, Arizona
P. Baldwin, Peoria
W. Kielhorn, East Texas
T. Kienbaum, Colorado
E. Norman, Ozark
S. Strader, Portland
T. Buchanana, Mid-Ohio Valley
J. Cox, Northern Plains
J. Goodson, New Orleans
J. Livesay, Nashville
A. Mattox, Lexington
T. Shir, Tidewater
D. Zabel, Southeast Nebraska
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 committee, or as a 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 Richard L. Arn, Chairman, National Nominating Committee, American Welding Society, 550 NW LeJeune Rd., Miami, FL 33126.

The next meeting of the National Nominating Committee is currently scheduled for April 2003, in Detroit, Mich. The terms of office for candidates nominated at this meeting will commence June 1, 2004.

Honorary-Meritorious Awards

The Honorary-Meritorious Awards Committee has the duty to make recommendations regarding nominees presented for Honorary Membership, National Meritorious Certificate, William Irgang 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, Executive Director, 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 Irgang Memorial Award:** This award is administered by the American Welding Society and sponsored by The Lincoln Electric Co. to honor the late William Irgang. It is awarded each year to the individual who has done the most to advance 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 should reflect “Service to the International Welding Community” in the broadest terms. The awardee is not required to be a member of the American Welding Society. Multiple awards can be given per year as the situation dictates. The award consists of a certificate to be presented at the award’s luncheon or at another time as appropriate in conjunction with the AWS President’s travel itinerary, and, if appropriate, a one-year membership to AWS.

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

April 8 – 10, 2003 • Cobo Center

Since 1999 the Motor City has been undergoing a massive renaissance. From the time you land in Detroit at the new Northwest Airlines/Edward H. McNamara World Terminal to the time you call it a day and relax in your newly renovated hotel room you will experience a new Detroit.

After the show or meeting enjoy one of three new Las Vegas style casinos, one of many new restaurants or check out a baseball game at the new Comerica Park.

Congratulations on your 50th Anniversary Welding Show

www.visitdetroit.com

For a complete list of events and other visitor information – visit www.visitdetroit.com or call 1-800-DETROIT for a free Visit Detroit magazine.
Q: I work in a small welding repair shop and am often asked to perform repair welding on aluminum structures. Sometimes I know the base metal type and sometimes I don’t. I have two questions relating to repairing aluminum. First, is there a filler metal that can be used to successfully weld all types of aluminum alloys? Second, I come into contact, from time to time, with two aluminum alloys that are difficult to obtain arc welding information about. These alloys are 2024 and 7075. Can you provide some information on how to weld these alloys with either the gas metal arc or gas tungsten arc welding processes?

A: With regard to your first question, the short answer is there is no filler metal that is suitable for welding all types of aluminum alloys. There are currently more than 400 wrought aluminum alloys and more than 200 aluminum alloys in the form of castings and ingots registered with the Aluminum Association. The alloy chemical composition limits for all these registered alloys are contained in the Aluminum Association’s teal-colored book titled International Alloy Designations and Chemical Composition Limits for Wrought Aluminum and Wrought Aluminum Alloys and in its pink-colored book titled Designations and Chemical Composition Limits for Aluminum Alloys in the Form of Castings and Ingots.

Aluminum alloys can be categorized into a number of groups based on the particular material’s characteristics, such as its ability to respond to thermal and mechanical treatment and the primary alloying element added. Probably the most important consideration encountered during repair operations is identification of the base metal type. If the base material type is not available through a reliable source, it can be difficult to select a suitable welding procedure.

There are some guides as to the most probable type of aluminum used in different applications. For example, most extruded aluminum is 6xxx series (Al-Mg-Si). In the automotive industry, air-conditioning systems and heat exchangers are typically made from 3003 sheet and 6061 tubing. Car wheels are often made from 5454, which, because of its controlled magnesium (less than 3% Mg), is suitable for temperature applications. Ship hulls are often manufactured from 5083 (5% Mg), which is recognized as a marine material.

Unfortunately, there is no guarantee. If the base material type is not known, or unavailable, the only reliable way to establish the exact type of aluminum alloy is through chemical analysis. A small sample of the base material must be sent to a reliable aluminum testing laboratory and a chemical analysis performed. Generally, the chemistry can then be evaluated and a determination made regarding the most suitable filler metal and welding procedure. Be aware that incorrect assumptions about the chemistry of an aluminum alloy can seriously affect the welding results.

In response to the second question, the reason you are having difficulty finding information on welding 2024 and 7075 is because both materials belong to a small group of aluminum alloys generally considered to be unweldable by arc welding. These materials are often found in aircraft, sporting equipment, and other types of high-performance, safety-critical equipment and are not usually arc welded on the original component. Probably the two most commonly found aluminum alloys within this category are 2024, which

is an aluminum-copper-magnesium alloy, and 7075, which is an aluminum-zinc-copper-magnesium alloy. Both materials can become susceptible to stress corrosion cracking after welding. This phenomenon is particularly dangerous because it is not detectable immediately after welding, but usually develops at a later date when the component is in service. The completed weld joint can appear to be of excellent quality immediately after welding. However, changes that occur within the base material adjacent to the weld during the welding process can produce a metallurgical condition that results in intergranular microcracking, which may be susceptible to propagation and cause failure of the welded component. Failure probability can be high, and the time to failure is generally unpredictable and dependent on various variables such as tensile stress applied to the joint, environmental conditions, and the period of time the component is subjected to these variables.

I strongly recommend great care be taken in considering the repair of components made from these materials. It must be stressed that arc welding repairs should not be performed on these alloys and they should not be returned to service if there is any possibility of a weld failure becoming the cause of damage or injury to personnel or property.

TONY ANDERSON is Technical Services Manager for AlcoTec Wire Corp., Traverse City, Mich. He is Chairman of the AWS D10H Subcommittee on Aluminum Piping and D8G Subcommittee on Automotive Arc Welding — Aluminum, Vice Chairman of the AWS D1G Subcommittee 7 on Aluminum Structures, and Chairman of the Aluminum Association Technical Advisory Committee Welding and Joining. Questions may be sent to Mr. Anderson c/o Welding Journal, 550 NW LeJeune Rd., Miami, FL 33126 or via e-mail at tanderson@alcotec.com.
The newest way to learn about welding and the welding industry through web-based training.

This 10-module course covers a broad range of instruction, from practical areas such as safety, welding processes, and welding symbols to more advanced topics like welding inspection, metallurgy, and discontinuities.

December's Featured Module
Module 8: Welding Metallurgy for Welding Personnel

The mechanical properties of metals are all affected by the metallurgical transformations that result from the elevated temperatures of welding. This module can help you better understand the behavior of metals once welded, and also help you decide which materials will be safe, economical, and high performing in different conditions.

This is just one component of the 10-module training course on welding technology. It is a must for anyone who needs to understand the welding and fabrication process at the most basic level. It is particularly valuable for those who are responsible for the specification of base or weld metal alloys and their pre- and post-weld treatments.

Call Impart Knowledge today to learn more about this exciting new training course for the welding industry.

1-888-488-5669
8:30am - 5:00pm (CST)

Visit us online at www.weldacademy.com

Circle No. 40 on Reader Info-Card
Guide Offered in Print and CD-ROM Version

The company's more than 650-page 2002-2003 Machine and Process Safeguarding Guide offers comprehensive machine and process safety product and technical reference information. It features nearly 30 new products across a broad spectrum of safety technologies, including safety light curtains, safety contact strips and bumpers, safety mats, safety interlock switches, safety monitoring relays, two-hand controls, enabling switches, and process safeguards. Each product category details product features, options, application examples, specifications, schematic/system drawings, dimensions, and ordering information. Most categories include a product selection guide. Additionally, more than 100 pages of the guide are dedicated to educational resource material, including fully illustrated articles on safety regulations and directives, risk assessment, types of protective measures, and background on safety technologies. The reference guide also comes in a CD-ROM version that contains the complete company catalog, as well as product certificates and declarations of conformity, and downloadable CAD drawings.

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

Thermal Management Guide Offers Revised Information

The company's 2003 Thermal Management Guide offers more technical information including the following:

- An overview of cold plate technologies
- A description of new Press-Lock technology
- Performance data for third-generation Kodiak® recirculating chillers
- Instructions on "How to Select a Cold-Plate, Recirculating Chiller, Ambient Coiling System, or Heat Exchanger"

- Various coolant fluid's thermal properties, product weight and volume, and conversion factors
- Specifications, performance data options, ordering information, product pictures, and selection guidelines for the company's thermal management products.

Lytron
55 Dragon Ct., Woburn, MA 01801

Brochure Describes Orbital Pipe Welding Power Source

The MPS-4000, a microprocessor-based, portable inverter power source for GMAW/FCAW process welding applications, is described in the company's brochure. Specifically designed for all-position orbital pipe welding applications, the integral weld head controller operates all Pipeliner weld head models. The power source provides synergic control of electrode speed and power output; the welder has only to change electrode speed and the power supply will adaptively correct the power supply output characteristics to maintain a stable process. Factory-developed programs are stored for many combinations of alloy, electrode diameter, and shielding gas. The power source is rated IP23 for outdoor job site usage.

Magnatech Limited Partnership
6 Kripes Rd., East Granby, CT 06026

Brochure Features Batch Ovens

The company's brochure includes information about features and specifications on 75 standard sizes of gas-fired or electric-heated walk-in ovens with gentle air circulation patterns. Heating chambers are 96 to 768 ft³ with operating tem-
temperatures up to 450°F (232°C). Standard features include solid-state digital indicating set-point controllers, gasketed door openings and heavy-duty, belt-driven blowers with magnetic motor starters.

Precision Quincy Corp.
1635 W. Lake Shore Dr., Woodstock, IL 60098
112

Brochure Highlights Plasma Cutting System

The Merlin® 6000GST automated plasma cutting system with gas-stepping technology is the subject of this four-page brochure. Specification and cutting speed charts are major features of the brochure. Considerable attention is focused on the system's automated process controls and advanced technology plasma processes. A variety of color photos and drawings illustrate the system's details. The cutting systems are designed for high-production metal cutting using oxygen, air, nitrogen, or Ar-H₂ plasma gases. The 150-A base system, consisting of a master power supply, remote arc starter box, remote current control, and a Maximizer™ 300 liquid-cooled torch with cable, hoses, and leads is rated for up to ½-in., (19.1-mm) plate. The system can be configured with a second power supply so it can become a 300-A plasma cutting system rated for 1-in., (25.4-mm) plate.

Thermal Dynamics Corp.
101 S. Hanley Rd., Ste., 600, St. Louis MO 63105
113

Application Guide Features Clean Air Systems

The full-color application guide introduces the company's full line of products. The guide is formatted to help users select equipment and applications including welding smoke and fumes, machining mist and smoke, metalworking dust, process dust and powders, and commercial applications. The guide also has detailed information on the use of source-capture vs. ambient collection equipment, which types of equipment can be used for more than one application, and sample installation photographs. Technical information and illustrations are included as well as descriptions of various filter and accessory features.

Micro Air
P.O. Box 1138, Wichita, KS 67201
114

Guide Gives Stainless Steel Welding 'How-To' Tips

Stainless Steels: Properties — How to Weld Them, Where to Use Them is available at no cost from the company. Written by experts in stainless steel applications, the main purpose of the literature is to provide a comprehensive guide to stainless steel alloys, welding processes, and consumables. The guide can be a resource for fabricators and welding engineers. Topics covered include types of stainless steels and their weldability, selecting an appropriate filler metal and arc welding process, and tips on weld preparation and operator techniques.

The Lincoln Electric Co.
22801 St. Clair Ave., Cleveland, OH 44117-1199
115

Guide Offers Space-Saving Tips

The Vertical Solutions Space Savings Guide details how welding supply storage areas can recover up to 91% valuable floor space by using Shuttle™ vertical lift modules and vertical carousels to replace conventional shelving and drawer systems. The technical data guide provides charts that relate available ceiling height to the potential number of eliminated drawer cabinets and shelving sections when vertical lift modules or vertical carousels are used in welding part storage and retrieval applications. Space savings in square feet and percentage are calculated for each ceiling height.

Remstar International Inc.
41 Eisenhower Dr., Westbrook, ME 04092
116

Alloy Source Book Is Revised and Updated

The company has completely revised and updated its AL-6XN Alloy Source Book. The new book incorporates extensive corrosion data, mechanical and physical properties, and welding guidelines along with fabrication information. Design stress information and a complete index of ASME/ASTM specifications are also included.

Rolled Alloys
125 W. Stevens Rd., Temperance, MI 48182
117
Koike Aronson Appoints President

Koike Aronson, Inc., Arcade, N.Y., has appointed Gerald J. Leary president. The company is a member of the Koike Sanso Kogyo Group, Tokyo, Japan. Most recently, Leary served as vice president and general manager of the Engineered Products Group of Mueller Industries, Port Huron, Mich. Leary is a graduate of Fairfield University, Fairfield, Conn., and earned a M.B.A. degree in marketing from River College, Nashua, N.H.

Butler Mfg. Names Vice President

Louis L. Pisani has joined the Building Division of Butler Manufacturing Co., Kansas City, Mo., as vice president of engineering and builder services. Pisani has worked for more than 27 years in the steel industry and has been with Northwestern Steel, Birmingham Steel, Inland Steel, and Rust Engineering. In addition to senior management responsibilities, he has overseen major projects, plant logistics, environmental compliance, and facilities maintenance programs. Prior to joining Butler, Pisani held the position of vice president and general manager of structural operations at the former Northwestern Steel Company in Sterling, Ill. He earned a B.S. degree in structural engineering from the University of Illinois at Chicago and a M.B.A. from the University of Chicago Graduate School of Business and is a licensed professional engineer in several states.

National-Standard Appoints Director

National-Standard, Niles, Mich., has appointed Jim Harbaugh [AWS] director of sales and marketing for the Welding Products Division. In his new position, Harbaugh is responsible for developing and implementing a business plan to maximize growth and profitability. Harbaugh has been with the company for 35 years.

PCI Adds Managers

PCI Energy Services, Lake Bluff, Ill., has promoted Mike Okolita to manager of thermal operations. Okolita joined the company in 1993 as an electronics technician. Most recently, he served as electronics supervisor at the company's headquarters in Lake Bluff. Ill. Okolita holds a B.S. in electrical engineering from Southern Illinois University.

Wall Colmonoy Adds Staff

Wall Colmonoy Corp., Madison Heights, Mich., has appointed Linda J. Fitzpatrick customer service manager for its Nicrobraz® and Colmonoy® products. Her previous experience includes ten years as a sales engineer in the machine tool industry and four years as a university-level business management instructor. Fitzpatrick holds a master's degree in management from Central Michigan University.

Michigan Arc Products Names Manager

Tom Wehner, formerly with ESAB Welding & Cutting Products, Hanover, Pa., has joined Michigan Arc Products as regional account manager for Indiana, Illinois, and Kentucky. Wehner brings 18 years of welding experience to the company.

Alloy Engineering Names Manager

Alloy Engineering Co., Berea, Ohio, has named Gerald M. Pierman as sales and marketing manager. In this position,
Pieman will oversee and coordinate the marketing efforts of the company's North American network of sales engineers and sales representatives. He most recently served as branch manager of the Cleveland District for TW Metals/Williams & Co. Pieman graduated from Cleveland State University with a degree in marketing.

Hernon Manufacturing Hires Sales Manager

Hernon Manufacturing has hired Gary Vaughn as regional sales manager for the Southeast United States territory. In this position, he will manage the company's sales representatives in this territory as well as establish and maintain relationships with authorized Hernon dealers. Vaughn holds a bachelor's degree from Arkansas State University.

Centerline Announces New Manager

Centerline LTD, Windsor, Ontario, has named Julio Villafuerte [AWS] corporate product development manager. Villafuerte has a mechanical engineering background with a M.A.Sc. and Ph.D. in welding technology from the University of Waterloo. Waterloo, Canada. He was formerly a senior technical director for Tregaskiss Ltd. and director of technology for the Welding Institute of Canada. Villafuerte is an active member of the American Welding Society, the AWS Welding Research Committee, National Electrical Manufacturers Association, Professional Engineers Ontario, and a reviewer for the ASM Journal of Materials Engineering and Performance.

PMA Elects District Chairs

Chairs have been elected to serve in twenty local chapters of the Precision Metalforming Association, Cleveland, Ohio. As district chairs, they will preside at district meetings throughout the year, establish programs, and promote and maintain membership among companies in the district.

The newly elected chairs and their districts are as follows: Wayne Agate, Canada; William Heffin, Tennessee; Robert J. Nellermann, Chicago; Jeffrey J. Pfaff, Cleveland; Patricia Westergaard, East Michigan; Herman Russi and Barry Brandt, Eastern Pennsylvania; Pete Fischer, Greater Missouri; John W. Farley, Indiana; Wayne J. Boeckman, Dallas/Fort Worth; Tammy C. Casper, North Carolina; Paul Legare, New England; Jim Vines, Northwest Ohio; Ed May, New York/New Jersey; James B. McGregor, Ohio Valley; Peter Doolittle, Southern New England; David Gaulke, Southern California; Robert R. Hurst Jr., South Carolina; Robert Duvall, Twin Cities; Robert S. Stawicki, Wisconsin; and Merle Emery, West Michigan.

Sameth Receives Charles H. Glasier Award

Jerry Sameth, an engineering manager for Matheson Tri-Gas Inc., was awarded the Charles H. Glasier Safety Award by the Compressed Gas Association (CGA). The award was presented during the 89th CGA Annual Meeting at the Saddlebrook Resort in Wesley Chapel, Fla.

This award is presented annually to an individual in recognition of safety leadership in the compressed gas industry. It is in memory of Charles H. Glasier, a former CGA chairman and leading proponent of compressed gas safety.

Sameth, who joined Matheson Tri-Gas in 1980, is cylinder and valve engineering manager for the company's Corporate Engineering Group. He graduated magna cum laude from City College of New York in 1971 with a degree in chemical engineering.

During his active participation with CGA, Sameth served as chairman, vice chairman, and voting member of several committees including Connection Standards, Pressure Relief Devices, and Cylinder Specifications.

Sameth's major accomplishments include development and implementation of the restrictive flow orifice and the DISS connection for semiconductor cylinder valves. He is also coauthor of the Matheson Tri-Gas, Inc., Gas Data Book, 7th ed., published in 2001.

Always Guaranteed Quality with ATLAS

Take the sweat out of handling, positioning, rotating, & supporting with these ATLAS welding helpers

Circle No. 1

ATLAS Pipe Supports

Four head styles:
- V-wheel
- Ball caster transfer
- Bar stock roller
- Dual wheel roller

Circle No. 2

ATLAS Roller Stands

Three head styles:
- Dual wheel roller (steel or stainless)
- Dual wheel (rubber)
- Ball caster transfer

Circle No. 3

ATLAS Pipemate and Idler Rolls

- Unit with idler rolls supports balanced loads up to 1000 lbs.
- Rotates pipe and tube up to 17° dia.
- Portable, low profile for shop or field
- Dual speed 0 to 30 in/min or 0 to 60 in/min
- High frequency filter prevents interference with GTA welding

Circle No. 4

ATLAS Rotary Table Positioners

- Two models: 9" table, 100 lb. capacity, 10" tilt table, 200 lb. capacity
- Heavy duty grounding circuit for stick electrode, MIG or TIG welding
- Low profile for bench mounting
- Foot switch for feathering speed and on/off control
- Heavy duty steel construction
- Front panel speed and rotation controls

ATLAS WELDING ACCESSORIES, INC.

