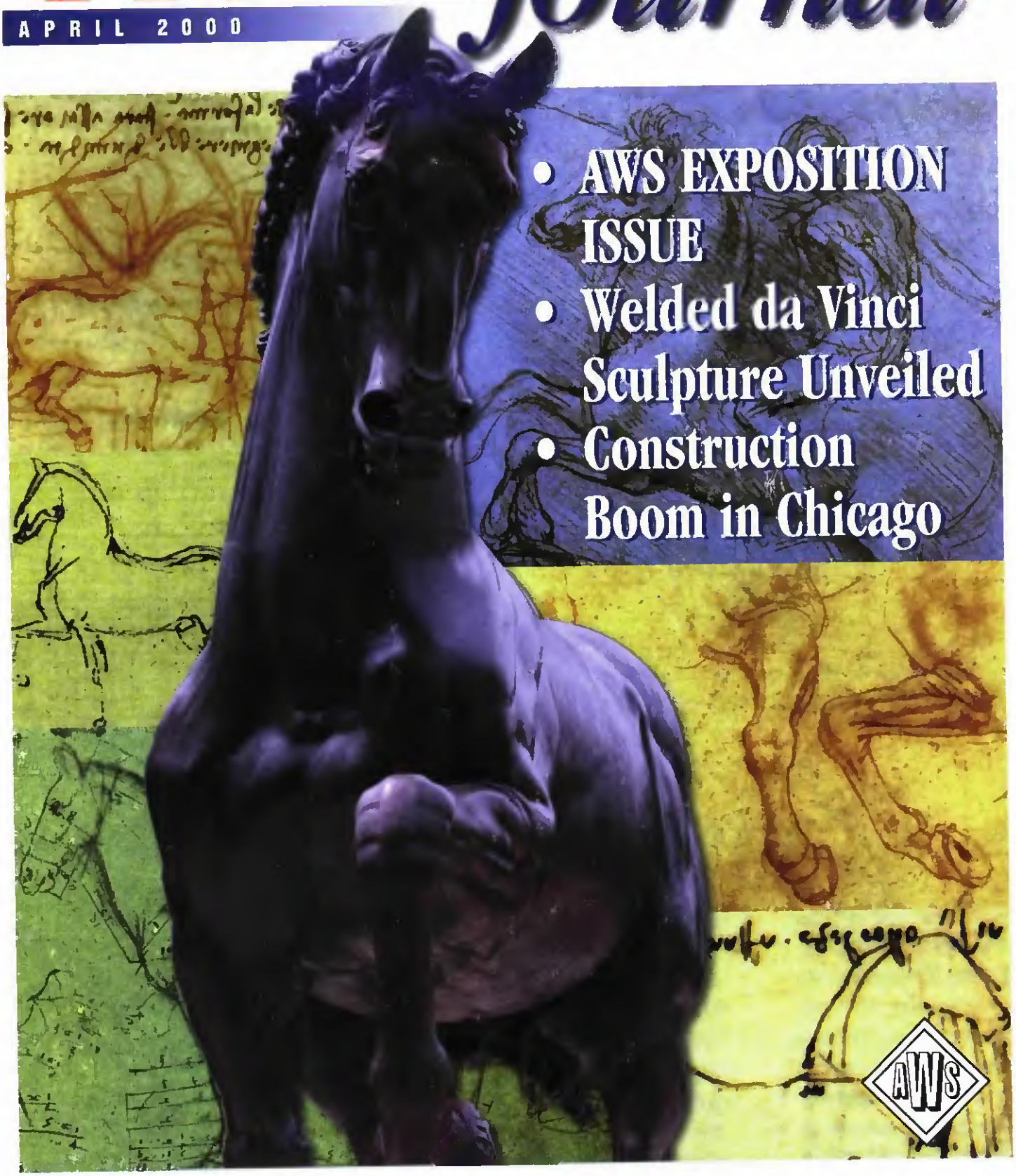
WELDING Journal

APRIL 2000



- AWS EXPOSITION ISSUE
- Welded da Vinci Sculpture Unveiled
- Construction Boom in Chicago