Troy, MI 48099
800-962-9353
email: atlaswelding@ameritech.net

Circle No. 6 on Reader Info-Card
**Part 1 — WELDING JOURNAL SUBJECT INDEX**

A New Metal Spray Option — J. Intrater, 43 (Nov)

A New Life for Shipbuilding in Philadelphia — M. R. Johnsen, 30 (Jan)

Abrasive Wheels, Tips for Selecting — 33 (May)

Actinic Ultraviolet Emissions, Knowing the Dangers of — T. L. Lyon, 28 (Dec)

Advantages and Disadvantages, Metal Cored Wires: D. Myers, 39 (Sept)

Affiliate Company Membership Program Launched — A. Cullison, 32 (Jul)

Air Conditioning Manufacturer Explores Silicon-Tin Brazing Alloy — J. W. Harris, 42 (Oct)

Aluminum Alloy Fillet Welds, Reestablishing the Shear Strength of — R. Iasconne and C. C. Menzemer, 29 (Apr)

Aluminum Alloys, Understanding — 69 (Apr)

Aluminum Sheet, Single-Sided Projection Welding of — D. J. Spinella, 22 (Apr)

Aluminum Welds, Magnetic Pulse Welding Produces High-Strength — V. Shribman, A. Stern, Y. Livshitz, and O. Gafri, 33 (Apr)

Aluminum Winch House, Welding an — S. Collins, 95 (Sept)

Art of Welding, The — D. Yamamoto, 42 (Feb)

Astute-Class Submarines, Welding — R. G. Murray, 32 (Sept)

Barge Building, Making Waves in — 27 (Jan)

Behind the Mask: Nanette Samanich — M. R. Johnsen, 28 (March)


Brazing Alloy, Air Conditioning Manufacturer Explores Silicon-Tin — J. W. Harris, 42 (Oct)

Brazing Copper Tubing, Tips for Soldering and — A. Kireta, Jr., 36 (Aug)

Building Better Submarines in Less Time — M. R. Johnsen, 36 (May)

Brazing Tips, Flame — S. A. Urban, 38 (Oct)

Certifies Fabricators, New Program — S. T. Snyder, 38 (Feb)

Challenging Project Launches Fabricator into New Territory — 30 (Feb)

Chemical Treatment Enhances Stainless Steel Fabrication Quality — J. W. Hill, 40 (May)

Clads Ship Shafts, Electroslag Process — L. Scott and R. Andreini, 41 (Nov)

College Opens Doors for Women Welders — B. Irving, 35 (Jan)

Compressed Gases, Safe Handling of — 109 (Sept)

Copper Tubing, Tips for Soldering and Brazing — A. Kireta, Jr., 36 (Aug)

Cored Wires: Advantages and Disadvantages, Metal — D. Myers, 39 (Sept)

Cored Wires for Hardfacing, Recent Advances in — R. Menon, 53 (Nov)

Cost-Efficient Shop, Custom Fabricator Runs a — A. Cullison, 38 (Jul)

Custom Fabricator Runs A Cost-Efficient Shop — A. Cullison, 38 (Jul)

Dangers of Actinic Ultraviolet Emissions, Knowing the — T. L. Lyon, 28 (Dec)

Determining Marine Pipe Quality — J. R. Still and J. B. Speck, 54 (Jun)

Developing Optimum Toughness for GMA Welds — J. R. Matthews and D. S. Begg, 46 (May)

Electroslag Process Clads Ship Shafts — L. Scott and R. Andreini, 41 (Nov)

Fabrication Quality, Chemical Treatment Enhances Stainless Steel — J. W. Hill, 40 (May)

Fabricator into New Territory, Challenging Project Launches — 30 (Feb)

Fabricator Runs A Cost-Efficient Shop, Custom — A. Cullison, 38 (Jul)

FABTECH International Travels to Cleveland — 31 (Oct)

Fillet Welds, Reestablishing the Shear Strength of Aluminum Alloy — R. Iasconne and C. C. Menzemer, 29 (Apr)

Flame Brazing Tips — S. A. Urban, 38 (Oct)


Friction Stir Welding, Laser-Assisted — G. Kohn, Y. Greenberg, I. Mankov, and A. Muntilz, 46 (Feb)

Friction Stir Welding, Railway Manufacturers Implement — S. W. Kalle, J. Davenport, and E. D. Nicholas, 47 (Oct)

Gas Delivery Systems for CO₂ Lasers, The Importance of — P. Carlucci, 55 (Sept)

Gas Mixtures for Semiautomatic Welds, Shielding — V. Vaidya, 43 (Sept)

GMA Welds, Developing Optimum Toughness for — J. R. Matthews and D. S. Begg, 46 (May)

GTA Pipe Welds, Subsea Structural Demands High-Quality — R. O. Bews, 36 (Jun)

Guidelines Affect Flux Cored Welding in Seismic Areas, New — R. S. Funderburk, D. Krebs, and K. Lee, 32 (Mar)

Head to Toe, Protecting Welders from — T. Anderson, 69 (Sept)

Helping to Understand Power Sources — 81 (Apr)

How to Insulate Vessels Missing Their Support Pins — G. S. Crisi, 107 (Sept)

International Travels to Cleveland, FABTECH — 31 (Oct)

Insulate Vessels Missing Their Support Pins, How to — G. S. Crisi, 107 (Sept)

Knowing the Dangers of Actinic Ultraviolet Emissions — T. L. Lyon, 28 (Dec)

Laser-Assisted Friction Stir Welding — G. Kohn, Y. Greenberg, I. Mankov, and A. Muntilz, 46 (Feb)


Magnetic Pulse Welding Produces High-Strength Aluminum Welds — V. Shribman, A. Stern, Y. Livshitz, and O. Gafri, 33 (Apr)

Making Waves in Barge Building — 27 (Jan)

Mark This Event — A Great Show Is Coming Your Way — 48 (Nov)
Mask: Nanette Samanich, Behind the — M. R. Johnsen, 28 (Mar)
Membership Program Launched, Affiliate Company — A. Cullison, 32 (Jul)
Metal Cored Wires: Advantages and Disadvantages — D. Myers, 39 (Sept)
Multimedia Sources of Welding Information — M. R. Johnsen and A. Cullison, 26 (Jul)
Multiple-Wire Welding Boosts Steel Pipe Output — 44 (Jun)
Navy Upgrades Ship’s Piping — M. Sammons, 31 (Jun)
Neck Pain, Tips for Avoiding — J. W. Western, J. Rhodes, and K. Stevenson, 36 (Dec)
New Guidelines Affect Flux Cored Welding in Seismic Areas — R. S. Funderburk, D. Krebs, and K. Lee, 32 (Mar)
New Program Certifies Fabricators — S. T. Snyder, 38 (Feb)
Orbital Welds Take Flight — 40 (Jun)
Picture-Perfect Kodak, Welding Maintains a — M. R. Johnsen, 22 (Jan)
Pipe Output, Multiple-Wire Welding Boosts Steel, 44 (Jun)
Pipe Quality, Determining Marine — J. R. Still and J. B. Speck, 54 (Jun)
Pipe Welds, Subsea Structure Demands High-Quality GTA — R. O. Bews, 36 (Jun)
Piping with No Backing Gas, Welding Stainless Steel — B. Messer, G. Lawrence, V. Opera, C. Patrick, and T. Phillips, 32 (Dec)
Plutonium-Bearing Containers, Welds Safeguard— G. R. Cunnell, W. L. Daugherty, and M. W. Stokes, 42 (Jul)
Power Sources, Helping to Understand — 81 (Apr)
Production Welding Machines?, What’s New in — M. R. Johnsen and A. Cullison, 26 (Aug)
Project Launches Fabricator into New Territory, Challenging — 30 (Feb)
Projection Welding of Aluminum Sheet, Single-Sided — D. J. Spinella, 22 (Apr)
Protecting Welders from Head to Toe — 69 (Apr)
Pulse Welding Produces High-Strength Aluminum Welds, Magnetic — V. Shribman, A. Stern, Y. Livshitz, and O. Gafri, 33 (Apr)
Railway Manufacturers Implement Friction Stir Welding — S. W. Kallee, J. Davenport, and E. D. Nicholas, 47 (Oct)
Recent Advances in Cored Wires for Hard-facing — R. Menon, 53 (Nov)
Reestablishing the Shear Strength of Aluminum Alloy Fillet Welds — R. Iasconne and C. C. Menzemer, 29 (Apr)
Safe Handling of Compressed Gases — 109 (Sept)
Seismic Areas, New Guidelines Affect Flux Cored Welding in — R. S. Funderburk, D. Krebs, and K. Lee, 32 (Mar)
Semiautomatic Welds, Shielding Gas Mixture for — V. Vaidya, 43 (Sept)
Shear Strength of Aluminum Alloy Fillet Welds, Reestablishing the — R. Iasconne and C. C. Menzemer, 29 (Apr)
Sheet Metal, Tips for Successfully Welding — M. Brace and J. Brook, 23 (Mar)
Shielding Gas Mixtures for Semiautomatic Welds — V. Vaidya, 43 (Sept)
Shielding Gas, The Evolution of — N. Moyer, 51 (Sept)
Ship’s Piping, Navy Upgrades — M. Sammons, 31 (Jun)
Shipbuilding in Philadelphia, A New Life for — M. R. Johnsen, 30 (Jan)
Show — Gaining Momentum, The AWS Welding — A. Cullison, 25 (Dec)
Show Is Coming Your Way, Mark This Event — A Great — 48 (Nov)
Show 2002 in Review, Welding — A. Cullison and M. R. Johnsen, 24 (May)
Soldering and Brazing Copper Tubing, Tips for — A. Kireta, Jr., 36 (Aug)
Soldering Technology for Ultrahigh Temperatures — P. T. Bianco, 51 (Oct)
Spray Basics, Thermal — T. Degitz and K. Dobler — 50 (Nov)
Spray Option, A New Metal — J. Intrater, 43 (Nov)
Stainless Steel Fabrication Quality, Chemical Treatment Enhances — J. W. Hill, 40 (May)
Stainless Steel Piping with No Backing Gas, Welding — B. Messer, G. Lawrence, V. Opera, C. Patrick, and T. Phillips, 32 (Dec)
Submarines in Less Time, Building Better — M. R. Johnsen, 36 (May)
Subsea Structure Demands High-Quality GTA Pipe Welds — R. O. Bews, 36 (Jun)
Successfully Welding Sheet Metal, Tips for — M. Brace and J. Brook, 23 (Mar)
Systems for CO₂ Lasers, The Importance of Gas Delivery — P. Carlucci, 55 (Sept)
Technology for Ultrahigh Temperatures, Solder — P. T. Bianco, 51 (Oct)
The Art of Welding — D. Yamamoto, 42 (Feb)
The AWS Welding Show — Gaining Momentum — A. Cullison, 25 (Dec)
The Evolution of Shielding Gas — N. Moyer, 51 (Sept)
The Importance of Gas Delivery Systems for CO₂ Lasers — P. Carlucci, 55 (Sept)
Thermal Spray Basics — T. Degitz and K. Dobler, 50 (Nov)
Tips for Avoiding Neck Pain — J. W. Western, J. Rhodes, and K. Stevenson, 36 (Dec)
Tips for Selecting Abrasive Wheels — 33 (May)
Tips for Successfully Welding Sheet Metal — M. Brace and J. Brook, 23 (March)
Toughness for GMA Welds, Developing Optimum — J. R. Matthews and D. S. Begg, 46 (May)
Trucks to New York, Welding Speeds Fire — M. R. Johnsen, 34 (Feb)
Ultraviolet Emissions, Knowing the Dangers of Actinic — T. L. Lyon, 28 (Dec)
Understanding Aluminum Alloys — T. Anderson, 77 (Apr)
Welding an Aluminium Winch House — S. Collins, 95 (Sept)
Welding Asute-Class Submarines — R. G. Murray, 32 (Sept)
Welding FAQs — D. K. Miller, J. Hietpas, and R. DePue, 40 (Dec)
Welding Information, Multimedia Sources of — M. R. Johnsen and A. Cullison, 26 (Jul)
Welding Maintains a Picture-Perfect Kodak — M. R. Johnsen, 22 (Jan)
PART 2 — RESEARCH SUPPLEMENT

SUBJECT INDEX

A Study of Weld Pore Sensitivity of Self-Shielded, Flux Cored Electrodes — Q. Wei, Q. Hu, F. Guo, and D. J. Xiong, 90-S (Jun)

A Study on the Modeling of Magnetic Arc Deflection and Dynamic Analysis of Arc Sensor — Y. H. Kang and S. J. Na, 8-S (Jan)


Alloying and Microstructural Management in Developing SMAW Electrodes for HSLA-100 Steel — W. Wang and S. Liu, 132-S (Jul)

Aluminum Alloys during Welding, Liquefaction Mechanisms in Multicomponent — C. Huang and S. Kou, 211-S (Oct)

Aluminum Alloys, Weldability Testing of Dissimilar Combinations of 5000- and 6000-Series — M. M. Mossman and J. C. Lippold, 1804 (Sept)


Aluminum vs. Steel, Process Sensitivity of GMAW: — T. P. Quinn, 55-S (Apr)

ANSI/AWS A5.1-91 E6013 Rutile Electrodes: The Effect of Calcite — N. M. R. de Rissone, J. E. Farias, I. de Souza Bott, and E. S. Surian, 113-S (Jul)

Au-Ni-Ti Braze Alloy, Aging of Brazed Joints; Interface Reactions in Base Metal/Filler Metal Couples, Part II: High-

Austenite as a Hydrogen Trap in Steel Welds, Retained — Y. D. Park, I. S. Maroef, A. Landau, and D. L. Olson, 27-S (Feb)


Chloride Contributions in Flux-Assisted GTA Welding of Magnesium Alloys — M. Marya and G. R. Edwards, 291-S (Dec)


Cored Electrodes, A Study of Weld Pore Sensitivity of Self-Shielded, Flux — Q. Wei, Q. Hu, F. Guo, and D. J. Xiong, 90-S (Jun)

Cracking of Type 308 Stainless Steel, Segregation of Phosphorus and Sulfur in Heat-Affected Zone Hot — L. Li and R. W. Messler, Jr., 78-S (May)


Design-of-Experiments Study to Examine the Effect of Polarity on Stud Welding — S. R. Ramasamy, J. Gould, and D. Workman, 19-S (Feb)

Determination of Gradients in Mechanical Properties of 2.25 Cr-1Mo Weldments Using Shear-Punch Tests — V. Karthik, K. V. Kasiviswanathan, K. Laha, and B. Raj, 265-S (Dec)

Development of Appropriate Resistance Spot Welding Practice for Transformation-Hardenable Steels — W. L. Chuko and J. E. Messier, Jr., 78-S (May)

Development of CuAl10Si7 Coated Niobium Interlayer, Joining Using Semisolid Metal — P. E. Mendez, C. S. Rice, and B. Zhang, and M. Jiang, 249-S (Nov)

Dissimilar Combinations of 5000- and 6000-Series Aluminum Alloys, Weldability Testing of — M. M. Mossman, and J. C. Lippold, 188-S (Sept)


Dual Beam Laser Welding — J. Xie, 223-S (Oct)


Ferrous-Alloy Additions and Depth on the Quality of Underwater Welds, The Effect of — M. D. Rowe, S. Liu, and T. J. Reynolds, 156-S (Aug)

Flux-Assisted GTA Welding of Magnesium Alloys, Chloride Contributions in — M. Marya and G. R. Edwards, 291-S (Dec)

Flux Cored Electrodes, A Study of Weld Pore Sensitivity of Self-Shielded — Q. Wei, Q. Hu, F. Guo, and D. J. Xiong, 90-S (Jun)

Fume Model for Gas Metal Arc Welding — C. J. Redding, 95-S (Jun)

GMAW: Aluminum vs. Steel, Process Sensitivity of — T. P. Quinn, 55-S (Apr)

GMAW Using Dimensional Analysis, Selecting Parameters for — P. E. Murray, 125-S (Jul)

Gradients in Mechanical Properties of 2.25 Cr-1Mo Weldments Using Shear-Punch Tests, Determination of — V. Karthik, K. V. Kasiviswanathan, K. Laha, and B. Raj, 265 (Dec)

GTA Welding of Magnesium Alloys, Chloride Contributions in Flux-Assisted — M. Marya and G. R. Edwards, 291-S (Dec)

Hardened Steels, Development of Appropriate Resistance Spot Welding Practice for Transformation — W. L. Chuko and J. E. Gould, 1-S (Jan)


Heat-Affected Zone Characteristics in Submerged Arc Welding of Structural Steel Pipes, Prediction of — V. Gunaraj and N. Murugan, 45-S (Mar)

Heat-Affected Zone Hot Cracking of Type 308 Stainless Steel, Segregation of Phosphorus and Sulfur in — L. Li and R. W. Messler, Jr., 78-S (May)


Heat Treatments on the Weldability of Waspauloy, The Effect of Multiple Postweld — M. Quian and J. C. Lippold, 233-S (Nov)

High-Strength Structural Steel Weld under Isoheat Input Conditions, Microstructural Variations in a — B. Basu and R. Raman, 239-S (Nov)


HSLA-100 Steel, Alloying and Microstructural Management in Developing SMAW Electrodes for — W. Wang and S. Liu, 132-S (Jul)

Hydrogen Trap in Steel Welds, Retained Austenite as a — Y. D. Park, I. S. Maroef, A. Landau, and D. L. Olson, 27-S (Feb)

In-Service Gas Pipelines, Numerical Simulation of Sleeve Repair Welding of — I.-W. Bang, Y.-P. Son, K. H. Oh, Y.-P. Kim, and W.-S. Kim, 273-S (Dec)

Investigation of Monitoring Systems for Resistance Spot Welding — C.-S. Chien, and E. Kannaty-Anisb, Jr., 195-S (Sept)

Isoheat Input Conditions, Microstructural Variations in a High-Strength Structural Steel Weld under — B. Basu and R. Raman, 239-S (Nov)


Lap Joints Determined by Outer Surface Strains, Stresses in Laser-Beam-Welded — S. Zhang, 14-S (Jan)

Laser-Beam-Welded Lap Joints Determined by Outer Surface Strains, Stresses in — S. Zhang, 14-S (Jan)


Laser Welding, Weld Morphology and Thermal Modeling in Dual Beam — J. Xie, 283-S (Dec)

Laser Welding, Dual Beam — J. Xie, 223-S (Oct)

Liquation Mechanisms in Multicomponent Aluminum Alloys during Welding — C. Huang and S. Kou, 211-S (Oct)
Sulfur in Heat-Affected Zone Hot Cracking of Type 308 Stainless Steel, Segregation of Phosphorus and — L. Li and R. W. Messler, Jr., 78-S (May)

Submerged Arc Welding of Structural Steel Pipes, Prediction of Heat-Affected Zone Characteristics in — V. Gunaraj and N. Murugun, 45-S (Mar)


The Effect of Ferro-Alloy Additions and Depth on the Quality of Underwater Wet Welds — M. D. Rowe, S. Liu, and T. J. Reynolds, 156-S (Aug)

The Effect of Multiple Postweld Heat Treatment Cycles on the Weldability of Waspaloy® — M. Quian and J. C. Lippold, 233-S (Nov)

The Stress Field Characteristics in the Surface Mount Solder Joints under Temperature Cycling: Temperature Effect and Its Evaluation — Y. Y. Qian, X. Ma, and F. Yoshida, 85-S (Jun)

Thermal Modeling in Dual-Beam Laser Welding, Weld Morphology and — J. Xie, 283-S (Dec)


Underwater Wet Welds, The Effect of Ferro-Alloy Additions and Depth on the Quality of — M. D. Rowe, S. Liu, and T. J. Reynolds, 156-S (Aug)


Weld Morphology and Thermal Modeling in Dual-Beam Laser Welding — J. Xie, 283-S (Dec)

Weldability of Waspaloy®, The Effect of Multiple Postweld Heat Treatment Cycles on the — M. Quian and J. C. Lippold, 233-S (Nov)

Weldability Testing of Dissimilar Combinations of 5000- and 6000-Series Aluminum Alloys — M. M. Mossman and J. C. Lippold, 188-S (Sept)


Weldments Using Shear-Punch Tests, Determination of Gradients in Mechanical Properties of 2.25Cr-1Mo — V. Karthik, K. V. Kusiviswanathan, K. Laha, and B. Raj, 265-S (Dec)

AUTHORS FOR RESEARCH SUPPLEMENTS


Bang, J.-W., Son, Y.-P., Oh, K. H., Kim, Y.-P., and Kim, W.-S. — Numerical Simulation of Sleeve Repair Welding of In-Service Gas Pipelines, 273-S (Dec)


Basu, B., and Raman, R. — Microstructural Variations in a High-Strength Structural Steel Weld under Isoheat Input Conditions, 239-S (Nov)


Butler, D., Elmer, J. W., Terrill, P., and Brasher, D. — Joining Depleted Uranium to High-Strength Aluminum Using an Explosively Clad Niobium Interlayer, 167-S (Aug)


Cho, Y., and Rhee, S. — Primary Circuit Dynamic Resistance Monitoring and Its Application to Quality Estimation during Resistance Spot Welding, 104-S (Jun)


de Souza Bott, I., Surian, E. S., de Rissone, N. M. R., and Farias, J. P. — ANSI/AWS A5.1-1 E6013 Rutile Electrodes: The Effect of Calcite, 113-S (Jul)

Edwards, G. R., and Marya, M. — Chloride Contributions in Flux-Assisted GTA Welding Magnesium Alloy, 291-S (Dec)

Elmer, J. W., Terrill, P., Brasher, D., and Butler, D. — Joining Depleted Uranium to High-Strength Aluminum Using an Explosively Clad Niobium Interlayer, 167-S (Aug)


Guo, F., Xiong, D. J., Wei, Q., and Hu, Q. — A Study of Weld Pore Sensitivity of Self-Shielded, Flux Cored Electrodes, 90-S (Jun)


Hu, Q., Guo, F., Xiong, D. J., and Wei, Q. — A Study of Weld Pore Sensitivity of Self-Shielded, Flux Cored Electrodes, 90-S (Jun)

Huang, C., and Kou, S. — Liquidation Mechanisms in Multicomponent Aluminum Alloys during Welding, 211-S (Oct)


Kang, Y. H., and Na, S. J. — A Study on the Modeling of Magnetic Arc Deflection and Dynamic Analysis of Arc Sensor, 8-S (Jan)


Kim, W.-S., Bang, I.-W., Son, Y.-P., Oh, K. H., and Kim, Y.-P. — Numerical Simulation of Sleeve Repair Welding of In-Service Gas Pipelines, 273-S (Dec)

Kim, W.-Y., and Bang, K.-S. — Estimation and Prediction of HAZ Softening in Thermomechanically Controlled-Rolled and Accelerated-Cooled Steel, 174-S (Aug)

Kim, Y.-P., Kim, W.-S., Bang, I.-W., Son, Y.-P., and Oh, K. H. — Numerical Simulation of Sleeve Repair Welding of In-Service Gas Pipelines, 273-S (Dec)

Kou, S., and Huang, C. — Liquidation Mechanisms in Multicomponent Aluminum Alloys during Welding, 211-S (October)


Li, L. I., and Messler, Jr., R. W. — Segregation of Phosphorus and Sulfur in Heat-Affected Zone Hot Cracking of Type 308 Stainless Steel, 78-S (May)


Lippold, J. C., and Mossman, M. M. — Weldability Testing of Dissimilar Combinations of 5000- and 6000-Series Aluminum Alloys, 188-S (Sept)

Lippold, J. C. and Quian, M. — The Effect of Multiple Postweld Heat Treatment Cycles on the Weldability of Waspaloy®, 233-S (Nov)

Liu, S., Reynolds, T. J., and Rowe, M. D. — The Effect of Ferro-Alloy Additions and Depth on the Quality Underwater Wet Welds, 156-S (Aug)

Liu, S., and Wang, S. — Alloying and Microstructural Development in Managing SMAW electrodes for HSLA-100 Steel, 132-S (Jul)

Ma, X., Yoshida, F., and Qian, Y. Y. — The Stress Field Characteristics in the Surface Mount Solder Joints under Temperature Cycling: Temperature Effect and Its Evaluation, 85-S (Jun)

Marya, M., and Edwards, G.R. — Chloride Contributions in Flux-Assisted GTA Welding Magnesium Alloy, 291-S (Dec)


Messler, Jr., R. W., and Li, L. — Segregation of Phosphorus and Sulfur in Heat-Affected Zone Hot Cracking of Type 308 Stainless Steel, 78-S (May)


Murray, P. E. — Selecting Parameters for GMAW Using Dimensional Analysis, 125-S (Jul)


EMPLOYMENT

Sales Management Positions - Technical Sales

Manufacturing of tubular welding wires located in Florence, Kentucky, is currently looking to hire two managers to be based at the Florence facility. Qualified candidates should have a degree in welding engineering or equivalent degree with welding experience using MIG, FCAW and SAW processes. Must be able to effectively deal with customers on an inside as well as outside sales basis. Other duties will include involvement with daily operations, account management, technical welding applications and expansion of the business. We offer a competitive salary with benefits package. This is a unique opportunity for an individual interested in becoming an integral part of an international business management team. Please send resume (including salary history/requirements) to Jeff Schnabel, Welding Alloys USA Inc., 8535 Dixie Highway, Florence, KY 41042.

EQUIPMENT TO BUY OR SALE

robots4welding.com
CUattheAWSshow.com

We Buy & Sell Surplus
Welding Rod & Wire
All types, sizes & Quantities

Call us first!
800-523-2791
PA: 610-625-1250
FAX: 610-625-1553

USED ROBOTS
We buy and sell all types.
ANTENEN RESEARCH
1-800-323-9555
www.antenen.com

Attention Welding Contractors
Brand-new, heavy-duty portable band saws—only $139.80 each.
Also available, bi-metal master cobalt band saw blades for portable electric band saws—$4.84 each.
Larger band saw blades available upon request.
Call Best Supply Inc. 1-800-879-2645

ATTENTION!
Welding Equipment Sales Personnel
We pay you for finding us good used welding systems, seamers, positioners, manipulators, turning rolls, etc.
We will buy your customers' trade-ins.

WELD PLUS, INC.
1-800-288-9414

REDUCE LABOR UP TO 80%
Automation *Lean Mig. * JIT
We engineer dedicated systems for manufacturers. If you have 2 or more welders making similar parts, we can develop a system to dramatically reduce your cycle and changeover times.

Engineered Projects, Inc. 1-314-534-9585
grey@engineeredprojects.com

USED, RECONDITIONED WELDING MACHINERY

JUST IN! Koike-Aronson 14 x 14-ft travel car manipulator. Koike-Aronson WSD-300, 300-ton turning rolls for up to 20 ft. 1998 Pandjiris 2 head, seam tracked, 14-ft box beam tab system. Many 2000- to 3000-lb positioners ready to ship. More than 100 positioners up to 75 tons. Turntables up to 60 tons. Pandjiris, Aronson, and Ransome manipulators on travel cars up to 15- x 22-ft. Turning rolls up to 200 tons. Seam welding machines up to 18 ft. Planishers, Thermal PAK-45 plasmas, AMI orbital welders.

WELDING-RELATED MACHINERY IS OUR ONLY BUSINESS
TALK TO US - WE KNOW WELDING
Web site: weldplus.com e-mail: jack@weldplus.com
WELD PLUS, INC., CINCINNATI, OHIO
800-288-9414 Jack, Pete, Paul, or Dennis
Fax: 513-467-3585
Mitrowski
Welding & Positioning Equipment
(800) 218-9620  (713) 943-8032
1315 College, South Houston, TX 77587
sales@mitrowskiwelding.com
www.mitrowskiwelding.com

SALES - RENTAL - REBUILD
Welding positioners, tank turning rolls, manipulators, seamers, welding machines

CERTIFICATION/TRAINING

Training for 2003
REAL EDUCATIONAL SERVICES, INC.
CWI PREPARATORY
Guarantee - Pass or Repeat FREE!
SPECIAL WEEKEND COURSE
New Orleans, LA Jan. 10-12 & 17-19
Corpus Christi, TX Jan. 31-Feb. 2 & 7-9
SAT-FRI COURSE (7 DAYS)
Pascagoula, MS Jan. 18-24 & Mar. 15-21
MON-FRI COURSE (5 DAYS)
Pascagoula, MS Jan. 20-24 & Mar. 17-21
Houston, TX Feb. 10-14
Test follows on Saturday at same facility
APPLICATIONS OF VISUAL INSPECTION
Pascagoula, MS Jan. 13-17
Houston, TX Feb. 3-7
RT FILM INTERPRETATION
Pascagoula, MS Jan. 27-29
Corpus Christi, TX Feb. 7-9 (Weekend)
WELDING PROCEDURES
Learn how to write and review procedures
Pascagoula, MS Jan. 27-29
Pascagoula, MS Jan. 27-29 & Mar. 18-21
Corpus Christi, TX Feb. 7-9 (Weekend)

ATTENTION
Welding Engineering Professional Engineers (PE)
If you possess a current PE license in welding engineering, you may be eligible to receive the IIW International Welding Engineer diploma.

For more information, contact Jeff Hufsey at hufsey@aws.org

BUSINESS FOR SALE

RETIRED:
Est. 1983, make bench-top proprietary pulse arc and resistance welding machines for industry. International market, medical, jewelry, dental, appliance, automotive, etc. Strong GP, 86% with 20% BTE, N.E. Local.
Business 4 Sale
P.O. Box 893
East Greenwich, RI 02818

PLACE YOUR CLASSIFIED AD HERE!

Contact Frank Wilson,
Advertising Production Coordinator
800-443-9353, ext. 465
fwilson@aws.org
All papers published in the Welding Journal's Welding Research Supplement undergo Peer Review before publication for: 1) originality of the contribution; 2) technical value to the welding community; 3) prior publication of the material being reviewed; 4) proper credit to others working in the same area; and 5) justification of the conclusions, based on the work performed. The following individuals serve on the AWS Peer Review Panel and are experts in specific technical areas. All are volunteers in the program.

<table>
<thead>
<tr>
<th>Principal Reviewers</th>
<th>Principal Reviewers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y. Adonyi</td>
<td>L. H. Flasche</td>
</tr>
<tr>
<td>C. E. Albright</td>
<td>D. W. Meyer</td>
</tr>
<tr>
<td>S. S. Babu</td>
<td>J. O. Milewski</td>
</tr>
<tr>
<td>J. A. Brooks</td>
<td>W. F. Gale</td>
</tr>
<tr>
<td>H. R. Castner</td>
<td>J. M. Gerken</td>
</tr>
<tr>
<td>S. C. Chapple</td>
<td>D. A. Hartman</td>
</tr>
<tr>
<td>M. J. Cieslak</td>
<td>D. D. Harwig</td>
</tr>
<tr>
<td>M. J. Cola</td>
<td>D. Hauser</td>
</tr>
<tr>
<td>C. E. Cross</td>
<td>G. K. Hicken</td>
</tr>
<tr>
<td>C. B. Dallam</td>
<td>P. Hochanadel</td>
</tr>
<tr>
<td>B. Dammroger</td>
<td>J. E. Indacochea</td>
</tr>
<tr>
<td>V. R. Davé</td>
<td>M. Q. Johnson</td>
</tr>
<tr>
<td>S. A. David</td>
<td>R. R. Kapoor</td>
</tr>
<tr>
<td>A. Degiaccari</td>
<td>T. J. Kelly</td>
</tr>
<tr>
<td>T. Dehlroy</td>
<td>G. A. Knorovsky</td>
</tr>
<tr>
<td>J. H. Devladian</td>
<td>D. J. Kutecki</td>
</tr>
<tr>
<td>R. D. Dixon</td>
<td>R. Kovacevic</td>
</tr>
<tr>
<td>P. Dong</td>
<td>F. Y. Lawrence, Jr.</td>
</tr>
<tr>
<td>J. N. Dupont</td>
<td>T. J. Lienert</td>
</tr>
<tr>
<td>T. W. Eager</td>
<td>W. Lin</td>
</tr>
<tr>
<td>G. R. Edwards</td>
<td>J. C. Lippold</td>
</tr>
<tr>
<td>J. W. Elmer</td>
<td>S. Liu</td>
</tr>
<tr>
<td>D. F. Farson</td>
<td>H. W. Ludewig</td>
</tr>
<tr>
<td>Z. Feng</td>
<td>R. P. Martukanitz</td>
</tr>
<tr>
<td>S. R. Finne</td>
<td>R. Menon</td>
</tr>
<tr>
<td></td>
<td>R. W. Messler, Jr.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Principal Reviewers</th>
<th>Principal Reviewers</th>
</tr>
</thead>
<tbody>
<tr>
<td>O. Myhre</td>
<td>G. W. Ritter</td>
</tr>
<tr>
<td>K. Nagarathnam</td>
<td>I. Varol</td>
</tr>
<tr>
<td>P. Nagy</td>
<td>P. T. Vianco</td>
</tr>
<tr>
<td>S. Nasla</td>
<td>G. Wang</td>
</tr>
<tr>
<td>T. W. Nelson</td>
<td>D. K. Watney</td>
</tr>
<tr>
<td>A. Ortega</td>
<td>M. M. Weir</td>
</tr>
<tr>
<td>T. A. Palmer</td>
<td>C. E. Wirsing</td>
</tr>
<tr>
<td>M. Parekh</td>
<td>W. F. Wood</td>
</tr>
<tr>
<td>R. A. Patterson</td>
<td>J. Jie</td>
</tr>
<tr>
<td>R. L. Peaslee</td>
<td>Y. P. Yang</td>
</tr>
<tr>
<td>D. D. Peter</td>
<td>Z. Yang</td>
</tr>
<tr>
<td>E. Pfender</td>
<td>J. Zhang</td>
</tr>
<tr>
<td>M. Pitchc</td>
<td>S. Zhang</td>
</tr>
<tr>
<td>L. E. Pope</td>
<td></td>
</tr>
<tr>
<td>N. Potluri</td>
<td></td>
</tr>
<tr>
<td>J. E. Ramirez</td>
<td></td>
</tr>
<tr>
<td>K. P. Rao</td>
<td></td>
</tr>
<tr>
<td>C. Ribardo</td>
<td></td>
</tr>
<tr>
<td>W. Ridgeway</td>
<td></td>
</tr>
<tr>
<td>A. Ritter</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Principal Reviewers</th>
<th>Principal Reviewers</th>
</tr>
</thead>
<tbody>
<tr>
<td>D. A. Fink</td>
<td>D. J. Rybicki</td>
</tr>
<tr>
<td>D. W. Fitting</td>
<td>E. F. Rybicki</td>
</tr>
<tr>
<td>W. R. Frick</td>
<td>K. Sampat</td>
</tr>
<tr>
<td>E. Friedman</td>
<td>J. M. Sawhill, Jr.</td>
</tr>
<tr>
<td>Y. P. Gao</td>
<td>A. P. Seidler</td>
</tr>
<tr>
<td>J. A. Gianette</td>
<td>L. R. Shockley</td>
</tr>
<tr>
<td>F. E. Gibbs</td>
<td>L. E. Shoemaker</td>
</tr>
<tr>
<td>P. Hall</td>
<td>M. Sierdzinski</td>
</tr>
<tr>
<td>I. D. Harris</td>
<td>T. A. Siewert</td>
</tr>
<tr>
<td>R. T. Hemzacek</td>
<td>S. D. Smith</td>
</tr>
<tr>
<td>M. J. Higgins</td>
<td>C. D. Sorensen</td>
</tr>
<tr>
<td>T. Hikido</td>
<td>T. M. Sarschuch</td>
</tr>
<tr>
<td></td>
<td>W. J. Sporko</td>
</tr>
<tr>
<td></td>
<td>J. E. Stallemeyer</td>
</tr>
<tr>
<td></td>
<td>R. J. Steele</td>
</tr>
<tr>
<td></td>
<td>H. Tang</td>
</tr>
<tr>
<td></td>
<td>D. W. Trees</td>
</tr>
<tr>
<td></td>
<td>J. J. Vagi</td>
</tr>
<tr>
<td></td>
<td>D. M. Vandergriff</td>
</tr>
</tbody>
</table>
Determination of Gradients in Mechanical Properties of 2.25Cr-1Mo Weldments Using Shear-Punch Tests

A test technique was developed to more accurately determine mechanical properties of individual regions in the HAZ

BY V. KARTHIK, K. V. KASIVISWANATHAN, K. LAHA, AND B. RAJ

ABSTRACT. The heat-affected zone (HAZ) of 2.25Cr-1Mo steel weldments consists of coarse-grained bainite, fine-grained bainite, and intercritical structures. Mechanical properties of the individual regions of the HAZ are difficult to determine by conventional methods because of the difficulty in making mechanical test pieces of adequate dimensions from the individual microstructures of very small regions in the HAZ. This paper describes the use of shear punch tests to determine the mechanical properties of the individual regions in the HAZ. A linear correlation established between the tensile properties and the corresponding properties obtained from the shear punch test of various heat-treated structures was used to characterize the mechanical properties for individual regions in the HAZ of actual weldments.

Introduction

The evaluation of gradients in mechanical properties that exist in a weldment is essential for understanding the behavior of welded structures employed in high-performance applications. The microstructures that evolve in a weldment (comprised of base metal, heat-affected zones (HAZ), and weld metal) are heterogeneous due to the temperature gradients associated with the welding process and the chemical gradients that evolve during the process. During welding, the peak temperatures attained and the subsequent cooling rates decrease with increasing distance from the fusion boundary, leading to the formation of various nonequilibrium microstructures across the heat-affected zone (HAZ). This microstructural inhomogeneity is most severe in dissimilar or multipass welds, resulting in gradients in mechanical properties across the individual zones of the weldments. It is practically impossible to obtain standard specimens cut from individual regions of the weldment for evaluating mechanical properties by conventional test techniques due to the narrowness of the various zones. Therefore, early investigators resorted to a variety of special heat-treatment techniques to obtain sizeable volumes of materials that would approximate the individual weld/HAZ microstructures (Ref. 1). However, actual microstructures that evolve in a weldment with the formation of substructure and precipitation kinetics can never be fully simulated by these methods. Therefore, mechanical properties evaluated from specimens prepared by heat treatment techniques that simulate weld microstructures are not true representative of weldments.

An attempt has been made for the first time to utilize a recently developed miniature test technique to get a more accurate estimation of the mechanical properties in various zones of weldments. The material chosen for the current study is low-alloy ferritic 2.25Cr-1Mo steel, which is used extensively as a structural material in steam generating systems of both nuclear and conventional power plants. In welded 2.25Cr-1Mo steel structures, a high percentage of failures have been reported in the HAZ of these weldments (Ref. 2). Hence, it is essential to understand the yield and fracture behavior of 2.25Cr-1Mo weldments by characterizing the mechanical property gradients in the HAZ. For a single weld bead on 2.25Cr-1Mo steel plate, typical microstructures obtained in the weld and HAZ are shown schematically in Fig. 1. It can be seen from Fig. 1 that the HAZ consists of three distinct zones, namely the prior austenitic coarse-grained bainite, the prior austenitic fine-grained bainite, and the intercritical (ICR) microstructures. It is well known that the bainitic microstructure is a two-phase structure of ω-ferrite (BCC) and cementite (orthorhombic).

The three principal microstructures in the HAZ depend on the peak temperatures attained in the different regions during multipass welding. The regions closest to the fusion boundary experience peak temperatures above Ac3. At these temperatures, the carbides dissolve and, hence, coarse-grained austenite forms, which transforms to a coarse-grained bainitic structure on cooling. With increasing distance from the weld interface, the peak temperature experienced by the HAZ decreases, resulting in a line-grained bainitic structure. When the thermal cycle peak temperature seen by the HAZ is between Ac1 and Ac3, only partial transformation to austenite takes place during heating and a mixture of austenite-transformed products with ferrite (intercritical struc-
Heat affected zone
- Coarse grained
- Fine grained
- Intercritical
Weld metal
- Coarse columnar
- Recrystallised coarse
- Recrystallised fine

Fig. 1 — Schematic representation of microstructures in 2.25Cr-1Mo steel weldments. A — Single pass; B — multipass.

Table 1 — Summary of Various Heat Treatments on 2.25Cr-1Mo Steel with the Resultant Microstructures and Hardness Values

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Temperature T Kelvin</th>
<th>Time t Min</th>
<th>Hardness HVN</th>
<th>Details of Heat-treatment</th>
<th>Resultant Microstructure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Base metal</td>
<td>—</td>
<td>200</td>
<td>70% Bainitic-30% Ferritic</td>
<td>Mixed ferrite and 13.44% austenite-transformed product</td>
</tr>
<tr>
<td>2</td>
<td>Weld metal</td>
<td>—</td>
<td>250</td>
<td>Lath bainite structure</td>
<td>Mixed ferrite and 16.95% austenite-transformed product</td>
</tr>
<tr>
<td>3</td>
<td>1083</td>
<td>5</td>
<td>152</td>
<td>Mixed ferrite and 20% austenite-transformed product</td>
<td>Mixed ferrite and 33.44% austenite-transformed product</td>
</tr>
<tr>
<td>4</td>
<td>1098</td>
<td>5</td>
<td>147</td>
<td>Mixed ferrite and 20% austenite-transformed product</td>
<td>Mixed ferrite and 61.6% austenite-transformed product</td>
</tr>
<tr>
<td>5</td>
<td>1100</td>
<td>1</td>
<td>170</td>
<td>Mixed ferrite and 61.6% austenite-transformed product</td>
<td>Mixed ferrite and 100% austenite-transformed product</td>
</tr>
<tr>
<td>6</td>
<td>1128</td>
<td>5</td>
<td>155</td>
<td>Mixed ferrite and 61.6% austenite-transformed product</td>
<td>Mixed ferrite and 98% austenite-transformed product</td>
</tr>
<tr>
<td>7</td>
<td>1138</td>
<td>5</td>
<td>177</td>
<td>Mixed ferrite and 61.6% austenite-transformed product</td>
<td>Mixed ferrite and 100% austenite-transformed product</td>
</tr>
<tr>
<td>8</td>
<td>1143</td>
<td>5</td>
<td>180</td>
<td>Mixed ferrite and 98% austenite-transformed product</td>
<td>Mixed ferrite and 100% austenite-transformed product</td>
</tr>
<tr>
<td>9</td>
<td>1153</td>
<td>5</td>
<td>186</td>
<td>Mixed ferrite and 100% austenite-transformed product</td>
<td>Mixed ferrite and 100% fine-grained bainite</td>
</tr>
<tr>
<td>10</td>
<td>1173</td>
<td>1</td>
<td>196</td>
<td>Mixed ferrite and 100% fine-grained bainite</td>
<td>100% coarse-grained bainite</td>
</tr>
<tr>
<td>11</td>
<td>1473</td>
<td>1</td>
<td>240</td>
<td>Mixed ferrite and 100% fine-grained bainite</td>
<td>Mixed ferrite and 100% coarse-grained bainite</td>
</tr>
</tbody>
</table>

Heating to temperature T Kelvin, soaking for t minutes followed by oil quenching and tempering at 973 K/1 h
(a) Normalized at 1223 K for 17 rain and tempered at 1003 K for 60 min.

Miniature-specimen test techniques enable the characterization of mechanical behavior by using an extremely small volume of the material. These miniature-specimen test techniques can be broadly classified into the following categories:

1) Tests based on miniaturization or scaling down of conventional specimen size (similar to miniature tensile, fatigue, impact, and fracture toughness tests). The specimens used here are very small relative to their conventional counterparts.

2) Tests based on novel techniques using disk-sized specimens of approximately 0.3 mm thickness (like disk bend tests, shear/small punch tests).

3) In-situ mechanical test microprobes based on dynamic ball indentation techniques (Ref. 3).

This paper describes the use of the shear punch (ShP) test technique to determine strength and ductility parameters by using extremely thin specimens extracted from various regions of the HAZ. The ShP test utilizes a cylindrical punch with a flat end to punch a hole in a disk-sized specimen axisymmetrically. The load-displacement curve obtained from the ShP test is analyzed to extract the uniaxial tensile properties (Refs. 4–6). Since the test technique requires only a very small volume of test material, it can be applied to thin sections cut out from various regions of the HAZ. It has been found that the yield and maximum loads in the shear punch can be correlated with the uniaxial tensile yield and ultimate strengths, respectively. Tensile uniform elongation can also be predicted from shear punch data. The correlation equations between tensile data and the corresponding ShP test data are basically empirical in nature. Hamilton et al. (Ref. 7) has experimentally shown these correlation equations vary with alloy class.