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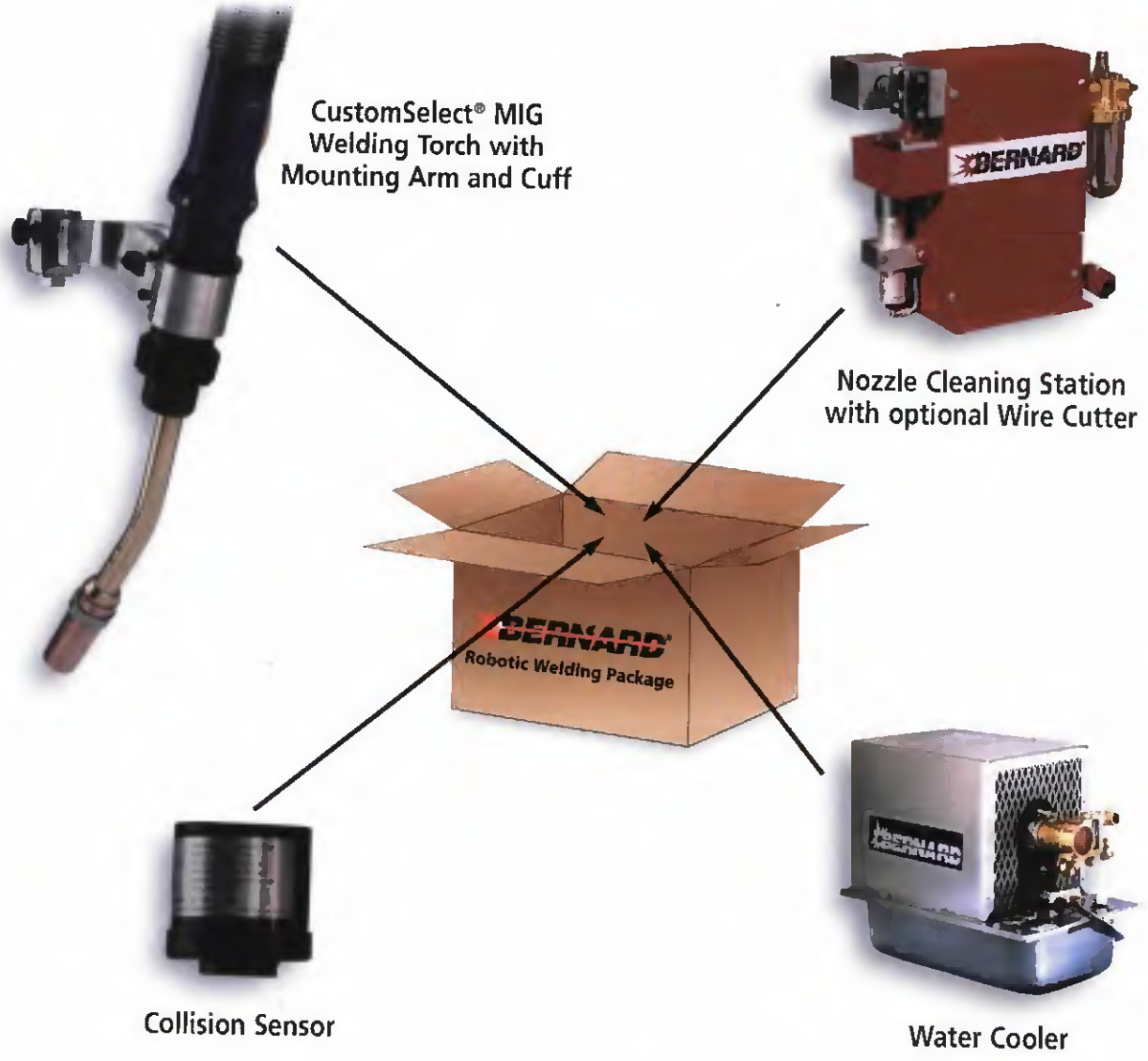

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WELDING Journal

APRIL 2000 • Volume 79 • Number 4

AWS Web site: http://www.aws.org

Feature Articles

Leonardo da Vinci's original design sketches for a 24-ft bronze equestrian sculpture outline the majestic concept that finally came to fruition 500 years later. Gas metal arc and gas tungsten arc welding were used extensively in joining the sculpture's cast sections.

Welding Research Supplement

Monthly Columns

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ITW

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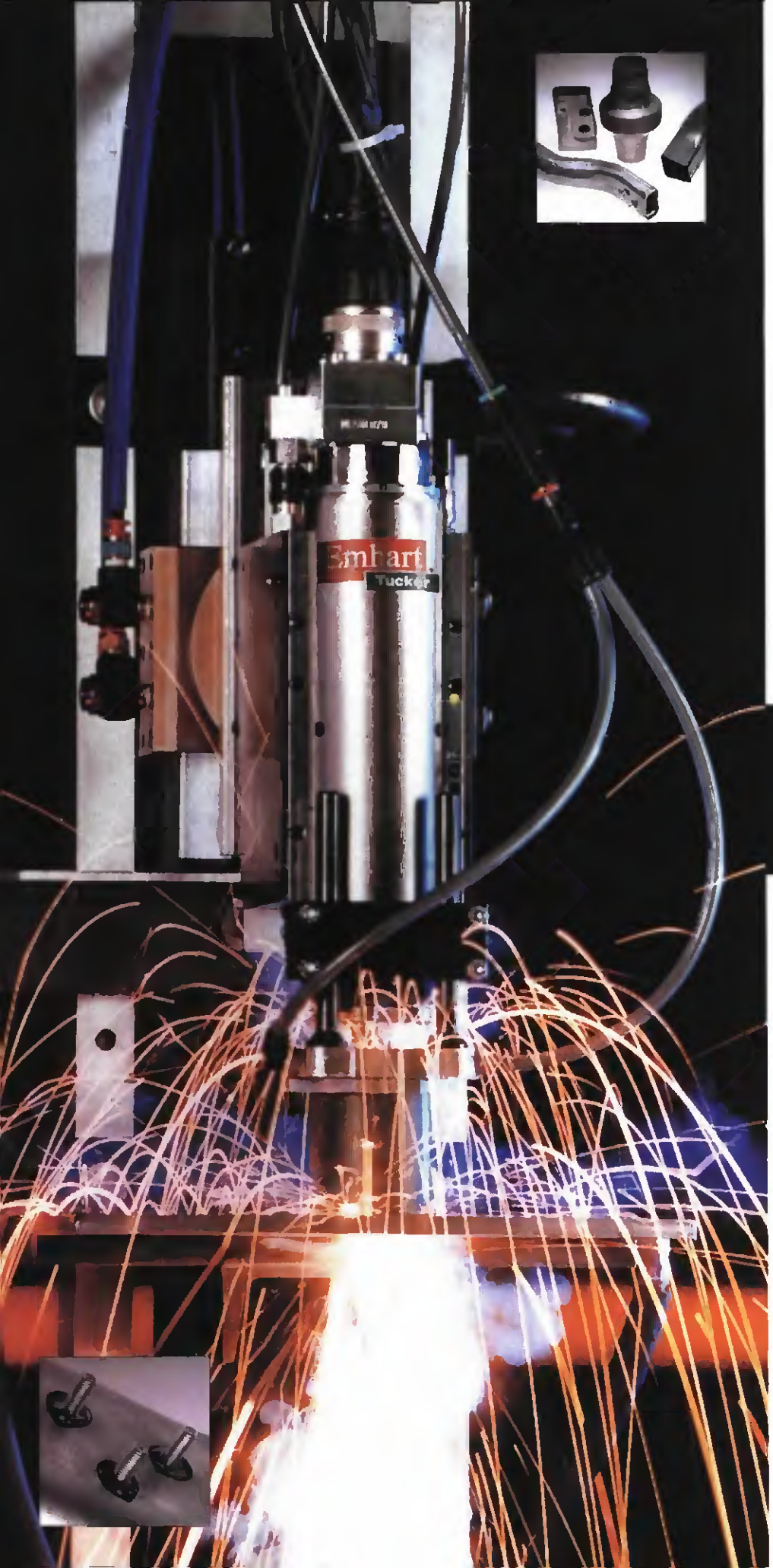

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Trade Commission Hands U.S. Steel Companies a Defeat in Struggle against Steel Imports

The U.S. International Trade Commission (ITC) ruled recently that imports of certain cold-rolled steel products from six countries haven't materially hurt the U.S. steel industry. The ruling means the U.S. Department of Commerce will not impose duties of more than $590 million on imports from those countries.