To obtain correlation between the uniaxial tensile properties and shear punch
test data, specimens from various heat-treated 2.25Cr-1Mo steel with widely varying microstructures and tensile properties were used. ShP tests were carried out on specimens taken from the collar portion of the tensile test coupon with corresponding microstructure. A shear-tensile correlation established from an extensive database was then used to establish the mechanical properties of individual regions of the HAZ for a 2.25Cr-1Mo weldment.

Experimental Procedure

The 2.25Cr-1Mo steel base metal (normalized at 1223 K for 17 min and tempered at 1003 K for 60 min) was subjected to a variety of heat treatments to obtain widely varying microstructures and mechanical properties. This includes the simulation of microstructures, namely the coarse-grained bainite, the fine-grained bainite, and the intercritical (ICR) structures expected in the HAZ of a 2.25Cr-1Mo weldment. The parameters for heat treatments were selected to obtain the range of expected strength values in the HAZ and, thereby, ensure the validity and further improve the accuracy of the thus-arrived correlation. Table 1 summarizes the details of various heat treatments with the resultant microstructures and hardness values. The simulation treatments were carried out by 1) inserting rough machined base metal bars (60 x 12 x 12 mm) in a resistance heating furnace at 873 K, 2) heating for 30 to 40 min to attain peak temperatures in the range 1083-1473 K, 3) soaking for a selected time (1-5 min) followed by oil quenching, and 4) tempering at 973 K/1 h. Cylindrical tensile specimens (26-mm gauge length and 4-mm diameter) were fabricated from the different heat-treated microstructures. Tensile tests were carried out at a nominal strain rate of 3 x 10^-4 s^-1 at ambient temperature (298 K) using a floor model Instron 1195 Universal testing machine.

ShP test specimens were cut from the collar region of uniaxially tensile-tested specimens of different heat-treated structures mentioned above. The specimens were cut using a high-precision, slow-speed, thin-wafer tool, which resulted in a uniformly thick specimen that required only mechanical polishing with 600-grit SiC paper to achieve the required uniformity in thickness of ± 0.01 mm. Uniformity in specimen thickness (± 0.01 mm) was maintained to ensure good contact with the die surface. For carrying out the ShP test, a test fixture was developed at the authors' laboratory, shown schematically in Fig. 2. Shear-punch tests were performed at room temperature by forcing the flat cylindrical punch through the specimen clamped in the fixture using a desktop servo-hydraulic universal testing machine (BiSS make). The loading rate of all the shear punch tests carried out was maintained at 0.10 mm/min. The stress in a ShP test is primarily shear stress with contributions from compression, stretching, and bending in the deformation region between the punch and the die (Ref. 8). Unlike tensile tests, there are no means for measuring the strain in the specimen, and this can be only approximated by the punch displacement. Due to the characteristic loading configuration and the complex stress states in the specimen during the test, it may not be possible to quantify the nominal shear strain rate in a ShP test. Hence, the approximate strain rate determined from the ratio of punch speed to initial specimen thickness is 5 x 10^-3/s, while the nominal strain rate in a tensile test is 3 x 10^-4/s. However, it can be seen the crosshead speed is of the same order in both the tensile and shear punch tests (i.e., 0.1 mm/min). Load was monitored with a standard load cell (30 kN) in its reduced range of ± 3.75 kN (accuracy ± 1% of the range). A minimum of four shear punch tests were performed for each heat-treated microstructure.

To establish the mechanical properties of individual regions of the HAZ for 2.25 Cr-1 Mo weldments, plates of 12 mm thickness were welded together by shielded metal arc welding (SMAW)
using basic-coated 2.25Cr-1Mo electrodes. Details of the weld edge preparation are shown in Fig. 3. The chemical compositions of the weld and base metals are given in Table 2. The weld pads were examined by radiography for their soundness. Locating the region of HAZ by optical microscopy, specimens from coarse-grained bainite, fine-grained bainite, and intercritical regions in the HAZ were cut using an Isomet cutting machine (0.6-mm SiC tool). Metallographic examinations were carried out on both sides of the specimen by optical microscopy to ensure homogeneity of structure within a shear punch specimen. Figure 4 shows the microstructures of the shear punch test specimens extracted from the HAZ of the weldments. Shear punch tests were carried out on HAZ specimens with the setup mentioned above.

Results and Discussion

A typical load-displacement curve obtained from the ShP test is shown in Fig. 5. The curve is similar to the load-displacement plot of a conventional tensile test. The curve exhibits an initial linear portion (region 1), deviation from linearity (Pc), nonlinear increase of load with displacement (region 2), and decrease in load with displacement (region 3), leading to final failure. Details of data analysis of the ShP tests are discussed elsewhere (Refs. 4-7).

Shear Punch Tensile Strength Correlation

The tensile strength parameters, such as the 0.2% proof stress (YS) and ultimate tensile strength (UTS), were obtained from tensile test data of various microstructures of 2.25Cr-1Mo steel as given in Table 3.

In the ShP test, the ShP maximum stress is estimated from the maximum point Pm on the load-displacement curve, as shown in Fig. 5. The ShP yield stress is evaluated using the load corresponding to the point of deviation from linearity in the initial portion of the load-displacement curve corresponding to the points (d, Pe) of the load-displacement curve shown in Fig. 5.

The acoustic emission technique (AET) was used in the present study for a more accurate determination of the yield load in the ShP test. Acoustic emission (AE) occurs during deformation due to rapid release of transient energy from localized sources such as dislocation movements, phase transformation, crack formation, and extension. Studies of emission from ferritic steels under uni-
Table 3 — Data on Mechanical Properties Obtained from Tensile and Shear Punch Tests of Various Heat-Treated Microstructures of 2.25Cr-1Mo Steel

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Tensile Test Results</th>
<th>Shear Punch Test Results</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>UTS</td>
<td>YS</td>
</tr>
<tr>
<td>1</td>
<td>591</td>
<td>476</td>
</tr>
<tr>
<td>2</td>
<td>702</td>
<td>595</td>
</tr>
<tr>
<td>3</td>
<td>514</td>
<td>380</td>
</tr>
<tr>
<td>4</td>
<td>512</td>
<td>390.2</td>
</tr>
<tr>
<td>5</td>
<td>534</td>
<td>405</td>
</tr>
<tr>
<td>6</td>
<td>561.2</td>
<td>444</td>
</tr>
<tr>
<td>7</td>
<td>594</td>
<td>508.6</td>
</tr>
<tr>
<td>8</td>
<td>674</td>
<td>570</td>
</tr>
<tr>
<td>9</td>
<td>762</td>
<td>685</td>
</tr>
</tbody>
</table>
The shear punch strength data ($\tau_{xy}$) of the various microstructures plotted against their corresponding uniaxial tensile data ($\sigma_{u}$) are shown in Fig. 8 (YS vs. $\tau_{u}$) and Fig. 9 (UTS vs. $\tau_{u}$). When corresponding sets of $\tau$ and $\sigma$ are plotted, they fall along a straight line. A least-squares linear regression is performed to obtain the constants $A$ and $B$ of the equation

$$\sigma_{u} = A + B \tau_{u}$$

where $\sigma$ is the uniaxial tensile stress and $\tau$ is the shear punch stress. The linear regression equations obtained for the yield load (Fig. 8) and maximum load (Fig. 9) conditions, respectively, are

$$\sigma_{y} = -176.92 + 1.78 \tau_{y}$$

and

$$\sigma_{u} = -339.40 + 1.98 \tau_{u}$$

where both $\tau$ and $\sigma$ are in MPa with the regression coefficient ($r$) values of 0.99 for both regressions.

The effectiveness of the above correlation is inferred by estimating the standard deviation of the measured tensile property from the value that the correlation predicts from the shear punch data, which is 9 MPa for UTS-$\tau_{u}$ correlation and 11 MPa for YS-$\tau_{u}$ correlation. The reliability of the predicted tensile properties is established by constructing a 95% confidence band for the predicted value. The 95% confidence interval is inferred by estimating the standard deviation of the measured property from the true plastic strain up to maximum load, from the tensile test plots.

It is required to determine the strain hardening exponent $n_{T}$ from the load-displacement data of ShP tests. The idea is to correlate $n$ and $\varepsilon_{U}$ obtained from tensile tests with $n_{T}$ of ShP tests. But for a ShP test, it is not possible to readily convert load vs. displacement data to stress-strain values from which $n_{T}$ can be estimated. This is due to the complex stress states in the specimen during deformation in ShP tests. Hence, the following relationships have been used for a simple estimate of $n_{T}$ from ShP test data:

For a tensile test

$$\sigma_{y} = K (n)^{n}$$

Combining the above equations

$$\left(\frac{n}{0.002}\right)^{n} = \left(\frac{\sigma_{y}}{\sigma_{u}}\right)$$

To determine the strain hardening exponent $n_{T}$ in a ShP test, $(\sigma_{y}/\sigma_{u})$ is replaced with $(\varepsilon_{U}/\varepsilon_{T})$ in the above equation, resulting in

$$\left(\frac{n}{0.002}\right)^{n} = \left(\frac{\varepsilon_{U}}{\varepsilon_{T}}\right)$$
where \( n_u \) is the strain-hardening exponent determined using the \( \tau_u \) and \( \tau_y \) values obtained in a ShP test. It is seen that \( n \) from tensile tests and \( n_u \) from ShP tests do not follow a 1:1 relationship, but can be linearly correlated. This shows that Equation 7 is only a semiempirical relationship to estimate \( n_u \). The values of \( n \) and \( n_u \) obtained from tensile test data and \( n_u \) from ShP test data for various simulated microstructures are tabulated in Table 3.

A linear relationship was found to exist between \( n \) (determined from the log-log plots of \( \sigma \) vs. \( \varepsilon_0 \)) and \( n_u \) with an \( r^2 \) coefficient of 0.86 — Fig. 10. The \( n \) obtained from log-log tensile plots was compared with the true uniform elongation \( \varepsilon_U \) (also obtained from tensile plots) for all the microstructures. It is seen from Fig. 11 that \( n = 1.1 \varepsilon_0 \) with \( r^2 = 0.93 \), for the different microstructures of 2.25Cr-1Mo steel. This implies the tensile flow behavior of all microstructural conditions of 2.25Cr-1Mo steel and its weldments can be adequately described by the Hollomon equation (Equation 4) and the resulting approximation \( n = \varepsilon_U \).

An attempt was made to obtain a linear relationship between true uniform elongation \( \varepsilon_U \) of the tensile data and \( n_u \) obtained from ShP tests for various microstructures. A least squares linear regression is performed to obtain the constants \( C \) and \( D \) of the equation.

\[
e_u = C + D \varepsilon_U
\]

A linear relationship was found to exist between \( \varepsilon_U \) and \( n_u \) (Fig. 12), and there appears to be less data scatter compared to the \( n \) vs. \( n_u \) plot. This can be seen from the \( r^2 \) coefficient, which is 0.90 for \( \varepsilon_U \) vs. \( n_u \) plot (Fig. 12) as compared to 0.86 for \( n \) vs. \( n_u \) plot (Fig. 10), indicating a better correlation between \( \varepsilon_U \) vs. \( n_u \). The linear regression equation obtained for \( \varepsilon_U \) vs. \( n_u \) correlation using the data in Table 3 is

\[
ev_U = -0.00652 + 1.44357 n_u \quad (9)
\]

An attempt was made to calculate the reduction in area (RA) based on displacement from yield point to failure using the equation

\[
RA = (d_f - d_y)/t \quad (10)
\]

where \( d_f \) is displacement to failure in mm, \( d_y \) is displacement to yield in mm, and \( t \) is initial specimen thickness in mm.

Some difficulty was encountered in the measurement of \( d_f \) due to variations observed in the load-displacement curve beyond the maximum load in the four or five ShP tests carried out on specimens of the same microstructure. Hence, the \% RA values reported here is an average of two tests, from each microstructure. The \% RA calculated as per the above procedure for the ShP tests are compared with the \% RA values obtained from the tensile tests as shown in Fig. 13. A reasonably good agreement was observed for the \% RA values between the ShP test and the tensile test. The linear regression equation obtained for RA correlation is

\[
\% (RA)_{tensile} = 1.013 \times (RA)_{ShP} \quad (11)
\]

Equations 3A, 3B, 9, and 11 are the correlation equations obtained between the tensile properties and corresponding shear punch test properties using the data in Table 3. The above results clearly show that shear punch test data can be reliably correlated to determine the uniaxial tensile properties (both strength and ductility) for a range of microstructures and mechanical properties for 2.25Cr-1Mo ferritic steels. The tensile-shear punch correlation is effectively independent of starting state condition over a very wide range of microstructures, whether they are induced thermally or by mechanical treatment. This clearly brings out the possibility of using the ShP test to estimate the property gradient (both strength and ductility) in an actual weldment using small specimens extracted from the various regions of the HAZ of a 2.25Cr-1Mo weldment.

Table 4 summarizes the data obtained from the shear punch testing of the specimens where the ShP test results are compared with the average values of UTS, YS, and RA obtained from the tensile test. The linear regression equation obtained for RA correlation is

\[
\% (RA)_{tensile} = 1.013 \times (RA)_{ShP} \quad (11)
\]

where the standard deviation is 4.9%.

Equations 3A, 3B, 9, and 11 are the correlation equations obtained between the tensile properties and corresponding shear punch test properties using the data in Table 3. The above results clearly show that shear punch test data can be reliably correlated to determine the uniaxial tensile properties (both strength and ductility) for a range of microstructures and mechanical properties for 2.25Cr-1Mo ferritic steels. The tensile-shear punch correlation is effectively independent of starting state condition over a very wide range of microstructures, whether they are induced thermally or by mechanical treatment. This clearly brings out the possibility of using the ShP test to estimate the property gradient (both strength and ductility) in an actual weldment using small specimens extracted from the various regions of the HAZ of a 2.25Cr-1Mo weldment.

Table 4 summarizes the data obtained from the shear punch testing of the speci-
mens extracted from individual microstructures of the HAZ of the 2.25Cr-1Mo weldments and the corresponding uniaxial tensile properties estimated using the correlation established as per Equations 3a, 3b, 9, and 11. The yield strength and ultimate tensile strength values of the 2.25Cr-1Mo weldments (comprising base metal, weld, and HAZ) determined through shear punch tests were found to be in the following order: coarse-grained bainite (CGB), weld metal, fine-grained bainite (FGB), base metal, and intercritical structure (ICR) — Fig. 14. This is in agreement with the earlier results, relating the evolution of microstructures and tensile deformation characteristics of 2.25Cr-1Mo weldments, reported in the literature (Ref. 14). The higher strength of the coarse-grained bainite (CGB) may be attributed to its fine bainitic structure and finer distribution of carbides, while the lower strength of the intercritical structure (ICR) is attributed to the absence of Mo-C and the reduced bainitic content in this region.

Most of the failure in a 2.25Cr-1Mo weldment is reported to occur in the ICR region. The lower strength of the ICR is consistent with the results of the uniaxial tensile test of a welded joint in which failure in the weld HAZ occurred in the ICR (Ref. 14). It is also found intercritical structure has maximum ductility (% true uniform elongation) while the coarse-grained bainite showed the least. It is clearly seen from Fig. 14 that the fine-grained bainite displayed moderately high strength and adequate ductility while coarse-grained bainite (FGB) had high strength and low ductility and the intercritical zone had minimum strength. The results revealed that neither coarse-grained bainite nor the intercritical structure is a desirable microstructural feature in the HAZ of a weldment. Therefore, it is beneficial to maximize the proportion of fine-grained bainitic microstructure in the HAZ.

The strength values of the three simulated microstructures of 2.25Cr-1Mo, namely the CGB, FGB, and ICR obtained in the present study, have been compared with the strength values of the respective regions of the HAZ in an actual 2.25Cr-1Mo weldment by ShP test methodology. It is seen that differences of about 12% (maximum) in the strength values between the two approaches exist. This may be attributed to the following:

1. The precipitation kinetics occurring during fast thermal cycles in actual welding could be different from that during simulation. The effects of thermal cycles experienced during multipass welding have not been studied in the simulation techniques. The aim of simulating various microstructures including that of CGB, FGB, and ICR was to obtain a tensile-ShP correlation over a range of strengths expected in an actual weldment. Hence, the strength values estimated using the ShP technique by extracting small specimens from various regions of HAZ could be considered to be the actual strength values in a typical weldment.

Conclusions

1) Reliable correlation between the shear punch test data and uniaxial tensile property was obtained for a variety of microstructures and mechanical properties of 2.25Cr-1Mo steel. This is indicated by degree of scatter (~9 MPa for UTS correlation and ~11 MPa for YS correlation) and the 95% confidence interval (~ ± 2% of σ_y for UTS and ~ ± 2.5% of σ_y for YS) between the actual tensile data and correlation predicted value. True uniform elongation ε_u is linearly related to n, permitting direct estimates of ε_u from ShP tests.

2) Using these correlations and shear punch test, both the strength and ductility parameters of individual regions of HAZ of an actual 2.25Cr-1Mo weldment were estimated. The fine-grained bainitic structure displayed moderately high strength and adequate ductility, while coarse-grained bainite had high strength and low ductility, and the intercritical zone had minimum strength. Therefore, fine-grained bainitic structure is the most desirable microstructure in a 2.25Cr-1Mo weldment.

3) The trends and quantification of gradients in the HAZ of weldments by shear punch test technique are useful in determining the structural integrity of welds and in improving the welding procedures. In addition to this, such tests could also be applied to assess the service-induced degradation of weldments in an actual structure upon analysis of the specimens, without damaging the structural integrity of the component.

Acknowledgments

The authors thank Dr. P. Rodriguez, director, Indira Gandhi Centre for Atomic Research, for his keen interest and encouragement in this work. The authors express their deep sense of gratitude to Dr. T. P. S. Gill and Dr. A. K. Bhaduri for many useful discussions. The help of R. Parthasarathy and M. Sekar during the course of work is duly acknowledged.

References


WELDING RESEARCH

Numerical Simulation of Sleeve Repair Welding of In-Service Gas Pipelines

A model was developed to predict conditions for successful sleeve repair of in-service gas pipelines

BY I.-W. BANG, Y.-P. SON, K. H. OH, Y.-P. KIM, AND W.-S. KIM

ABSTRACT. The purpose of this study is to develop an appropriate numerical model for full encirclement, sleeve repair welding of in-service gas pipelines and to investigate the effects of in-service welding conditions. An axisymmetric finite element model was used to calculate the temperature distribution, maximum HAZ hardness, and the distribution of residual stress and plastic strain during multipass sleeve fillet welding of in-service API 5L X65 pipelines of 14.3 mm thickness. Experiments were also conducted for sleeve repair welding on pipe with internal pressure. The calculated geometry of the fusion zone and HAZ was in good agreement with the macrostructures of sleeve repair fillet welds. The calculated maximum HAZ hardness was in good agreement with the measured value. The effect of gas flow rate on the maximum HAZ hardness and the effects of internal pressure on residual stress and plastic strain distribution were investigated. Risk of melt-through and susceptibility to cold cracking were also estimated using a simplified analysis.

Introduction

In buried natural gas pipelines, defects can occur as a result of construction faults, corrosion, third-party interference, and ground movement. When a segment of a pipeline is found to be defective, one of the repair methods is to vent the gas within the pipeline and cut out the defective segment after shutting down the pipeline. However, the cost is extremely high in terms of venting and stopping the gas supply. Therefore, most pipeline companies have developed repair methods without stopping flow through the pipe. These in-service repair methods are widely used throughout the natural gas, petroleum and petrochemical industries (Refs. 1-4). Welding onto a gas pipeline in operation, known as in-service welding, is a frequently employed repair technique. The direct deposition of weld metal, sleeve repair welding, and hot-tap welding are typical examples of in-service welding.

There are two important concerns with welding on in-service pipelines. The first concern is the possibility of melt-through due to localized heating, leading to loss of material strength on the inner surface of pipe during the welding process. The pipe wall can burst under internal pressure if the loss of the strength is large.

The second concern is the high cooling rate of the weld as a result of flowing gas quickly removing heat from the pipe wall. The high cooling rate can promote the formation of heat-affected zone (HAZ) microstructure with high hardness, making these weldments susceptible to cold cracking and sulfide stress cracking in sour service. The rapid cooling can be compensated by increasing heat input, but the increased heat input can promote weld penetration and the possibility of melt-through. Thus, suitable welding procedures must ensure optimal HAZ hardness, no melt-through, and proper heat input.

Over the 12-year period between 1978 and 1990, a series of hot-tap welding research programs was carried out at Battelle and Edison Welding Institute (EWI). A thermal analysis model, based on the two-dimensional finite difference method, was developed to simulate sleeve and direct-branch in-service welding. The cooling rate of the HAZ and the maximum inside surface temperature were predicted for a given pipe geometry and a set of welding parameters. The HAZ hardness was estimated from the cooling rate at 540°C (1000°F) and the carbon equivalent of the material. Taking Vickers hardness, 350 HV as a low cracking potential, the maximum inside surface temperature of 962°C (1800°F) was regarded as the limiting maximum temperature to prevent melt-through for low-hydrogen-electrode welding. However, the estimation of HAZ cracking was highly simplified and not applicable to today's high-strength pipeline steels. Also, melt-through limits were predicted only by the maximum inside surface temperature and the effects of internal pressure and stresses were not considered.

The finite element method offers a computational tool for simulation and analysis of in-service welding of gas pipelines (Refs. 8-10). In addition to investigating the transient thermal field and cooling rates by thermal analysis, stress field and melt-through have been analyzed using a thermoelastic-plastic model or thermoelastic-viscoplastic model by the finite element method. Sabapathy et al. (Ref. 10) predicted melt-through using a thermoelastic-plastic model and also developed an alternative and convenient method to predict the bursting pressure during in-service fillet welding.