The ITC issued a statement saying, "The Commission determined that an industry in the United States is not materially injured or threatened with material injury by reason of imports of certain cold-rolled steel products from Argentina, Brazil, Japan, Russia, South Africa and Thailand that the Department of Commerce has determined are sold in the United States at less than fair value, and those from Brazil that the Department of Commerce has determined are also subsidized." The ITC voted 5–1 that the imports did not harm domestic steel.

The move is seen as a major defeat in the U.S. steel industry's two-year war against steel imports. The steel companies and steel workers have complained cheap steel imports have flooded the market, resulting in, among other things, job losses. In the past, Commerce has ruled in the steelmaker's favor, imposing punitive tariffs on some steel imports including hot-rolled steel.

Approximately 30 companies in the United States produce cold-rolled steel products, which are used extensively for automobiles and household appliances.

New Litton Company to Provide Shipbuilding-Related Services

Litton Industries, Woodland Hills, Calif., parent company of Ingalls Shipbuilding and Avondale Industries, recently announced the formation of a new company, the Litton Ship Systems Full Service Center. The new company, based in Pascagoula, Miss., will provide a full range of research and development, design analysis and lifetime maintenace support services. It will operate as a stand-alone business within the existing Litton Ship Systems organization.

"In forming this company, Litton is taking the next step in broadening our ability as a significant industry partner in R&D, as a prime contractor for design and production, and as a single point of contact for support services throughout the operational lifetime of a single ship or a fleet of vessels," Michael R. Brown, Litton chairman, president and chief executive officer, said.

Dr. Lawrence J. Cavaiola has been named president of the new company. Cavaiola joined Litton Ingalls in 1998 as vice president for government relations and strategic development. Prior to the new assignment, he had been named Litton Ship Systems vice president for strategic and business development.

Litton is one of the nation's leading shipbuilders for the U.S. Navy and the largest builder of nonnuclear ships.

U.S. Steel to Sell Products On-Line

U.S. Steel Group, a unit of USX Corp. and the largest U.S. steel producer, recently acquired a minority interest in the e-Steel business-to-business e-commerce site in order to sell its products on-line. U.S. Steel plans to use the e-STEEL Exchange for prime and nonprime transactions.

e-Steel Corp. (*www.e-steel.com*), founded in September 1998, is one of the two major metal selling e-commerce sites. The other is MetalSite, which began operating a year before e-Steel and has alliances with several major steelmakers including Weirton Steel Corp., Bethlehem Steel Corp. and LTV Corp.

As part of the agreement, USX Engineers and Consultants, Inc., a wholly owned subsidiary of USX, will provide software and engineering expertise, as well as sales and marketing support.

"We believe e-commerce will provide real value to U.S. Steel and our customers," U.S. Steel President Paul Wilhelm said. In 1999, U.S. Steel generated revenues in excess of $5.3 billion primarily from sales of 10.6 million tons of steel products.

Currently, the e-Steel Exchange has 1300 member companies from 65 countries.

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WASHINGTON WATCHWORD

BY HUGH K. WEBSTER
AWS Washington Government Affairs Office

Administration Releases 2001 Budget

The Clinton Administration has sent to Congress its fiscal year 2001 budget plan, calling for a 2.5% increase in spending, up to $1.84 trillion. Of course, this is simply the beginning of the budget process, which is not scheduled to be completed until October 1, and usually is delayed even beyond that date.

Federal research and development, which has received a great deal of attention and bipartisan support over the past few years, would increase by 3% to just over $85 billion. Of this, one half, or $43 billion, is for civilian science, engineering and technology R&D programs. Universities, which tend to focus on basic research, show significant increased funding under the proposed budget. Federal agencies that would be favorably affected include the National Science Foundation, Department of Energy, Department of Defense and the National Institute of Standards and Technology.

Liability Bill Passes House

The U.S. House of Representatives has passed the Small Business Liability Reform Act (H.R. 2366). The legislation now moves on to the Senate.

The act is directed at small businesses with fewer than 25 employees and is designed primarily to address the issue of punitive damages. Specifically, the legislation would require "clear and convincing" evidence of wrongdoing in order for an award of punitive damages to be made, and also would limit such damages to the lesser of $250,000 or three times compensatory damages. There are also provisions that would limit so-called joint and several liability, and that would absolve distributors and retailers, who do not actually manufacture any product, from liability in most cases.

The fate of the bill in the Senate is uncertain.

Congressional Centrists Organize

Moderate Democrats and Republicans were expected to wield significant power in the 106th Congress, representing the "vital center" that so many voters claim to prefer. Instead, the intense partisanship of last year's Congress, particularly in the Senate, has resulted in many of the moderates' favored issues becoming mired in gridlock. In fact, recent studies show party line voting has actually increased in the Senate.

Now moderates on both sides of the aisle are attempting to counteract this trend. Specifically, 20 Senate Republicans and Democrats, one-fifth of the Senate, have loosely organized themselves into a "Centrist Coalition" designed to increase cooperation on issues such as health care and taxes.

In a separate but related development, nine moderate Democrats have joined together in an attempt to exercise greater influence within their own party.

Centrists have been encouraged by statements of several presidential candidates of the need to avoid gridlock. In addition, several Senators that define themselves as centrists are newly elected, perhaps signifying the beginning of a trend.

OSHA Partners with Contractors

The Occupational Safety and Health Administration (OSHA) and Associated Building Contractors (ABC) have entered into a partnership designed to create a "platinum" level safety designation for select members. Platinum will be the highest in a four-step program designed to recognize ABC's safest contractors. To reach platinum status, contractors need to meet stringent safety guidelines. Those ABC members that achieve the platinum status will receive specific benefits including not being targeted by OSHA for a planned or unplanned inspections within twelve months; not issued penalties for nonserious violations that are promptly abated; and receiving reduced citations by the maximum amounts for good faith, size and history.

China is expected to gain official WTO membership later this year.

Both OSHA and ABC have expressed hope their partnership may become an industry model and a template for future collaborations between OSHA and other industry groups or companies.

China's Trade Status Battle Continues

The effort to achieve permanent normal trade relation status for China is continuing in Congress and within the Administration. While both the Clinton Administration and leadership in Congress support these efforts, there are significant obstacles that make the ultimate outcome in doubt. These obstacles include opposition by many groups across the political spectrum such as organized labor, which fears the continual loss of jobs to cheaper labor markets, human rights activists, religious conservatives and environmental groups. Ironically, President Clinton may have complicated the matter with his remarks last fall at the World Trade Organization (WTO) meeting in Seattle, which were particularly supportive of the labor and environmental constituencies. This alienated many free-trade advocates in Congress. China's increasingly aggressive moves toward Taiwan also are not helping the situation.

China is expected to gain official membership in the World Trade Organization later this year, a move that does not require U.S. Congressional approval.

Contact the AWS Washington Government Affairs Office at 1747 Pennsylvania Ave. N.W., Washington, DC 20006; telephone (202) 466-2976; FAX (202) 835-0243.

EDITORIAL

Developing the Finest in the World

In the world of welding, the words certified and certification are used all the time, and, certainly, the American Welding Society offers many successful certification programs. But do you know the philosophy behind the AWS programs and who creates the standards and determines policy for managing these programs? That job goes to the members of the Certification Committee, which is a market-driven standing committee reporting directly to the Standards Council. In turn, the Council reports to the AWS Board of Directors.

Certification is a very active committee. The members meet face-to-face four or five times a year. However, there are numerous communications and votes taken between meetings. This is a high-achieving team that takes its responsibilities seriously.

Take a look at just some of the AWS certification programs already in place: Certified Welding Inspector, Senior Certified Welding Inspector, Certified Welding Educator, Certified Welder, AWS NDE Inspector and the National Skill Standards certifications such as Entry-Level Welder and Advanced Welder. And more programs are in the works such as AWS Certified Welding Engineer, Certified Fabricator and NDE certifications such as Magnetic Particle Inspector and Dye Penetrant Inspector.