Presently, repair welding on an in-service natural gas pipeline is a primary concern of Korea Gas Corporation (KOGAS). Therefore, a systematic study was undertaken for the repair welding of API 5L X65 main pipeline operating under the internal pressure of 6.9 MPa (70 kgf/cm²), with a diameter of 762 mm and a thickness of 17.5 or 14.3 mm. Following a previous study of bead-on-plate welding and repair welding by direct deposition of
weld metal (Ref. 11), a numerical and experimental study was conducted on in-service sleeve repair welding. The objective of this work was to develop an appropriate numerical model for sleeve repair welding of in-service gas pipelines and to investigate the effects of in-service welding conditions.

An axisymmetric finite element model was developed to simulate multipass sleeve fillet welding on in-service API 5L X65 pipelines of 14.3 mm thickness. The model was used to predict the temperature distribution, maximum HAZ hardness, and the distribution of residual stress and plastic strain. The experimental study was also conducted on sleeve repair welding with internal pressure applied. The calculated maximum HAZ hardness was used to predict the occurrence of cold cracking, and the effect of gas flow rate on the maximum HAZ hardness was investigated. An analysis of single-pass fillet welding was also carried out to assess the allowable heat input for sleeve fillet welding.

**Experimental Procedure**

Full encirclement, sleeve repair welding on in-service gas pipelines is a repair welding method for relatively large de-
sects. The schematic illustration of this sleeve repair welding method is shown in Fig. 1. Two sleeves are attached to the pipe around damaged sections and then circumferential fillet welding and longitudinal butt-joint welding are performed.

Figure 2 shows the configuration of the pressurized sleeve repair welding test equipment. Both ends of the pipe were welded using the cap made of WPHY 65, and a pressure gauge and a fitting for measuring the gas temperature were installed. In order to simulate the in-service condition, an internal pressure of 4.4 MPa was applied using a nitrogen gas.

The diameter and thickness of the pipe are 762 and 14.3 mm, and the repair sleeves were made by expanding radially a 762-mm-diameter pipe with a 17.5-mm thickness. The chemical compositions of the API 5L X65 pipe, sleeve, and weld metal are listed in Table 1.

Figures 3A and B show the weld joint shape and welding sequence of sleeve fillet welds and groove welds, respectively. Manual shielded metal arc welding (SMAW) and gas tungsten arc welding (GTAW) processes were applied to sleeve repair welds. The welding conditions for fillet welding and butt-joint welding are shown in Tables 2 and 3, respectively.

In the butt-joint welds, melt-through is a matter of little concern because the weld metal is not in direct contact with the pipe. In this study, fillet welds are in direct contact with a pipe with an internal pressure of 4.4 MPa, but melt-through can be avoided by controlling heat input. Small-diameter electrodes are recommended for welds in contact with the pipe because heat input can be reduced with them (Ref. 12). Small-diameter electrodes were used in this experiment. A 2.4-mm ER70S-G electrode was used for pass 1, and a 2.6-mm low-hydrogen E9016-G electrode was used for passes 2, 3, and 6. A 3.2-mm low-hydrogen E9016-G electrode was used for the layers that were not in direct contact with the pressure-containing pipe. Preheating was not applied considering the field welding conditions.

The weld joints were sectioned and polished to observe the geometry of the weld metal and the HAZ. The penetration of weld metal and depth of HAZ were measured. Microhardness measurements with a 500-g load were made in base metal, coarse-grained HAZ (CGHAZ), fine-grained HAZ (FGHAZ), and weld metal of pipe and sleeve.

Computational Procedure

The commercial finite element code ABAQUS (Ref. 13) was used for the thermal and mechanical analysis. A sequentially coupled analysis of thermal and mechanical analyses was performed. An axisymmetric model was used to calculate the distributions of temperature, residual stresses, and plastic strain during the multipass sleeve fillet welding of in-service API 5L X65 pipeline. The welding conditions listed in Table 2 were used. An analysis of a single-pass fillet weld applied with SMAW was also carried out to assess the allowable heat input.

Finite Element Mesh

The thermal and mechanical response of a weldment is a three-dimensional problem that requires a considerable amount of computational time. The computational time required to simulate multipass welding increases in proportion to the number of weld passes. Therefore, it is necessary to develop cost-effective procedures to reduce computational time while preserving the accuracy of the solution. An assumption common for most analysis of circumferential multipass welding is the assumption of axisymmetry, that is, welding heat is assumed to be deposited at the same time around the circumference. This assumption, which strongly reduces the
size of the FE model and the CPU time needed, can be justified by observation in experiments that residual stresses in circumferential groove welds are reasonably axisymmetric (Refs. 14, 15). So, a two-dimensional axisymmetric model was used in this study.

Based on the geometry and weld pass sequence shown in Figs. 2 and 3, an axisymmetric finite element mesh for sleeve fillet welding was made as shown in Fig. 4. In Fig. 4, the r-coordinate and z-coordinate correspond to the radial and axial direction of the pipe, respectively, and the welding direction is hoop direction. The x-coordinate was defined along the inner surface of pipe in order to describe the distributions of residual stresses and strain. The origin of the axis corresponds to the position at the inner surface of the pipe below the weld root.

Actual circumferential sleeve fillet welding is performed sequentially or simultaneously at both left and right sides of a sleeve. Assuming the welding is performed simultaneously at both left and right sides of a sleeve, half of the geometry was modeled by applying the symmetry condition at the centerline of the axial direction. The finite element model of Fig. 4A consists of 750 quadrilateral elements and 919 nodes. A refined finite element mesh was used in and near the weld region.

Modeling of one-pass welding is an efficient way to investigate the effects of heat input on penetration, melt-through, and cold cracking. The finite element mesh for single-pass welding near the weld region is shown in Fig. 4B. The geometry of the pipe and sleeve is equal to that of the finite element mesh of Fig. 4A and only the mesh of weld metal was changed in the simple triangular geometry.

The area of weld metal (weld bead reinforcement) was assumed to be proportional to heat input. The SMAW process was used for modeling single-pass welding.

**Thermal Analysis**

To simulate arc heating effects efficiently during multipass welding, the equivalent heat input can be assumed as the combination of both surface and body heat flux components (Ref. 14). The total heat input can be given as follows:

\[ Q = Q_s + Q_b = \eta EI \]  

where \( Q_s \) and \( Q_b \) are the heat input due to surface flux and body flux, respectively, \( \eta \) is the arc efficiency, \( E \) is voltage, and \( I \) is current. The ratio of \( Q_s/Q_b \) can be adjusted to achieve an accurate representation of the fusion zone. In this study, the total heat input was assumed to be 20% of surface flux and 80% of body flux from the comparison between the experimental and calculated size of the fusion zone. The arc efficiencies used in the analysis are 0.75 for SMAW and 0.40 for GTAW.

The surface flux \( q_s \) and body flux \( q_b \) are
generally represented in the form of a Gaussian distribution as follows (Ref. 16):

\[ q_s = \frac{3Q}{\pi atc} \exp \left( -\frac{3x^2}{a^2} - \frac{3z^2}{c^2} \right) \]  

(2)

\[ q_B = \frac{6\sqrt{3}Q_{B}}{abc\pi} \exp \left( -\frac{3x^2}{a^2} - \frac{3y^2}{b^2} - \frac{3z^2}{c^2} \right) \]  

(3)

where \( a, b, \) and \( c \) are the semicharacteristic arc dimensions in \( x, y, \) and \( z \) direction. This heat source model has often been used to approximate simple welding processes carried out in the flat position, i.e., welding horizontally in a straight line on a horizontal flat plate with the electrode perpendicular to the plate (Ref. 10). A characteristic of a low-hydrogen electrode is often a shallow penetration, which suggests a heat distribution flatter and more evenly distributed than Gaussian. Sabapathy et al. (Ref. 10) modified the Gaussian heat source model by changing the exponential terms and simulated in-service welding. In this study, the heat fluxes of Equations 2 and 3 were modified by assuming the uniform distribution of heat fluxes in width and thickness direction in order to simulate the shallow penetration. The surface and body fluxes can be given as follows:

\[ q_s = \frac{\sqrt{3}Q_{s}}{a\pi} \exp \left( -\frac{3z^2}{c^2} \right) \]  

(4)

\[ q_B = \frac{\sqrt{3}Q_{B} A}{A\pi} \exp \left( -\frac{3z^2}{c^2} \right) \]  

(5)

where \( A \) is the cross-sectional area of the fusion zone. The values of \( a \) and \( c \) were chosen as the half width of the fusion zone. The fixed \( z \)-coordinate is related to the moving coordinate as follows:

\[ z = v(t - t_0) \]  

(6)

where \( v \) is the welding speed and \( t_0 \) is the lag factor to define the position of the heat source at time \( t = 0 \).

The element birth technique was used to model the multipass weld metal deposition effects (Ref. 13). The elements of each weld pass were meshed separately and then connected to adjacent passes and the base metal mesh with contact surfaces. The weld metal finite elements and contact surfaces were inactive at the beginning of the analysis, and then activated at the specified time to simulate the deposition.
Mechanical Analysis

Temperature histories from the thermal analysis were given as inputs for the mechanical analysis. Similar to the thermal model, the filler metal passes were tied to adjacent passes and the base metal with contact surfaces. It is also possible to use the element birth technique in the mechanical analysis. However, this may give serious numerical problems in the mechanical analysis because inactive elements at the boundary between old, already deposited material, and new material deposited in the particular weld pass may be strongly distorted when being activated. Attempts to fit the undeformed filler material to the deformed geometry will lead to a stress buildup in this stress-free material and a redistribution of residual stresses from previous passes. Moreover, the computation will break down immediately if the magnitudes of deformation of the inactive elements exceed the size of the elements.

Trove and Johnson (Ref. 19) modified the common element birth technique where the degrees of freedom for all unique birth nodes are fully constrained until the time of birth by changing the con-

Fig. 9 — Contour plots of residual stress distributions. A — Axial stress; B — hoop stress using the welding conditions listed in Table 2.

Fig. 10 — Evolution of residual stress along the inner surface of the pipe. A — Axial stress; B — hoop stress using the welding conditions listed in Table 2.

gas was characterized with a heat transfer coefficient, \( h_g \), determined from the following dimensionless relation (Ref. 18):

\[
\frac{h_g D}{\kappa_g} = 0.023 \left( \frac{\nu_g D}{\mu_g} \right)^{0.8} \left( \frac{C_{pg} \mu_g}{k_g} \right)^{0.4}
\]

where \( D \) is the pipe diameter, \( \nu_g \) is the velocity of the gas, \( \mu_g \) is the viscosity of the gas, and \( h_g \) is the heat transfer coefficient between pipe and flowing gas. Thermophysical data to calculate \( h_g \) are listed in Table 4 (Ref. 7).

Mechanical Analysis

Temperature histories from the thermal analysis were given as inputs for the mechanical analysis. Similar to the thermal model, the filler metal passes were tied to adjacent passes and the base metal with contact surfaces. It is also possible to use the element birth technique in the mechanical analysis. However, this may give serious numerical problems in the mechanical analysis because inactive elements at the boundary between old, already deposited material, and new material deposited in the particular weld pass may be strongly distorted when being activated. Attempts to fit the undeformed filler material to the deformed geometry will lead to a stress buildup in this stress-free material and a redistribution of residual stresses from previous passes. Moreover, the computation will break down immediately if the magnitudes of deformation of the inactive elements exceed the size of the elements.

Trove and Johnson (Ref. 19) modified the common element birth technique where the degrees of freedom for all unique birth nodes are fully constrained until the time of birth by changing the con-

Fig. 9 — Contour plots of residual stress distributions. A — Axial stress; B — hoop stress using the welding conditions listed in Table 2.

Fig. 10 — Evolution of residual stress along the inner surface of the pipe. A — Axial stress; B — hoop stress using the welding conditions listed in Table 2.
Cold cracking, or hydrogen-induced cracking, is one of the most serious problems encountered during welding. Depending on the location of the cold crack, it is called underbead crack, root crack, or toe crack. Major factors that contribute to cold cracking are susceptible microstructure of high hardness, hydrogen content, and tensile restraint stresses.

These factors mutually interact, and it is difficult to simply evaluate the effect they may have on cold cracking susceptibility. Generally, the maximum HAZ hardness is regarded as an approximate index for susceptibility to cold cracking. The maximum HAZ hardness is often limited to 350 HV in welding fabrication of offshore structures and line-pipes for avoidance of cold cracking (Refs. 20, 21).

A previous study showed HAZ microstructures with hardness of 248 HV and higher are susceptible to stress corrosion cracking (SCC) when the welding is done on in-service pipelines used to transport mildly sour gas (Ref. 22).

The formulas for estimating maximum HAZ hardness can be separated into three different groups (Ref. 23): 1) formulas that estimate hardness entirely from carbon equivalents; 2) formulas that estimate hardness from various carbon equivalents in conjunction with welding parameters, such as cooling time \( t_{\text{coo}} \); and 3) formulas that estimate hardness by means of various carbon equivalents in conjunction with microstructure. For the first group, the application of the formulas must be restricted to the circumstances for which they were developed. The formulas belonging to the last group are not as versatile as the formulas from groups 1 and 2 because detailed information on the martensite content, which only can be obtained by detailed metallographic examination, is required in addition to chemical composition. The formula proposed by Kasuya et al. has the widest applicable range among the formulas belonging to group 2 and was reported to show good correlation between measured and estimated maximum HAZ hardness (Ref. 24).

The maximum HAZ hardness in the formula proposed by Kasuya et al. is given as follows:

\[
HV = \left( H_M + H_B \right) / 2 - \left( H_M - H_B \right) \arctan \left( \frac{\alpha}{2.2} \right)
\]

(8)

where \( H_M \) is the hardness value where martensite volume fraction reaches 100% in CGHAZ and \( H_B \) is where martensite volume fraction becomes almost 0% in CGHAZ. \( X \) is defined by the following equation:

\[
X = 4 \cdot \log \left( \frac{\tau_M}{\tau_B} \right) / \log \left( \frac{\tau_M}{\tau_B} \right)^2 - 2.0
\]

(9)

where \( \tau \) is the cooling time between 800 and 500°C (\( t_{\text{cool}} \)), and \( \tau_M \) and \( \tau_B \) are the cooling times corresponding to \( H_M \) and \( H_B \), respectively. The four constants \( \left( H_M, \tau_M, H_B, \tau_B \right) \) depend on the chemical composition of steel (wt-%) and are defined from the experimental data of vari-

---

**Fig. 11** — Evolution of equivalent plastic strain along the inner surface of the pipe using the welding conditions listed in Table 2.

**Fig. 12** — Effect of internal pressure on residual stress distribution along the inner surface of the pipe. A — Axial stress; B — hoop stress using the welding conditions listed in Table 2.
Equations 8-13 were used to predict maximum HAZ hardness from the chemical composition and calculate cooling time from thermal analysis in this study. The occurrence of cold cracking was assessed by the comparison between the calculated maximum HAZ hardness and the limiting hardness of 350 HV. This approach to predict maximum HAZ hardness and the occurrence of cold cracking was successfully applied in the analysis of bead-on-plate welding of API 5L X65 plates with the various welding conditions (Ref. 25).

**Results and Discussion**

**Temperature Distributions**

The geometry of the fusion zone and HAZ can be predicted from the peak temperature distributions. The peak temperature distributions were obtained from the calculated transient temperature field. The fusion zone is determined by the melting temperature and the geometry of the HAZ can also be determined by $\Delta T$. The HAZ consists of several subzones, which are normally defined by the peak temperatures. Lundin et al. (Ref. 26) reported the average peak temperatures of 1316°C and 954°C are commonly used to represent CGHAZ and FGHAZ, respectively.

Figure 6A shows the calculated peak temperature distributions for the weld zone. The isothermal lines of 1515.6°C, 1316.0°C, and 870.8°C correspond to melting, CGHAZ, and $\Delta T$ temperatures, respectively. Figure 6B shows the macrostructures of fillet welds. It can be seen that the size and shape of the fusion zone and HAZ observed in macrostructures are in good agreement with the isothermal lines of melting temperature and $\Delta T$ temperatures, respectively. From the agreement between calculated and experimental weld geometries, it is known the temperature distributions for multipass sleeve fillet welding can be satisfactorily calculated from the model.

Figure 7 shows the variation of temperature with time at the position where the peak temperature is maximum on the inner surface of the pipe. The temperature profile has higher values when the welds are in contact with the pipe, such as passes 2, 3, and 6, rather than when in contact with the sleeve. The highest peak temperature that corresponds to the maximum inside surface temperature was 515°C at pass 6.

This value is much lower than 982°C, which is the limiting maximum inside surface temperature for preventing melt-through (Ref. 7). As shown in Fig. 6B, excessive deformations or melt-through around welds were not observed in welding the pipe with an internal pressure of 4.4 MPa. The heat input of welding pass 4 was 4.32 kJ/mm due to low welding speed, but melt-through was not found numerically nor experimentally.

**Hardness Distributions and Effect of Gas Flow Rate on Maximum HAZ Hardness**

The measured hardness values for base metal, CGHAZ, FGHAZ, and weld metal are shown in Table 5. The hardness in the CGHAZ of the pipe has the highest value,
235 HV, which is much lower than 350 HV. The calculated maximum HAZ hardness is 242 HV and in good agreement with the measured value. Cold cracks were not observed in the macrostructures of fillet welds, as shown in Fig. 6B.

Natural gas flowing within a pipeline can increase the cooling rate of in-service welds. From the pipeline design standard of Korea Gas Corp., the safe flow rate of natural gas within a pipeline is generally below 18 m/s, and the normal operating flow rate is around 10 m/s. The effect of gas flow rate on the maximum HAZ hardness was numerically investigated at the gas flow rate from 0 to 20 m/s.

As the gas flow rate increases, the heat transfer coefficient of the inner surface of the pipe increases, but the maximum HAZ hardness increases only a little, as shown in Fig. 8. The maximum HAZ hardness at the gas flow rate of 20 m/s is 257 HV, which is only 6% higher than that with no gas flow. This result is in agreement with the fact that cooling rates for thicknesses greater than 0.5 in. (12.7 mm) are little influenced by the fluid inside the pipe (Ref. 7). From Fig. 8, it can be suggested that sleeve repair welding of API 5L X65 pipelines of 14.3-mm thickness with flowing gas can be performed without cold cracking occurring for the given welding conditions.

Residual Stresses and Plastic Strain Distributions

Residual stress and plastic strain are produced by localized heating and cooling during welding. The distributions of residual axial and hoop stresses are shown in Fig. 9. The axial residual stresses at the inner and outer surfaces of the pipe below the weld metal are tensile and compressive, respectively. During heating, the welds are expanded, and the pipe is deformed toward the outside of the pipe. During cooling, the pipe is bent toward the inside by the faster cooling weld region. Therefore, tensile axial residual stress is developed at the inner surface and compressive stress at the outer surface. Hoop stress is tensile at both inner and outer surfaces of the pipe near welds.

Figures 10A and B show the evolution of residual axial and residual hoop stresses along the inner surface of the pipe during welding, respectively. The intermediate residual stress distributions of the weld pass in contact with the pipe and the final residual stress distributions are shown in Fig. 10.

The axial stress at the inner surface gradually increases with each pass sequence as shown in Fig. 10A. The final residual axial stress is tensile within the zone ranging from +30 mm to -20 mm and becomes compressive outside the zone. The maximum value of tensile residual axial stress is found near the origin of the x-coordinate, that is, below the weld root. The hoop stress distributions on the inner surface also show the tendency of gradually increasing with pass sequence as shown in Fig. 10B. The residual tensile hoop stress shows a little decrease at the last pass (pass 8). High tensile hoop stress near the yield stress at room temperature is developed at passes 3 and 6, which are welds in contact with the pipe.

The evolution of equivalent plastic strain along the inner surface is shown in Fig. 11. The plastic strain gradually increases from the second pass to the last pass. The equivalent plastic strain is developed within the zone ranging from +40 mm to -10 mm. The maximum plastic strain is 0.44% at the given welding conditions. The equivalent plastic strain, which characterizes permanent deformation, may be used as an indicator of cumulative damage of the material during the welding process. Because the pipe material has more than 30% elongation, which is much higher than the maximum plastic strain, at a temperature range from room temperature to near 1000°C, it is known the severe loss of material strength or excessive deformation on the inner surface of the pipe will not occur by the above plastic strain. From the calculated plastic strain and the maximum inside surface temperature, it can be suggested the sleeve repair welding of API 5L X65 pipelines of 14.3-mm thickness can be performed without melting-through at the given welding conditions.

Effect of Internal Pressure on Residual Stresses and Plastic Strain

The effect of internal pressure on the residual stresses and plastic strain was investigated varying the magnitude of internal pressure from 0 MPa to the maximum operating pressure of 6.9 MPa. As shown in Fig. 12, the distributions of residual axial and hoop stresses on the inner surface are hardly influenced by the variation of internal pressure. The effect of the increase of hoop stress by internal pressure, which is called Barlow stress, is observed only in the compressive region. The residual plastic strain decreases as internal pressure increases, as shown in Fig. 13. This is because the bending deformation toward the inside of the pipe during cooling is reduced by internal pressure. In fact, the condition in which internal pressure has a significant effect on in-service welding is that the temperature of the inner surface of the pipe is high enough to cause melt-through.