You may wonder why we need some of these certifications and why so many people participate in them. After all, the AWS Certified Welding Inspector program alone has certified approximately 18,000 persons worldwide.

First of all, certification adds value to a person's marketability in the workplace. Further, these certifications allow you to prove you are qualified without the need for further training.

The European concept of certification and that of some other U.S. certification bodies is you must undergo training and take specific courses to become certified. This can't just be training in general, and it doesn't matter how much experience you have. These certifications are not competency based, and this training is required even if you are completely qualified and can prove it. This philosophy has created a roadblock to certification that has limited who can be certified in areas such as nondestructive examination, welding engineering, welding education and training, and welding inspection to name but a few.

The American Welding Society and some other U.S. organizations believe if you pass a test you prove you are qualified, and you should be able to be certified without a requirement for further training. Testing, however, is not the only element of the AWS programs. There are also requirements regarding work experience and some physical requirements such as for vision, both of which are very positive aspects of our programs.

Many people in the United States and abroad have embraced the American Welding Society for its commitment to certification by testing. That's part of the reason the Certification Committee works so hard. We not only want to develop new programs but continually improve those already in place.

Over the years, I have received letters from and met with many of the people who are certified by the American Welding Society. I am very impressed with their abilities and professionalism. I hope you get a chance to work with some of our fine AWS certified personnel. I also hope when you look to become certified you look to the AWS. We have the finest programs in the world.

Jim Greer
Chairman, AWS Certification Committee

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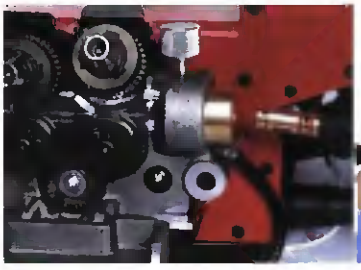

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COMMENTARY

Make Your Mark

Everyone, whether they're everyday nine-to-fivers or the titans of industry, wants to make a mark with their life. Now that may seem easy if you're fabulously wealthy. After all, look at the tremendous work Bill Gates and his wife are accomplishing with their wealth — they're giving back billions to people in need. Equally impressive, however, is the mark millions of people around the world are making through the combination of their small gifts working together. Last year in the United States, the top 50 foundations alone gave $3,620,476,665 to help people. There are 10,445 foundations in the United States with assets of more than $2 million and another 33,500 corporate and family foundations with assets less than $2 million giving billions for the betterment of people. Foundations, corporations and individuals give annually through gifts of cash, stock, real estate, tangible goods, insurance policies and bequests. And, out of all this giving, 83% of the contributions come from people with salaries under $60,000.

Ten years ago, through the vision of the AWS Board of Directors, the AWS Foundation was established to fulfill the desire of the members of the American Welding Society to give something back to their industry. Since then, the Foundation has developed programs such as the *Welding, So Hot It's Cool* video to help students become aware of the career potential within welding, and we offer National and District Scholarships to those who want to begin careers in our industry. A student loan program is available to assist those who either don't receive a scholarship or who need additional help. Through our Graduate Fellowship program, we support college graduates who want to further welding research and to advance our industry. For students from outside the United States, the Foundation offers an International Scholarship, and we are presently working with the Matsuo Bridge Company to develop the first AWS scholarship for students from Japan.

A new Visionary Club has also been established for individuals wishing to make a gift through their estate plan. Your gift of cash, life insurance policy, property, tangible items, trust, annuity, codicil or bequest can help carry on the industry that literally builds, shapes and advances the world we live in.

Last year, the AWS Foundation awarded more than $250,000 in grants to help students. Supporting the development of trained personnel to join our ranks is an investment in the future of our industry. This is why giving to the Foundation is so important.

The challenge gifts of The Lincoln Electric Co. and ESAB Welding & Cutting Products have created a lot of excitement about the work of the Foundation, resulting in a banner year. But the job is not done. We must look to every person involved in welding and every corporation that depends on welding to help raise an additional $4 million. These funds are an investment in our industry's future and are needed to fully serve the educational needs of the new members of our industry that the future will demand. We're asking you to consider, according to your ability, making a gift to the AWS Foundation. Not only will you help a young person start a rewarding career but you'll help make our industry stronger.