The calculated maximum inside surface temperature is much lower than the temperature of melt-through generation. From Fig. 13, it can be suggested the sleeve repair welding of API 5L X65 pipelines of 14.3-mm thickness can be carried out without melt-through at the maximum operating pressure of 6.9 MPa.

Allowable Heat Input for Single-Pass Sleeve Fillet Welding

An analysis of single-pass fillet welding was carried out to assess the allowable heat input for sleeve fillet welding. The SMAW process was used and the heat input was varied from 0.5 to 5 KJ/mm. The gas flow rate was varied from 0 to 20 m/s to investigate the effect of gas flow rate on the maximum HAZ hardness.

Figure 14 shows the variations of maximum inside surface temperature and maximum HAZ hardness with the variations of heat input and gas flow rate. The calculated maximum inside surface temperatures show lower values than the melt-through prediction temperature of 982°C for all conditions, as shown in Fig. 14A. The calculated maximum HAZ hardness shows lower values than the limiting hardness of 350 HV for all conditions, as shown in Fig. 14B. From Fig. 14, it is shown melt-through and cold cracking will not occur for a range of heat inputs and gas flow rates for single-pass sleeve fillet welding.

Conclusions

An axisymmetric finite element model was developed to simulate multipass sleeve fillet welding of in-service API 5L X65 pipelines of 14.3-mm thickness. The model was used to predict the temperature distribution, maximum HAZ hardness, and distributions of residual stresses and plastic strain. The calculated geometry of the fusion zone and HAZ was in good agreement with the macrostructures of the sleeve repair fillet welds. The predicted maximum inside surface temperature was much lower than the limiting maximum temperature for preventing melt-through. The calculated maximum HAZ hardness was in good agreement with the measured value and much lower than the maximum allowable HAZ hardness for avoiding cold cracking. Cold cracking was not found in either the numerical simulation or the experiment.

Tensile residual axial stress is developed at the inner surface and compressive stress at the outer surface. The hoop stress is tensile at both inner and outer surfaces of the pipe near welds. Melt-through was not predicted from the calculated plastic strain distribution and the maximum inside surface temperature. This was confirmed experimentally.
by applying internal pressure. The effect of internal pressure on the residual stresses and plastic strain was small. The equivalent plastic strain showed little decrease as internal pressure increased.

From the numerical simulation, it can be suggested the sleeve repair welding of API 5L X65 pipelines of 14.3-mm thickness can be carried out without melt-through at the maximum operating pressure. Melt-through and cold cracking were not predicted for a range of heat input and gas flow rates for single-pass sleeve fillet welding.

References

Weld Morphology and Thermal Modeling in Dual-Beam Laser Welding

Weld morphology in dual-beam laser welding was investigated and mathematical modeling was performed to understand the impact of the heat flow pattern on dual-beam laser welds.

BY J. XIE

ABSTRACT. Laser beam welding using two lasers, or dual-beam laser welding, is an emerging welding technology. An earlier experimental study (Ref. 1) showed use of the dual-beam laser welding technique could significantly improve weld quality for both steel and aluminum because process instability during laser welding was minimized. In the current study, weld morphology in dual-beam laser welding such as weld profiles, penetration depth, and weld width was experimentally investigated and the dual-beam laser process was mathematically modeled to understand the changes in heat flow pattern. It was found dual-beam laser welds had a wide width on the top surface of a workpiece, then narrowed down rapidly underneath the surface, forming a “nail” type weld. The penetration depth of dual-beam laser welds was less than single-beam laser welds in some conditions and a critical speed associated with the difference in penetration depth was identified based on experimental results. The penetration depth in dual-beam laser welding was less than that in single-beam laser welding at travel speeds below the critical speed and was the same at travel speeds above the critical speed. A laser melting experiment on an acrylic block indicated the keyhole in dual-beam laser welding was elongated, so there was a heat conduction loss along the longitudinal sides of the elongated keyhole leading to a reduction in penetration depth. An expression for the critical speed was obtained by comparing a travel speed to an expansion rate of a thermal layer in the transverse direction of the longitudinal sides. The predicted critical speed was 4.29 m/min for steel and 21.45 m/min for aluminum, respectively. A mathematical expression to predict the difference in penetration depth between single- and dual-beam laser welding was developed and the theoretical values of the penetration difference agreed well with the experimental data. Further analysis showed penetration capability of dual-beam lasers decreased with the increase in interbeam spacing.

Introduction

Laser welding has been widely used in the automotive, aerospace, electronic, and medical industries to join a variety of materials because it offers a number of advantages over conventional joining processes such as low heat input, minimal distortion, high welding speeds, noncontact and precision processing, and good repeatability. However, a number of weld defects are often encountered in laser welding such as porosity, undercuts, spatter, humping, cracking, and surface holes. How to make high-quality and consistent laser welds is one of the major concerns of industry. A laser welding technique called dual-beam laser welding was investigated in an earlier study (Ref. 1) to quantify the benefits of dual-beam laser processing when a high-power CO₂ laser beam was split into two equal-power beams by a wedge mirror. The “split” or dual laser beams were almost parallel and interbeam spacing was as small as 1.2 mm from center to center. The dual laser beams moved in tandem during welding, as shown in Fig. 1. Experimental results showed use of the dual-beam laser could significantly improve weld quality for both steel and aluminum (Ref. 1). An investigation of the plasma plume above a workpiece in laser welding indicated the plasma plume in conventional single-beam laser welding was unstable and fluctuated at an average frequency of 1.2 kHz (Ref. 1). Plasma fluctuation is generally considered to be associated with the keyhole instability that results in poor welds. In the case of dual-beam laser welding, plasma fluctuation was suppressed by the dual-beam laser due to the elongated keyhole that contributed to improved keyhole stability. As a result, the stabilized process could lead to improved weld quality.

According to the earlier experimental study (Ref. 1), the split or dual laser beams were close enough to create a common keyhole. The effect of reducing keyhole instability no longer existed if the interbeam space was too large to generate one common keyhole. In the case of a large space (for example, 10 mm), two keyholes would be created and the cooling rate during laser welding might be reduced (Refs. 2, 3) instead of the effect of improving process stability with a small interbeam space.

In the earlier experiment, the small interbeam space created a common keyhole, as with conventional single laser beam welding. However, keyhole shape and heat flow pattern during dual-beam laser welding were totally different from that of single-beam laser welding. The changes that occurred in dual-beam laser welding would lead to the change in weld profile, weld size, penetration depth, cooling rate, and thermal stress around the weld pool. In the current study, weld morphology in dual-beam laser welding was compared to conventional single-beam laser welding and mathematical modeling was performed based on the heat conduction theory to understand dual-beam laser processing and its impact on laser welds.
Experimental Studies

Both conventional single-beam and dual-beam laser welding were carried out using a 6-kW CO2 laser. In dual-beam laser welding, the laser beam was split into two equal-power beams at an interbeam space of 1.2 mm from center to center. The dual laser beams were focused down on the workpiece surface with a 200-mm parabolic focusing mirror at a spot size of 0.5 mm. The dual CO2 laser beams were almost parallel and moved in tandem during welding. The single- and dual-beam laser welding setups are shown in Fig. 1. For this study, laser power was kept at 6 kW; travel speeds varied from 0.625 to 7.62 m/min. For the dual laser beam setup, each split beam had a laser power of 3 kW and the total power of the dual beams was 6 kW. It was found all laser welds were in the keyhole welding mode in the speed range investigated, and coupling efficiency for both single- and dual-beam laser welding should be as high as 90% because of multiple reflections in the keyholes (Ref. 4).

Plates of 6.35-mm-thick 1045 steel and 6.0-mm-thick 5052 aluminum were used for the bead-on-plate welding experiment. Helium was used as the shielding gas to protect the weld pool from oxidizing and it was delivered to the welding area by a side jet at a flow rate of 20 L/min. Laser welds were cross sectioned, polished, etched, and photographed for weld profiles, and weld width and penetration depth were then measured.

Weld Profiles

In conventional single-beam laser welding, the welds are typically deep and narrow and have a high aspect ratio. In dual-beam laser welding, the welds still have a high aspect ratio, but the weld profile is slightly different from single-beam laser welds due to the change in keyhole shape and heat flow pattern. Weld profiles of dual-beam laser welds are compared to single-beam laser welds in Fig. 2. Since the 1045 steel used in the experiment had a medium carbon content (0.45% C), it was a crack-sensitive material for fusion weld-
Penetration Depth

Penetration depth for both single- and dual-beam steel welds was measured, as shown in Fig. 6. The penetration depth of the dual-beam welds was less than that of the single-beam laser welds at low travel speeds but was almost the same at high travel speeds. When travel speed was lower than 4.3 m/min, the difference in penetration depth for single- and dual-beam laser welds increased with the increase in travel speeds.

A critical speed, \( v_{cr} \), is defined as a speed boundary where the penetration depth in the dual-beam process is just less than that in single-beam laser welding — Fig. 6. Consequently, it could be said the penetration depth for both processes is different at travel speeds lower than the critical speed and is the same at speeds higher than the critical speed. The critical speed was found to be 4.3 m/min for steel according to the experimental data obtained in this investigation — Fig. 6. This difference in penetration depth at low travel speeds for both processes might be caused by changes in the keyhole shape that lead to a different heat flow pattern during welding. To understand the keyhole shapes in dual-beam laser processing, an acrylic block was irradiated by stationary single and dual laser beams for 100 ms at 3 kW. The top view of the plastic block after laser irradiation is shown in Fig. 7. As expected, the keyhole produced by the stationary single-beam laser is round, but the keyhole irradiated by the stationary dual-beam laser is elongated in the longitudinal direction due to the interbeam spaces.

Heat conduction flow patterns around the circular and elongated keyholes are depicted in Fig. 8. Obviously, in the case of the dual-beam laser process, extra heat is conducted away along the longitudinal sides of the elongated keyhole when compared to single-beam laser welding. The length of the longitudinal sides of the elongated keyhole is approximately equal to the interbeam space. The extra heat conduction loss could be the major reason causing the change in weld profiles and penetration depth in dual-beam laser welding.

When travel speed is in the range less than the critical speed, the extra heat conduction loss increases with the decrease in travel speed because laser/material interaction time is increased and more heat is conducted away along the longitudinal sides. The heat loss creates a temperature profile and a "thermal layer" in the Y-axis, as shown in Fig. 8B. The thermal layer is defined as a distance beyond which there is no heat flow; hence, the initial temperature distribution remains unaffected be-
yond the thermal layer (Ref. 5). The thermal layer in the Y axis increases with the decrease in travel speeds or increased laser/material interaction time. In other words, the thermal layer “grows” with the travel speed higher than the critical speed. In this case, the travel speed should be equal to or higher than the expansion rate of the thermal layer. The critical speed can, therefore, be estimated by comparing the expansion rate to travel speed in dual-beam laser welding.

According to the heat conduction theory (Ref. 5), thermal layer (8) is approximated as

\[ \delta = 4 \sqrt{\alpha t} \]  

(1)

where \( \alpha \) is the thermal diffusivity of material and \( t \) is the time of heat conducting. In dual-beam laser welding, the “thermal layer” in Equation 1 can be considered as the layer starting from the edge of the elongated keyhole in the transverse direction — Fig. 8B. The temperature at this keyhole edge is assumed to be the boiling point of the material, \( T_b \). Then, the average expansion rate of the thermal layer in the transverse direction (Y axis), \( \bar{v}_{TL,Y} \), is approximately derived from dividing Equation 1 by time \( t \)

\[ v_{TL,Y} = \frac{\delta}{t} = \frac{4 \sqrt{\alpha}}{\sqrt{t}} \]  

(2)

where time \( t \) should be considered as the laser/materials interaction time in laser welding. The interaction time in dual-beam laser welding can be estimated as the following:

\[ t = \frac{L_0 + d_0}{v} \]  

(3)

where \( v \) is the travel speed, \( d_0 \) is the keyhole width of the elongated keyhole that is roughly the same as the keyhole diameter in single-beam laser welding, and \( L_0 \) is the length of the elongated keyhole from center to center that is approximately equal to the interbeam spacing as shown in Fig. 8B. According to the definition of the critical speed and analysis of heat conduction loss, the travel speed should be equal to the expansion rate of the thermal layer \( (v_{TL,Y}) \) at the critical speed where the extra heat loss could be neglected. Therefore, the critical travel speed is obtained by substituting Equation 3 into Equation 2:

\[ v_{cr} = \frac{16 \alpha}{L_0 + d_0} \]  

(4)

where the thermal diffusivity \( (\alpha) \) of materials in the liquid state should be used in Equation 4 because the elongated keyhole is surrounded by molten metal and the extra heat loss is conducted away from the keyhole edge into molten metal in the weld pool. According to the expression in Equation 4, the critical speed is dependent on the dimensions of the elongated keyhole and physical properties of the material. Generally, the dimensions of the elongated keyhole increases with the increase in travel speed and hence the critical speed is expected to decrease.

Mathematical Modeling

To better understand the laser processes, mathematical modeling was performed to analyze the change in heat flow pattern in dual-beam laser welding and its influences on weld characteristics.

**Critical Speed**

According to the previous analysis of the dual-beam laser process, heat conduction loss along the longitudinal sides of the elongated keyhole creates a thermal layer; the effect of the extra heat loss could be neglected at the travel speed higher than the critical speed. In this case, the travel speed should be equal to or higher than the expansion rate of the thermal layer. The critical speed can, therefore, be estimated by comparing the expansion rate to travel speed in dual-beam laser welding.

Equation 1 by time \( t \)

\[ v_{TL,Y} = \frac{\delta}{t} = \frac{4 \sqrt{\alpha}}{\sqrt{t}} \]  

(2)

where time \( t \) should be considered as the laser/materials interaction time in laser welding. The interaction time in dual-beam laser welding can be estimated as the following:

\[ t = \frac{L_0 + d_0}{v} \]  

(3)

where \( v \) is the travel speed, \( d_0 \) is the keyhole width of the elongated keyhole that is roughly the same as the keyhole diameter in single-beam laser welding, and \( L_0 \) is the length of the elongated keyhole from center to center that is approximately equal to the interbeam spacing as shown in Fig. 8B. According to the definition of the critical speed and analysis of heat conduction loss, the travel speed should be equal to the expansion rate of the thermal layer \( (v_{TL,Y}) \) at the critical speed where the extra heat loss could be neglected. Therefore, the critical travel speed is obtained by substituting Equation 3 into Equation 2:

\[ v_{cr} = \frac{16 \alpha}{L_0 + d_0} \]  

(4)

where the thermal diffusivity \( (\alpha) \) of materials in the liquid state should be used in Equation 4 because the elongated keyhole is surrounded by molten metal and the extra heat loss is conducted away from the keyhole edge into molten metal in the weld pool. According to the expression in Equation 4, the critical speed is dependent on the dimensions of the elongated keyhole and physical properties of the material. Generally, the dimensions of the elongated keyhole increases with the increase in travel speed and hence the critical speed is expected to decrease.
gated keyhole can be varied only in a small range to have one common keyhole (Ref. 1), so the material property would be the major variable affecting the critical speed. The critical speeds for some metals were calculated in Table 1 based on the dual-beam CO₂ laser setup with an interbeam space of 1.2 mm and assumed keyhole diameter of 0.5 mm. The critical speed was found to be 4.29 m/min for steel, which was in good agreement with the experimental result as shown in Fig. 6.

For aluminum, the calculated critical speed is as high as 21.5 m/min because of aluminum’s high thermal diffusivity (Table 1). As a result, a lot of laser energy is conducted away along the longitudinal sides of the elongated keyhole during dual-beam laser welding of aluminum. The predicted critical speed of aluminum is much higher than the travel speeds often used in industry, so the penetration depth in the dual-beam laser process is expected to be less than in single-beam laser welding in the “common” range of travel speeds. The penetration depth of 5052 aluminum welds was measured for both processes in Fig. 9. The penetration depth of the dual-beam laser welds is always less than that of single-beam laser welds, but the difference in penetration depth decreases as travel speed increases and it tends to approach the predicted critical speed of 21.5 m/min.

In complete-penetration butt-joint welding, a higher laser power is needed to compensate for the extra heat conduction loss in dual-beam laser welding, especially for aluminum welding. For example, to obtain complete-penetration butt-joint welds of 3-mm 5083 aluminum plates, a laser power of 4.5 kW was needed in dual-beam laser welding while 3.0 kW was good enough in conventional single-beam laser welding at a travel speed of 3.81 m/min.

In general, a simple expression for the critical speed was derived from the thermal layer surrounding the elongated keyhole. To have an exact expression for the critical speed, a three-dimensional temperature profile induced by the dual-beam laser should be obtained and then the extra heat loss and expansion rate of the thermal layer in the Y axis could be calculated. However, the procedures would be complicated because the exact temperature profile and the expansion rate of the thermal layer are difficult to compute. In this study, the concept of “thermal layer” was introduced and some assumptions were made to calculate the expansion rate of the thermal layer such as one-dimensional heat conduction, linear temperature distribution, and neglecting solid/liquid phase change. As a result, Equation 4 is an approximate estimation for the critical speed but it is simple and easy to use. The simple expression was also found to be in good agreement with the available experimental data.

Penetration Depth

As mentioned earlier, penetration depth of dual-beam laser welds was less than single-beam laser welds at the travel speed of less than the critical speed. To further understand the change in penetration depth in the dual-beam laser process, a mathematical model to predict the penetration depth was developed by using a single-beam laser welding model developed by Lankalapalli et al. (Ref. 6). In this two-dimensional model for single-beam laser welding, the keyhole was assumed to be conical in the depth direction because the majority of normal laser welds tapered down (Ref. 6). The governing equation and boundary conditions for the temperature distribution in single-beam laser welding were described by Carslaw and Jaeger (Ref. 7):

\[
\frac{\partial^2 T(x, y)}{\partial x^2} + \frac{\partial^2 T(x, y)}{\partial y^2} = \frac{\partial T(x, y)}{\partial t} \quad (5)
\]

\[
T(x, y) = T_i \quad \text{at} \quad x^2 + y^2 = d_0^2 \quad (6)
\]

\[
T(x, y) \rightarrow T_0 \quad \text{as} \quad x, y \rightarrow \pm \infty \quad (7)
\]

where \(T(x,y)\) is the temperature distribution around the keyhole, \(T_i\) is the vaporization temperature of the material, \(T_0\) is
the initial temperature, \(d_0\) is the keyhole diameter on the surface, and \(x\) and \(y\) are axes in Cartesian coordinate. Lankalapalli et al. (Ref. 6) calculated the average temperature gradient around the keyhole based on Carslaw and Jaeger's solution to Equations 5-7, which is

\[
\left( \frac{\partial T}{\partial y} \right)_{\text{ave}} = -\left( T_T - T_0 \right) G(P_e) \tag{8}
\]

where

\[
G(P_e) = C_1 + C_2 P_e + C_3 P_e^2 + C_4 P_e^3 \tag{9}
\]

Here, \(r^*\) is the normalized radius of the keyhole, \(P_e\) is the Peclet number at a penetration depth of \(z\) (\(P_e = \frac{vd}{2c_0}\)), \(d\) is the keyhole diameter at penetration \(z\), and the coefficients \(C_1 = 2.1995\), \(C_2 = 6.962\), \(C_3 = -0.4994\), and \(C_4 = 0.0461\). The penetration depth in single-beam laser welding was obtained by integrating the laser power absorbed along the penetration depth (Ref. 6)

\[
\tilde{d}_z = \frac{P}{k(T_T - T_0)} \sum_{i=1}^{L} C_i (P_{e,0})^{i-1} \tag{10}
\]

where \(\tilde{d}_z\) is the penetration depth in single-beam laser welding, \(P\) is the incident laser power, \(k\) is the thermal conductivity of the material, and \(P_{e,0}\) is the Peclet number on the top surface (\(P_{e,0} = \frac{vd}{2c_0}\)). This expression for penetration depth was said to be in good agreement with the experimental data on single-beam laser welding of steel (Ref. 6).

In dual-beam laser welding, there is an extra heat conduction loss along the longitudinal sides of the elongated keyhole, as described in Fig. 8. To predict penetration depth in the dual-beam laser process, it is necessary to know the amount of the extra heat conduction loss in the transverse direction. According to the Fourier law, the extra heat loss per unit depth on both longitudinal sides of the elongated keyhole is

\[
P_{\text{loss}} = -2k \left( \frac{\partial T}{\partial y} \right)_{y=d_0/2} \tag{11A}
\]

and the temperature gradient in Equation 11A can be estimated from Equation 8 by considering the entire side length of the elongated keyhole, yielding the following:

\[
\left( \frac{\partial T}{\partial y} \right)_{y=d_0/2} = -\left( T_T - T_0 \right) G(P_e) \left( \frac{L_0}{nd_0} \right) \tag{11B}
\]

When travel speed is greater than critical speed, the extra heat loss in Equation 11 is very little and could be neglected. Therefore, a nondimensional term related to the critical speed, \((1-v/v_{cr})\), should be considered in expression of the extra heat loss. Since the heat conduction loss is not linearly proportional to interaction time, a quadratic relation of the nondimensional term is intentionally put in Equation 11B, so Equation 11A becomes:

\[
P_{\text{loss}} = 2k \left( T_T - T_0 \right) G(P_e) \left( \frac{L_0}{nd_0} \right) (L_0 - d_0) \left( 1 - \frac{v}{v_{cr}} \right)^2 \tag{12}
\]

The absorbed power per unit depth \((P_t)\) in dual-beam laser welding then becomes

\[
P_t = P_z + P_{\text{loss}} = k \left( T_T - T_0 \right) G(P_e) \left( L_0 \right) \left( \frac{L_0}{nd_0} \left( 1 - \frac{v}{v_{cr}} \right)^2 \right) \tag{13}
\]

where \(P_z\) is the laser power absorbed per unit depth in single-beam laser welding (Ref. 6). The total absorbed laser power determined by integrating Equation 13 along the entire penetration depth is equal to the incident laser power:

\[
P = \int_0^{d_D} P_t(z) dz \tag{14}
\]

Where \(d_D\) is the penetration depth in dual-beam laser welding. The Peclet number, \(P_e\), is a function of \(z\) according to the assumption of the conical keyhole in the depth direction, and then the boundary conditions on the top and bottom surfaces are given as

\[
P_e(0) = \frac{vd_0}{2c_0} \quad \text{at} \quad z = 0 \tag{15}
\]

and then

\[
P_e(d_D) = 0 \quad \text{at} \quad z = d_D \tag{16}
\]

The relationships between the Peclet number and penetration depth can then be estimated as (Ref. 6).
The ratio of the penetration depth in the single- and dual-beam laser processes is derived from Equations 10 and 20:

\[
\frac{\bar{d}_p}{\bar{d}_s} = \frac{1}{\frac{1}{d_D} + \frac{2L_D}{\pi d_D} \left( \frac{1}{v} \right)^2} \]  

when \( v \leq v_{cr} \) (21)

When the travel speeds are greater than the critical speed, the ratio is

\[
\frac{\bar{d}_p}{\bar{d}_s} = 1 \quad \text{when} \ v > v_{cr} \]  

(22)

From Equation 21, it can be seen that the difference in penetration depth or penetration ratio, \( \frac{d_p}{d_s} \), is a function of the dimensions of the elongated keyhole and travel speed. The dimensions of the elongated keyhole could be approximately estimated by the characteristics of the dual laser beams; determining the exact dimensions of the elongated keyhole is difficult. As a result, the length of the elongated keyhole \( L_D \) is approximately equal to the interbeam spacing and the keyhole diameter is slightly bigger than the laser beam diameters. In this study, the penetration ratio was estimated by using an interbeam space of 1.2 mm and an assumed keyhole diameter of 0.8 mm. The theoretical results were then compared with the experimental data in Fig. 10. It was found the predicted values of the penetration ratio were in good agreement with the experimental data.

As discussed in the earlier study (Ref. 1), interbeam spacing is an important variable in dual-beam laser welding. The penetration ratio \( \frac{d_p}{d_s} \) at various interbeam spaces was plotted against travel speeds in Fig. 11 according to the mathematical expression for the penetration ratio in Equations 21 and 22. It shows the penetration ratio decreases significantly with the increase in interbeam spaces at low travel speeds. Such a change in penetration ratio is associated with heat conduction loss along the longitudinal sides of the elongated keyhole. As interbeam space increases, the heat conduction loss is accordingly increased and the penetration depth is further reduced. In other words, penetration depth in dual-beam laser welding is expected to be further reduced when the interbeam space increases. This conclusion has been experimentally verified in complete-joint-penetration welding of steel sheets.

In the complete-joint-penetration welding experiment, various interbeam spaces were used to weld 0.7-, 1.0-, and 1.4-mm steel sheets in a lap joint configuration. A maximum welding speed, which is defined as the maximum travel speed at which the laser beam just penetrates through the total thickness, was compared in various welding conditions. It was found the maximum welding speed decreased with the increase in interbeam space, as shown in Fig. 12. This means the dual-beam laser becomes too “weak” to penetrate through a workpiece as the interbeam space increases due to the increased heat conduction loss along the longitudinal sides of the elongated keyhole.

As mentioned in an earlier study (Ref. 1), the effect of improving weld quality using dual-beam lasers was based on the assumption a small interbeam space created one common keyhole. When the interbeam space is increased to be higher than a limit, the welding mode could be...
changed to two keyholes in one weld pool or two keyholes in two separate weld pools. In this case, the mechanism of dual-beam laser welding could be completely different and the equations and conclusions obtained in this study are no longer valid.

Conclusions

1) The profile of dual-beam laser welds was slightly different from that of conventional single-beam laser welds. The dual-beam laser welds were wide on the top surface of a workpiece, then narrowed down rapidly like a "nail."

2) The keyhole was elongated in dual-beam laser welding due to the existence of the interbeam spaces. As a result, there was an extra heat conduction loss along the longitudinal sides of the elongated keyhole during welding when compared to single-beam laser welding. The penetration depth in dual-beam laser welding was found to be less than that in conventional single-beam laser welding in some cases because of the extra heat conduction loss.

3) There was a critical speed associated with the difference in the weld morphology and penetration depth between single- and dual-beam laser welding. The weld morphological difference was pronounced at travel speeds less than the critical speed and was small at speeds higher than the critical speed. The penetration depth of dual-beam laser welds was smaller than in single-beam laser welds when travel speed was lower than the critical speed, but was the same at travel speeds above the critical speed.

4) A mathematical expression for the critical speed was obtained by analyzing the heat conduction loss along the longitudinal sides of the elongated keyhole. The critical speed was a function of the dimensions of the elongated keyhole and material properties. The predicted critical speed was found to be 4.29 m/min for steel; it was extremely high for aluminum (21.5 m/min). Therefore, the penetration depth of dual-beam laser welds for aluminum was always less than single-beam laser welds at the welding speeds usually used in industry.

A mathematical model was developed to predict penetration depth of dual-beam laser welds and the ratio of penetration depth between single- and dual-beam laser welding. The predicted penetration ratio was favorable to the experimental results of steel.

6) The increase in interbeam space would result in the further decrease in penetration depth in dual-beam laser welding due to the increased heat conduction loss along the longitudinal sides of the elongated keyhole. In other words, the penetration capability of dual-beam lasers was reduced when the interbeam space increased.

References


Preparation of Manuscripts for Submission to the Welding Journal Research Supplement

All authors should address themselves to the following questions when writing papers for submission to the Welding Research Supplement:

- Why was the work done?
- What was done?
- What was found?
- What is the significance of your results?
- What are your most important conclusions?

With those questions in mind, most authors can logically organize their material along the following lines: using suitable headings and subheadings to divide the paper.

1) Abstract. A concise summary of the major elements of the presentation, not exceeding 200 words, to help the reader decide if the information is for him or her.

2) Introduction. A short statement giving relevant background, purpose and scope to help orient the reader. Do not duplicate the abstract.

3) Experimental Procedure, Materials, Equipment.

4) Results, Discussion. The facts or data obtained and their evaluation.

5) Conclusion, Acknowledgment. An evaluation and interpretation of your results. Most often, this is what the readers remember. References and Appendix.

Keep in mind that proper use of terms, abbreviations and symbols are important considerations in processing a manuscript for publication. For welding terminology, the Welding Journal adheres to ANSI/AWS A3.0-94, Standard Welding Terms and Definitions.

Papers submitted for consideration in the Welding Research Supplement are required to undergo Peer Review before acceptance for publication. Submit an original and one copy (double-spaced, with 1-in. margins on 8 1/2 x 11-in. or A4 paper) of the manuscript. Submit the abstract only on a computer disk. The preferred format is from any Macintosh® word processor on a 3.5-in. double- or high-density disk. Other acceptable formats include ASCII text, Windows™ or DOS. A manuscript submission form should accompany the manuscript.

Tables and figures should be separate from the manuscript copy and only high-quality figures will be published. Figures should be original line art or glossy photos. Special instructions are required if figures are submitted by electronic means. To receive complete instructions and the manuscript submission form, please contact the Peer Review Coordinator, Doreen Kubish, at (305) 443-9353, ext. 275; FAX 305-443-7404; or write to the American Welding Society, 550 NW LeJeune Rd., Miami, FL 33126.
ABSTRACT. For transition-metal alloys, chemical fluxes predeposited on the path of gas tungsten electric arcs can significantly increase weld penetration. Several mechanisms for this beneficial contribution of fluxes, including electrical charge redistribution (possibly constriction) and surface-energy-driven flow (Marangoni effect), have been postulated. Using argon shielding and chloride fluxes, magnesium alloy welding experiments revealed increases in weld penetration as much as one hundred percent were not unusual. Among all selected chlorides (LiCl, CaCl₂, CdCl₂, PbCl₂ and CeCl₃), cadmium chloride was the most effective.

Real-time monitoring demonstrated that all chlorides increased both the arc voltage and the arc temperature. Furthermore, video recordings showed the electric arc was broader with chlorides, particularly in the direction of welding. Increases in heat input, accompanied by a redistribution of the heat flux, are therefore suggested as the main contribution to the augmented weld penetration with chlorides.

Introduction

A number of studies regarding flux-assisted gas tungsten arc welding (FA-GTAW) have been published. In the mid-1960s, research (Refs. 1, 2) showed weld penetration could be augmented as much as three times when the base materials were coated with fluxes. Such fluxes remain interesting today because they allow full-penetration welding at greater rates while still employing the inexpensive and clean gas tungsten arc as the heat source. To date, however, fluxes have been developed only for joining titanium alloys (Refs. 2-6) and steels (Refs. 7, 8) and their compositions are not published.

Several mechanisms for the augmented penetration observed in FA-GTAW welding have been given (Refs. 5-10). The relative importance of each mechanism is a function of the chemical composition of the flux and the base metal, as well as the process parameters. A spatial redistribution of the current density is most probable. A redistributed current would affect the heat flux from the arc, the induced Lorentz electromagnetic force, the pressure on the weld pool, and thus its heat and mass transports. Although not entirely resolved, the mechanism of arc constriction that raises the current density and creates welds with greater depth-to-width ratios has often been invoked (Refs. 5, 8, 9). Because the flux also chemically interacts with the molten material, a surface-energy contribution that originates a redistribution (possibly constriction) and mass transports. Although not entirely resolved, the mechanism of arc constriction that raises the current density and creates welds with greater depth-to-width ratios has often been invoked (Refs. 5, 8, 9). Because the flux also chemically interacts with the molten material, a surface-energy contribution that originates a redistribution of fluxes, including electrical charge redistribution (possibly constriction) and surface-energy-driven flow (Marangoni effect), have been postulated. Using argon shielding and chloride fluxes, magnesium alloy welding experiments revealed increases in weld penetration as much as one hundred percent were not unusual. Among all selected chlorides (LiCl, CaCl₂, CdCl₂, PbCl₂ and CeCl₃), cadmium chloride was the most effective.

The influence of surface-active species on weld morphology has been well documented in transition-metal alloys (Refs. 11-15) since the work of Heiple and Roper (Refs. 11, 12, 15). These investigators discovered that sulfur often offsets normal weld fluid flow. Particularly after droplet levitation experiments by Mills and Keene (Ref. 13), sulfur segregation to a free surface and the corresponding effect on surface tension, γ, became understood. It was found sulfur could increase surface tension of liquid iron under increasing temperature conditions, thus making the temperature gradient, dγ/dT, positive. Because of the temperature profile over the weld pool, the surface tension normally pulls the liquid toward the solid phase, where temperature and surface tension are relatively smaller and greater. With trace amounts of sulfur in ferrous alloys (Refs. 11, 12, 15), however, a reversal of the fluid flow occurs when the surface tension becomes greater in the hottest regions. The fluid flow, then toward the weld centerline, diminishes the heat extraction sidewise and leaves narrower and deeper welds.

For light metals, elements like sulfur in steels that create this inward Marangoni flow have not been reported, making unlikely the existence of a surface-energy-driven flow due to a sign change of dγ/dT. However, with the flux ingredients unevenly distributed over the pool, composition may assist surface tension to participate in the weld pool circulation. As for steels and titanium alloys, a surface-tension component assisted by a redistribution of both heat and pressure from the arc may thus be at the origin of deeper and narrower welds in magnesium alloys.

From all the potential flux ingredients, metal chlorides were selected for this study. Chlorides are ionic compounds and thus are semiconductive. Their lower electrical conductivity (Ref. 16) relative to metals indicates the electric arc may be harder to strike if they are utilized as flux, and this may result in an arc constriction. The fact that metal chlorides serve for the casting of magnesium alloys suggests detrimental effects during solidification are negligible. Not only are chlorides ingredients for casting (Ref. 17), but they are also applied as fluxes for the submerged arc welding of steels and titanium alloys (Refs. 18, 19) where they primarily protect the molten metal. Chlorides also serve in "reaction" soldering fluxes (Ref. 20), where, by infiltrating and disrupting the thin and refractory oxide layer on light metals, they improve...
prove the wetting characteristics of the solder.

In arc welding of light metals, surface oxide is problematic. Usual techniques employ alternating currents to provide cathodic cleaning (Ref. 21). With these currents, time-averaged heat input, and thus melting efficiency and weld penetration, are lower than with a direct current electrode. Therefore, with a direct current, a tungsten-matrix cathode and an adequate chloride flux, thicker sections may be fused together by the GTAW process. In this article, the criteria for identifying the best chloride ingredients are discussed. Relevant arc physics and alloying theory are discussed and applied to bead-on-plate FA-GTA welding experiments.

Characteristics of GTA Arcs and Fluxes

Practically, a suitable flux must change the weld dimensions with uniformity and repeatability. If flux thickness varies, irregular weld beads and deteriorated properties may result. Spreading and wetting are thus both required, and these properties can be realized only with a highly fluid flux. Wetting implies the flux adheres to the base metal enough to resist the impact of the shielding gas. Investigations (Refs. 8, 9) showed fluxes are typically made of acetone, ethanol, or water. Once applied by brush or spray, welding proceeds usually after a thin layer of flux has become dry. The resulting welds must exhibit smooth surfaces for mechanical properties and corrosion resistance, thus making indispensable steady arcs.

Such practicalities can be resolved if the roles of fluxes are assessed both theoretically and experimentally. The interactions of fluxes, particularly chlorides, with the electric arc and the base metal are discussed later.

Potential Flux-Arc Interactions

The welding arc can be defined as a sustained discharged plasma with a highly nonuniform electric potential. Although a precise description of the chemical and electronic events within the arc is beyond the scope of this investigation, a description of the arc can be attempted using basic principles of plasma physics and experimental evidence from past investigations (Refs. 22, 23).

The arc is frequently separated into three regions (Refs. 22, 23): cathode, anode, and arc column. Gaseous particles within these regions originate from the shielding gas, the ambient air, and the vaporization of the flux, the base metal, and, to a lesser extent, the tungsten electrode. The arc is formed by the dissipation of the supplied electrical energy. The generated thermal energy measures the kinetic energy of particles colliding elastically as well as nonelastically. The nonelastic collisions create charged particles from initially neutral particles, thus making this initially nonconductive neutral gas mixture an electrical conductor. Initially, neutral atoms and molecules of this gas must be ionized, requiring dissociation of heavy molecules into lighter molecules, neutral atoms, positive ions (cations), negative ions (anions), and free electrons. An ion can be either an atom or a molecule, from which one or several electrons have been added or removed. Electrons are generated by two mechanisms: thermionic emission from the electrodes, as expressed by the Richardson-Dushman equation (Ref. 23) and ionization of initially neutral particles (first ionization) by collisions and self-induced heating. Their density and distribution vary within the arc regions. Due to coulombic interactions, cations and electrons are attracted to the anode and anions to the cathode. According to Langevin's equation (Ref. 24), mobility of a particle is inversely proportional to its mass. The electrons, due to their extreme lightness, are the major charge carriers. The charge density and the probability of inelastic collisions are greater in the near-electrode regions. The observed voltage drops and temperature profiles (Refs. 25, 26) are proof of inelastic collisions because Ohmic heating is an energy loss manifested by the voltage drop. In the arc column, however, potential drops are smaller, thus causing the carriers to travel with a more uniform and Maxwellian velocity. Despite cooling by the electrodes and the continuous flow of gas, temperatures within the arc column (Refs. 5, 23) are lower than temperatures nearer the electrodes (particularly the cathode, where voltage drops the most).

In GTA welding, cations are generated mainly from the ionization of electrode materials and shielding gas (Refs. 22, 23, 27). With ionic fluxes, anions must also coexist, although their presence within the arc is difficult to confirm. Chemical interactions inside the arc must be hypothesized. For a diatomic chloride, MCI (where M is a metal), the homolytic dissociation to neutral atoms (MCI→M+CI) (Ref. 28) is probable, as is the heterolytic dissociation into ions (MCI→M+e→CI+) (Ref. 28). When the metal is divalent, a reaction with an electron may add an intermediate reaction where an electron-negative molecular anion forms (MCI+e→MCI+Cl). Regardless of the events, several possibilities support the fact that the element M in a chloride MCI, (being 1 or 2) greatly influences the arc. In a heterolytic dissociation, deionization of the cation, M+e, by the capture of electrons is very plausible. If it occurs, reionization of M is made also necessary to maintain the charge carrier population and the current at constant levels. In a homolytic dissociation...
ion, direct ionization of M probably proceeds. The first ionization potential of M is only between 4 and 9 eV, and is considerably lower than that of the noble shielding gases. With elements of low first ionization potential, charge carriers form at lower temperatures and electrical conductivity is normally improved.

However, with ionic compounds, the possible enrichment of the arc with anions(e.g., chlorine ions) seemingly counterbalances the effects of elements that possess a low first ionization potential. Other investigators (Ref. 9) have reported that the welding voltage increased when fluxes were present. This response from the voltage supply to maintain current constant demonstrates arc conductance is reduced by fluxes. With fluxes, current is higher where the density of anions or particles with high ionization potentials is at a minimum. Using this argument, these particles probably do not enter the arc column but segregate to its periphery and force the electrons into a narrower arc column. The contraction of the anode and cathode spots discussed by several authors (Ref. 5) substantiates this hypothesis. Saha’s equation (Ref. 23), although strictly applicable to equilibrium and ideal gas plasmas, also rationalizes a contraction of the arc and arc column. It predicts that the density of electrons and cations decreases from the central region of the arc toward its periphery where lower temperatures prevail. The hypothetical situation of a flux constricting an arc may thus be analogous to that in forced cooled electrodes and pressurized atmospheres (Ref. 22) where the reduced conductivity of the arc periphery forces the current to pass through a narrower column, causing more collisions and a hotter arc column. Because current flows where conductance is highest, charge carriers first travel straight in the electrode tip extension. As in GTA welding under high current densities, deflection of the arc toward the pool tail may also occur.

Potential Flux-Weld Metal Interactions

The characteristics of fluxes for GTA welding must be speculated because they are unknown. First, the ionic nature of chlorides makes them electrical insulators relative to the electrodes, and in reference to the discussion above, their introduction must affect the arc. Their stability can be predicted from the simplistic concept of electronegativity. As a general rule, the higher the difference of electronegativity between two elements, the greater the bond strength and stability of a compound made of these two elements. Although electronegativity has various definitions, it invariably measures the power of an atom to attract electrons to itself. Pauling electronegativity (Ref. 29) is a well-accepted concept, although it is unitless. The electronegativity as defined by Mulliken and Pearson is roughly proportional to the Pauling electronegativity (Ref. 29) and has units of electronvolts (eV). This value has been defined as the sum of the electron affinity and the first ionization potential. Because the electron affinity is less than 10% of the first ionization potential, the first ionization potential is a reasonable approximation of electronegativity. Thus, the difference of electronegativity between two elements can be approximated by their difference of first ionization potentials, and the stability of a chloride MCI can be described by the first ionization potential of M only. As discussed above, first ionization potential partially measures the arc current-carrying capability, thus its temperature. Because both stability of chlorides and arc conductance are related to the first ionization potential of M, the element M must be selected so the first ionization potential is widely varied. Chlorides made from alkaline, alkaline earth, rare earth, and other simple-metal elements fulfill this criterion.

After dissociation of MCI, the element M must interact with the molten material. Although alloying is probably limited due to dilution (a function of the welding conditions), alloying may still be sufficient to alter weld properties. It is suspected elements with extensive solubility in the magnesium solid phase may be less detrimental. By staying in solution, solute segregation, hard and brittle intermetallic phase formation, and solute effects on solidification must be all reduced. Empirical correlations established that elements with high solubility (Ref. 30) in magnesium also have large partitioning coefficients. These elements, with the exception of cadmium, are all eutectic formers, and they change least the freezing range and the solidification cracking susceptibility, as was defined by Borland (Ref. 31). To prevent enhanced corrosion, solute with hydrogen potentials very different from that of magnesium must be avoided. Thus, most transition-metal chlorides are unsuitable, whereas the simple metals (with s and p electrons only) (Refs. 30, 32) satisfy most of the selection criteria. With the exception of cerium chloride, all chlorides of this study included simple-metal elements.

Experimental Procedure

Materials and Welding Procedure

Flux-assisted gas tungsten arc welding was investigated using bead-on-plate experiments on wrought AZ21 magnesium alloy rectangular plates (1.90 wt-% Al; 1.2 wt-% Zn; 0.5 wt-% others; Mg bal.). Specimen dimensions (140 x 70 x 10 mm³) were chosen to repeatedly guarantee steady-state and three-dimensional heat flow.
WELDING RESEARCH

Fig. 5 — Three-dimensional representation showing the effects of different chlorides and currents on arc temperature

Fig. 6 — Three-dimensional representation showing the effects of different chlorides and currents on weld penetration.