Call the Foundation office at (800) 443-9353 ext. 293, or (305) 443-9353 ext. 293 from outside the United States, and let us help you maximize your giving program. Everyone wants to leave their mark on the world; leave yours by helping students get the education they need.

Robert B. Witherell
Director of Development, AWS Foundation

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CyberNotes

A collection of industry news from the Internet

BY MARY RUTH JOHNSEN, Features Editor

Safety Products and Information

Arbill Glove & Safety. An addition to the Arbill Web site is its Safety First programs. These are monthly presentations geared toward a particular safety category formatted in PowerPoint® that can he used to assist in safety training, compliance and program development. Visitors simply click on the Safety First button on the Web site and select the program they are interested in. The following is the schedule for this year: Facility Maintenance I; Eye, Face & Head Protection; Storage & Handling; Facility Maintenance II; Emergency Response; Fall Protection & Confined Space; Respiratory Protection; Clothing & Footwear Protection; Hearing Protection; Hand & Arm Protection; Identification & Training; and Ergonomics & Matting.

The site includes plenty of information regarding the company's line of more than 4000 glove and safety products such as protective clothing, eye and hearing protection, hear gear, respiratory equipment and back supports. It also includes the current issue of the company's *Safety Net* newsletter, as well as articles from back issues that can be searched by either the subject or publication date.

The company is based in Philadelphia, Pa.

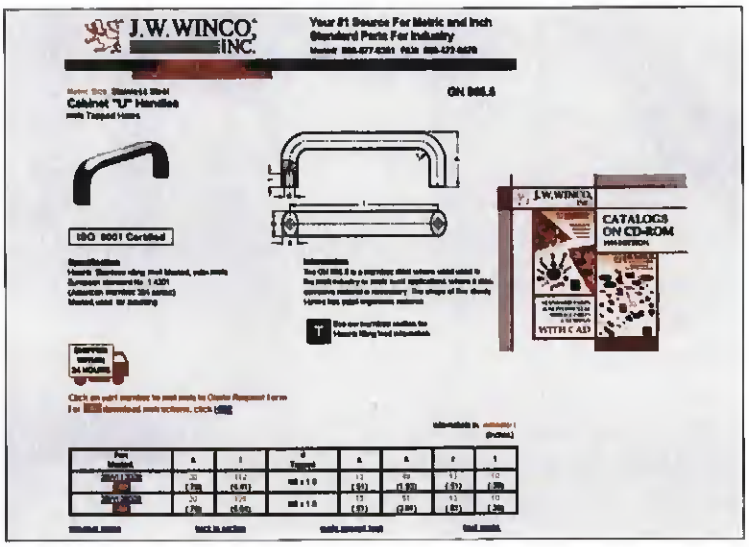
http://www.arbill.com

Standard Industrial Machine Components

J. W. Winco, Inc. The Web site for this New Berlin, Wis., based company now features its standard parts and supplemental service parts catalogs in their entirety, including specifications, dimensional information, photos and line drawings. The company offers a large selection of imperial- and metric-sized plastic and metal parts, including adjustable levers; cabinet U-handles; revolving and retractable handles; jig, fixture and fastening components; toggle clamps; casters and wheels; and hand knobs. The site also includes information regarding its in-house machining facility for custom-made and prototype work. Visitors can browse the catalogs using product group indexes or use the search button to find parts by keyword, series name or part number.

Browsers can also download the complete library of more than 9000 CAD drawings of the company's parts.

http://www.jwwinco.com



Digital Motion Control Technology

Galil Motion Control, Inc. Weekly live on-line conferences with company president Jacob Tal are one of the highlights of Galil's site. Tal provides information and answers questions most Tuesdays at 8:30 a.m. PST (11:30 a.m. EST). Advanced Tuning is the topic for the first two weeks in April; viewers must register on-line ahead of time to participate. If you miss the live seminar, recorded versions are available for viewing any time. The on-line registration also provides access to a library of tutorials, application bulletins and programming manuals.