Therefore promoting shallow welds with depth-to-width ratios smaller than those encountered in thin specimens where heat flow is two-dimensional (Ref. 33). Before welding, the specimens were ground using up to 600-grit silicon carbide papers. The chlorides were dissolved into distilled water, which was preferred over other liquid media because of enhanced dissolution. Preliminary welds showed this greater dissolution resulted in more uniform flux layers and less erratic welding conditions than with other liquid media. The chlorides were all dissolved up to their respective solubility limit to maximize their effects on welding. Lithium chloride (LiCl), calcium chloride (CaCl₂), lead chloride (PbCl₂), and cerium chloride (CeCl₃) were all added to water and used as single-solute ingredients.

Welding experiments were conducted with a 2-mm tungsten cathode delivering a direct current. In all experiments, the torch was set to travel from a bare-metal position to a position surfaced with the selected chloride. After extinction of the arc, the tungsten cathode tip was systematically inspected to ascertain that precedent and subsequent conditions were identical. If changes were observed, the tungsten electrode was replaced by another electrode machined with an identical 60-deg tip. Argon was selected for shielding and supplied at a constant rate of 40 L/min⁻¹, as recommended by handbooks (Ref. 33).

The electrode-to-workpiece distance was fixed at 12.5 mm's, an abnormally high travel speed selected to reduce the heat input and make weld pool formation more dependent upon the flux. To precisely record the experimental conditions, a current and voltage data acquisition system complemented by emission spectroscopy and digital video recording was used.

After welding, the beads were cross-sectioned, polished, and etched with a slightly acidic solution to reveal the weld interface and the internal microstructure. Fusion zone dimensions and microstructure were analyzed by optical microscopy, microhardness testing, and electron dispersive spectroscopy.

Spectroscopic Survey

Arc temperatures were measured using a single-channel emission spectrometer pointing at the arc central region. The two-line method, which involves measuring radiated intensity at two specific wavelengths, was adopted (Refs. 34, 35). The magnesium lines for excitation of a neutral atom (285.2 nm) and a singly ionized atom (285.2 nm) were preferred over others (such as the argon lines) because they could be separated consistently from the rest of the spectra, regardless of the welding parameters and the fluxes. The temperature, isolated from the Maxwell-Boltzmann statistical term of Equation 1, is expressed as an electron temperature.

\[
\frac{I_{Mg0}}{I_{Mg+}} = n_0 Z_e Z_0 + \frac{A_{0} \sigma_0 v_0}{A_{+} \sigma_+ v_+} \exp \left( \frac{E_+ - E_0}{kT} \right)
\]

(1)

Realistically, the electron temperature differs from temperatures of heavier particles because the conversion of momentum and energy to heat requires time. Although the welding plasma is likely not at equilibrium, thermal equilibrium was assumed, as had been done in other investigations (Refs. 34, 35). In Equation 1, the indices 0 and + apply to neutral and singly ionized atoms, I is the spectrum line intensity, \(n_0\) is the particle density, Z is its internal partition function, A is the transition probability (\(A_0 = 2.60 \times 10^{-6} \text{s}^{-1}; A_+ = 4.95 \times 10^{-4} \text{s}^{-1}\) for an electron moving to a lower quantum level (Ref. 29), \(\lambda\) is the level of degeneracy of an upper quantum level or statistical weight (Ref. 29), \(\lambda\) is the wavelength associated to this de-excitation (Ref. 29), \(E_0\) is the average energy level (\(E_0 = 4.346 \text{eV}; E_+ = 4.343 \text{eV}\) (Ref. 29), and \(k\) is the Boltzmann constant. The particle density was determined from Saha's equation (Ref. 23), assumes one ideal and homogeneous gas under thermal equilibrium. For the first ionization only, Saha's equation can be expressed as

\[
\frac{\alpha^2}{1 - \alpha^2} = \frac{2\mu_0}{h^2} \frac{1}{kT} \frac{1}{p} \frac{2Z_0}{Z_0} \exp \left(-\frac{E_t}{kT} \right)
\]

(2)

where \(\alpha\) is the degree of ionization (i.e., the fraction of electrons produced after ionization of a population of neutral atoms), and \(p\) is the total pressure, which follows Dalton's law and is approximated as the atmospheric pressure. The partition functions \(Z\) in Equations 1 and 2 are the sum of all possible energy states of a given particle, here a neutral atom or a cation. The partition function is defined as

\[
Z = \sum_i g_i \exp \left( \frac{E_i}{kT} \right)
\]

(3)
The method applied here to determine the arc temperature was clearly imperfect but sufficient for comparing the effects of chloride fluxes. Due to spectral line preferences, statistical weights were within a 25% error. Although such uncertainties affect temperature determination, Saha's remained most influential. The concepts of equilibrium and ideal gas behavior for the arc temperature was clearly imperfect. Due to spectral line preferences, statistical weights were within a 25% error. Although such uncertainties affect temperature determination, Saha's remained most influential. The concepts of equilibrium and ideal gas behavior for the arc temperature were used to estimate a mean arc temperature. The increases caused by the chlorides can be weak or strong, depending upon their chemical composition and the current.

Increased of voltage first suggest weld pool formation only occurred after the flux layer was breached. This process of displacing the flux, either by vaporization or fluid flow, is energy consuming. The increases of voltage, which can be interpreted as a strengthening of the electrical fields, indicate greater energies. Based upon these results, cadmium chloride was given more attention during the rest of this study.

The changes in arc profile with the chloride fluxes, as shown in Fig. 1, are intriguing. Although a thorough experimental verification is lacking, the arc profiles resemble a high-pressure jet that impacts a flat solid surface and is dispersed sidewise. The front views suggest the metal vapors from the anode region were spread sidewise when chlorides were present. The side views reveal the electric arc was deflected toward the weld pool rear in the presence of cadmium chloride. This arc deflection indicates the preset current was not restricted to the area straight beneath the cathode tip. With fluxes, it is clear the charge carriers were redistributed and the enlargement of the brightest region, although not quantified, must relate to visible emission intensity and, thus, to the arc temperatures and welding voltage.

Welding Voltage

Figure 2 shows voltage values during the welding of a specimen that was half coated with a thin layer of cadmium chloride. It can be seen the voltage stepped up rapidly when the arc encountered the flux. Because current is self-adjusted to its selected value, the increase in voltage corresponds to a comparable increase in heat input, both quantities being approximately proportional. Figure 3 is a three-dimensional graphical representation that summarizes the influence of both the chlorides and the current on the voltage. It is clear that not only cadmium chloride but also all chlorides increased the voltage. The increases caused by the chlorides can be weak or strong, depending upon their chemical composition and the current.

Increases of voltage first suggest weld pool formation only occurred after the flux layer was breached and possibly removed from the weld column. This process of displacing the flux, either by vaporization or fluid flow, is energy consuming. The increases of voltage, which can be interpreted as a strengthening of the electrical fields, indicate greater energies. Based upon these results, cadmium chloride was given more attention during the rest of this study.

The changes in arc profile with the chloride fluxes, as shown in Fig. 1, are intriguing. Although a thorough experimental verification is lacking, the arc profiles resemble a high-pressure jet that impacts a flat solid surface and is dispersed sidewise. The front views suggest the metal vapors from the anode region were spread sidewise when chlorides were present. The side views reveal the electric arc was deflected toward the weld pool rear in the presence of cadmium chloride. This arc deflection indicates the preset current was not restricted to the area straight beneath the cathode tip. With fluxes, it is clear the charge carriers were redistributed and the enlargement of the brightest region, although not quantified, must relate to visible emission intensity and, thus, to the arc temperatures and welding voltage.

Results and Discussion

The results of experiments related to the electric arc, the morphology, and the microstructures of the weld fusion zone are consecutively discussed to clarify the role of the chloride fluxes. Because chloride properties depend upon temperature, their effects differ at elevated temperature (when they are dissociated) and at low temperature. Hence, the possibility that their contribution changes with the process parameters was also important to address.

Arc Profiles

The role of chloride fluxes during GTA welding was first investigated using video recording. The images shown in Fig. 1 provide clear experimental verification of the influence of chlorides on the electric arc. Figure 1 illustrates the effect of cadmium chloride by comparing front view (left image) and side view (right image) profiles left by the arc and in the CCD camera. Figure 2 illustrates the effect of cadmium chloride by comparing front view (left image) and side view (right image) profiles left by the arc and in the CCD camera. Figure 3 is a three-dimensional graphical representation that summarizes the influence of both the chlorides and the current on the voltage. It is clear that not only cadmium chloride but also all chlorides increased the voltage. The increases caused by the chlorides can be weak or strong, depending upon their chemical composition and the current.

Figure 2 shows voltage values during the welding of a specimen that was half coated with a thin layer of cadmium chloride. It can be seen the voltage stepped up rapidly when the arc encountered the flux. Because current is self-adjusted to its selected value, the increase in voltage corresponds to a comparable increase in heat input, both quantities being approximately proportional. Figure 3 is a three-dimensional graphical representation that summarizes the influence of both the chlorides and the current on the voltage. It is clear that not only cadmium chloride but also all chlorides increased the voltage. The increases caused by the chlorides can be weak or strong, depending upon their chemical composition and the current.

Fig. 7 -- Three-dimensional representation showing the effects of different chlorides and currents on weld width.

Fig. 8 -- The effects of chlorides and welding current on weld depth-to-width ratio.
greater temperatures to release a first electron. Because electrical conductivity depends upon electron density, conductivity is lower with elements of high first ionization potential. The ohmic impedance of the arc, defined by the ratio of the voltage to the current, is greater with cadmium chloride (11 V/80 A) and lead chloride (9.3 V/80 A). The heat dissipated by the joule effect, indirectly given by the heat input, and the average arc temperature must also be greater with those two chlorides.

As expected from Ohm’s law, Fig. 3 also shows that increases in voltage correspond to increases in current. However, due to experimental difficulties, correlation between voltage change and current change for the various chlorides was not satisfactorily completed. Figure 3 shows that several data are missing to determine the voltage-current line slope, a quantity that would have allowed a precise evaluation of the ohmic impedance caused by each chloride.

Arc Emission Spectra

Like Fig. 2, where voltages with and without cadmium chloride are compared, Fig. 4 shows the corresponding normalized emission spectra. In the absence of fluxes, the most intense peaks were those of magnesium, aluminum, and argon. With cadmium chloride, the neutral argon peaks were observed to disappear unless current was increased. The observation that greater currents were needed to resolve the argon lines has at least two explanations. Electron excitation of the neutral and ionized argon atoms might have been small, thus implying arc temperatures were lower with cadmium chloride. However, this possibility is questionable in view of other results, and a second possibility must be considered. Because measurements were conducted near the weld pool, fumes containing flux ingredients might have interfered with the argon flow reaching the weld surface. The choice of peaks of either magnesium or aluminum was unavoidable. Because the magnesium peak at 518.0 nm was always highest, it was selected. The fact that several magnesium lines for both the neutral atom (385.0, 518.3, 552.8 nm) and the first cation (279.5, 448.1 nm) were always identifiable and highest suggests magnesium was the dominant emitting specie, although raditions of other elements contained in the fluxes were also detected.

Figure 5 summarizes the temperatures derived from the emission spectra corresponding to the voltages of Fig. 3. When compared to other studies (Refs. 34, 35), the temperatures shown in Fig. 5 are low, as was suggested from the argon emission that was frequently within the background noise. Compared to parameters used in investigations with different materials (Refs. 34, 35), the electrode-to-work distance (0.5 mm) and currents (less than 100 A) in this study were significantly smaller.

As for the voltage, the arc temperature increased with the current. The highest temperatures were with cadmium chloride. Despite uncertainties, the arc temperatures associated with lead chloride were the second highest. Cadmium and lead are the elements with the first and second highest ionization potentials among all the elements, M, for the selected chlorides MCI. The observation that arc temperatures increased with the first ionization potential of M is not a discovery, but the fact that the metallic component, M, of the chloride MCI can simply explain the chloride contribution is a new conclusion. Eastern European investigators (Ref. 5) established a linear relationship between first ionization potential and temperature, wherein temperature equaled 800 times the first ionization potential of the element. When this simple relationship is applied, the temperatures reported in this study are substantiated. Although first ionization potential is important, it is undoubtedly not the only key variable. The weld morphology data can help in identifying elements having a low first ionization potential, but also producing deep and narrow welds.

Weld Morphology

Figures 6-8 are graphical representations depicting the variations of weld fusion zone dimensions with both various chlorides and welding currents. All chlorides enhance weld penetration, weld width, and weld depth-to-width ratio. Increases in weld dimensions with chlorides were either weak or strong, depending upon chemical composition and current.

Figure 6 reveals cadmium chloride, again followed by lead chloride, then cerium chloride, and lithium chloride, maximizing weld penetration. In comparison, calcium chloride had a minor effect. Figure 7, which focuses on the weld width, shows that cadmium chloride and possibly lead chloride were best, followed by lithium chloride and cerium chloride. Calcium chloride was not observed to widen the fusion zone. On the contrary, it possibly promoted narrower weld beads. As a first approximation, the rankings of the chlorides, as measured by effects on voltage (Fig. 3), arc temperature (Fig. 5), weld penetration (Fig. 6), and weld width (Fig. 7), were similar. Cadmium (8.993 eV) and lead (7.416 eV) possessed the highest first ionization potentials, and always produced the most distinct results.

As for other characteristics, the effect of current alone was readily predictable. Figure 3 showed current and voltages were related as in Ohm’s law. Consequently, the
heat dissipated by the arc and its temperature, as confirmed in Fig. 5, increased with the current. As depicted in Figs. 6 and 7, both penetration and width also increased monotonically with the current, regardless of the chloride present. Figures 6 and 7 not only demonstrated that cadmium chloride and lead chloride produced greater penetration and width but also suggested weld penetration increased most significantly with these two chlorides. Just as the slope of the tension-current line approximates an impedance, the slope of a dimension-current line quantifies the augmentation in weld dimensions. For cadmium chloride and lead chloride, Figs. 6 and 7 show straight lines with these two chlorides were steepest, having slopes near 0.02 mm A⁻¹ for the penetration and 0.04 mm A⁻¹ for the width. In agreement with previous data, the remaining chlorides (i.e., cerium chloride, lithium chloride, and calcium chloride) exhibited fusion zone dimensions that varied little with the current. While correlations with voltage or temperature were partially expected, no obvious correlation between slopes is apparent. The fact that cadmium chloride and lead chloride showed similar variations is difficult to rationalize from the first ionization potential alone.

Unlike the increases in dimensions with current, depth-to-width ratios were occasionally unexpected, thus implying first ionization potential of M provides an incomplete explanation. Figure 8 shows cadmium chloride produced the greatest depth-to-width ratio. Also, cadmium chloride and lead chloride revealed the relative potency encountered for penetration, because the rates at which the depth-to-width ratio changes with the current were comparable for both chlorides, despite the fact cadmium chloride produced appreciably greater values. This observation is unexplained and may require consideration of other contributions. The results with calcium chloride were different from those with cerium chloride, where depth-to-width ratios decreased with the current. If it is hypothesized the depth-to-width ratio measured the potency of a chloride to alter the heat flux so deep and narrow welds may be promoted, then cadmium chloride was best. On the other hand, cerium chloride lost this effectiveness when current was increased. The first ionization potential of cerium is clearly insufficient to explain these results. Although it is now clear the first ionization potential controls arc voltage and arc temperatures, it remains unexplained how those two effects could be related to arc constriction. A strong possibility exists that are constriction indeed increases the arc voltage and the temperature. A good explanation for why calcium chloride created a greater depth-to-width ratio than lead chloride is missing. Likewise, a reason for why similar depth-to-width ratios were obtained by adding either lead chloride or lithium chloride is not available.

Weld Microstructure

In previous discussion, the alloying with magnesium of the element M included in the chloride MCl₃ was considered. These various elements were specifically selected to stay in solid solution so as to minimize changes in both microstructure and properties. Microhardness indentations did not reveal any appreciable differences within the fusion zones produced using chloride additions. Vickers microhardness averaged 48 with or without chloride flux. Chemical compositions measured by electron dispersive spectroscopy showed metallic elements of the flux were present in the fusion zone, but within the uncertainty of measurements (<0.5 wt-%). Although partially inconclusive, the results confirmed that alloying from the flux probably did not drastically affect the solute partitioning during solidification.

When micrographs of fusion zones created both with and without chlorides were compared (Fig. 9), differences could be seen. In the GTA welds (Fig. 9B), the solidification microstructure was columnar throughout the entire fusion zone. With identical process parameters, the fusion zone created using the cadmium chloride flux (Fig. 9B) was significantly more dendritic. Although columnar dendrites were still observed at the fusion boundary (a preexisting solid-liquid interface has no nucleation barrier and growth often is epitaxial), the remainder of the fusion zone exhibited fine dendrites. A transition between the columnar-to-dendritic regions was marked with the GTA welds, as shown in Fig. 9B.

In arc welding, constitutional undercooling, determined by the ratio of the thermal gradient and growth rate (Ref. 36), controls the solidification microstructure. Since travel speed and solidification rates are proportional (Ref. 36), solidification rates were unchanged. Differences in microstructure between welds with and without chlorides must therefore arise from the thermal gradient. With cadmium chloride, the arc temperature was significantly higher and the fusion zone microstructure substantially increases an increase in constitutional undercooling, i.e., an increase in the thermal gradient. To increase the thermal gradient, heat extraction in the presence of chloride fluxes had to be faster. A more intense weld pool circulation would have certainly assisted the thermal conduction and would have promoted greater thermal gradients.

Conclusions

The influences of metal chloride fluxes on the electric arc and weld fusion zone have been discussed. Although welding with chloride fluxes is complicated, a straightforward relationship between weld morphology and first ionization potential has been proposed. While further investigation is required to thoroughly understand the GTA-GTA welding of magnesium alloys, the following conclusions were reached:

- All selected chlorides affected cross-sectional fusion zone dimensions. More specifically, chlorides increased the weld penetration and the weld bead depth-to-width ratio.
- The extent of weld bead morphological changes depended upon the specific chloride and process parameters. A flux that is insensitive to the process parameters must, therefore, be made of several ingredients.
- Increases in weld penetration were accompanied by increases in voltage and, therefore, heat input. As a first approximation, arc temperature, voltage, and first ionization potential of the element M in the chloride MCl₃, correlated.
- Of all selected chlorides, cadmium chloride was the most effective in altering weld bead morphology. Weld penetration was increased by more than one hundred percent. The effectiveness of lead chloride followed that of cadmium chloride. Cadmium and lead have the two highest first ionization potentials of all the elements selected for this study.
- Captured images of the arc region during welding both with and without chlorides demonstrated noticeable differences. The heat flux from the arc appeared more concentrated toward the center of the pool when chlorides were present.
- The actual mechanisms for the changes in weld bead morphology remain uncertain. Elements possessing high first ionization potential produced hotter arcs, and arc constriction could not be verified. Likewise, any contribution from a surface-energy driven flow proved equally difficult to establish.

Acknowledgments

M. Matty would especially like to thank S. Patel and M. Matsusita for their assistance in the use of the emission spectrometer. The assistance of M. Shaba from Ecole Centrale Nantes in the use of the digital video camera is also greatly appreciated. The authors are very grateful for an American Welding Society Fellow-
ship for M. Marya and for funding provided by Visteon Automotive Systems (Dearborn, Mich.).

References


22. Jackson, C. E. The science of arc welding. Internal document of the Union Carbide Corporation, No. 52-301. also published in the Welding Journal with the following references:


All the Muscle Needed for E71T-1 Welding

SELECT-ARC, Inc. offers a complete line of E71T-1 flux cored, gas-shielded, carbon steel electrodes, including the proven Select 710 and the innovative Select 727.

Since Select-Arc commenced its tubular welding electrode production in 1959, Select 710 has served as the mainstay of the product line. That is because Select 710 is an excellent, general purpose electrode with outstanding welder appeal. It delivers better penetration than most "solfer arc transfer" products.

Select 710 is an excellent choice for general plate fabrication, structural steel welding and other applications where strength and toughness properties are primary requirements.

The new Select 727 is an exceptional all-position, lower fume version of Select 710. Formulated to provide improved deposition rates and enhanced welder appeal, Select 727 offers significant reductions in fume emissions (95%), and spatter levels, with superior bead geometry compared to conventional E71T-1 electrodes.

Select 727 is well-suited for situations where welding occurs indoors or in areas where reduced fumes are required. This electrode's strength and toughness make it ideal for applications such as structural steel, farm machinery, construction equipment, railcar fabrication and shipbuilding.

For more information on the time-tested Select 710 and the new Select 727 electrodes, call Select-Arc at 404-341-5215 or contact:

SELECT ARC INC.

P.O. Box 230
Fort Laramie, WY 82074-0230
Phone: (307) 295-5215
Fax: (307) 295-5217
www.select-arc.com

Circle No. 35 on Reader Inquiry Card
User-Friendly. FEMA-Tough.

Ideal for Structural Welding

With Coreshield® 6 and Coreshield® 8, ESAB is revolutionizing bridge and structural fabrication, particularly in seismic areas. These self-shielded, flux-cored wires combine outstanding toughness (meet FEMA 353 Specification) with welder appeal no other wires come close to. Characteristics like low spatter, stable arc, low fumes and high deposition rate make excellent weld results easy to achieve. Coreshield® 6 and Coreshield® 8 even help fabricators certify welders for demanding jobs in record time.

ESAB - Your Partner in Welding & Cutting

For wires that meet FEMA 353 specifications - and make welder certification easy, call 1-800-ESAB-123, or visit www.esab.com