The site's News section includes articles about motion control technology and applications and copies of *ServoTrend*, the company's quarterly newsletter. On the site's home page, the Product Finder directs visitors to the company's line of motion controllers. By indicating which bus (ISA, PC/104, VME, PCI, USB, Ethernet or RS232) and the number of axes needed, it provides links to the product that meets the application. The site includes full product specifications, manuals and ordering and pricing information. The company is based in Mountain View, Calif.

http://www.galilmc.com

Hardfacing Info

Postle Industries, Inc. This Web site offers information on the company's complete line of hardfacing wire in sizes from 0.045 through 7/64 in., electrodes in a variety of grades and sizes, thermal spray powders and abrasion-resistant epoxies. Besides product information, however, the site for this Cleveland, Ohio, based company offers information and graphics regarding the causes of wear, tips for better welding, how to apply hardfacing materials and how to calculate costs.

According to the site, ahrasive wear — the scratching or grinding of hard particles into a softer surface — accounts for 60% of all wear. The least severe form of abrasion is low-stress scratching abrasion. In this type of abrasion, small particles slide freely over a metal surface, scouring the surface as they move across it at varying velocities. An example is dry sand flowing over a part. "Since there is no impact associated with this type of wear, high-hardness, carbide-containing alloys, such as high-carbon/high-chromium carbide, complex carbide, tungsten and vanadium carbide, are best for this type of abrasion." The more severe type of abrasion is high stress grinding abrasion, which occurs "when abrasive particles are ground between two surfaces under pressure, causing the abrasive particles to fracture and be crushed." Fracturing of the ahrasive particles continually generates fresh, sharp cutting edges, which increases the rate of wear. Suggested alloys to resist this type of abrasion are chromium carbide and complex carbides.

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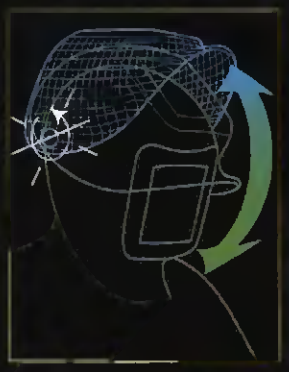

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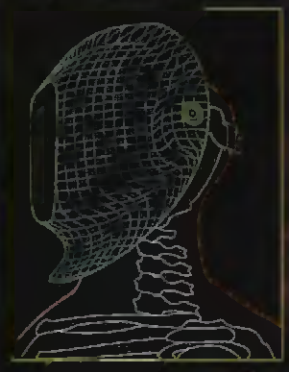

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AWS Conferences & Seminars

The AWS Conference Department Offers a Five-Day Seminar Dedicated to the New D1.1: 2000 *Structural Welding Code — Steel*

You have the option of registering for the entire week or selecting the date/topic of your choice.

Day 1 (Monday) D1.1 Road Map

This one-day program will provide a comprehensive overview of AWS *D1.1: 2000 Structural Welding Code — Steel.* Each of the Code sections, including General Requirements, Design of Welded Connections, Prequalification, Qualification, Fabrication, Inspection, Stud Welding, and Strengthening and Repair of Existing Structures, will be summarized, with emphasis on their interrelationships and usage. Additionally, the role of mandatory and nonmandatory annexes will be reviewed, along with tips for how to use the Code Commentary. Though not a prerequisite, the "D1.1 Road Map" provides a broad basis of understanding the Code for those who are attending other detailed sessions later in the week.

Day 2 (Tuesday) Design of Welded Connections

Engineers responsible for designing welded steel structures or reviewing designs will appreciate this in-depth look at the design rules of D1.1. This one-day program will include four sessions as follows:

- Common Requirements of Nontubular and Tubular Connections.
- Specific Requirements for Nontubular Connections (Statically or Cyclically Loaded).
- Specific Requirements for Cyclically Loaded Nontubular Connections.
- Specific Requirements for Tubular Connections.

Day 3 (Wednesday) Qualifications

By popular demand, AWS offers this one-day session on documentation and qualification of both welding procedure specifications and welding personnel. The ins and outs of prequalified WPSs will be covered, including tips on how to write an effective WPS. Other topics include filler metal selection, determinations of preheat and interpass temperatures and the use of prequalified joint details. For those who are unable to use prequalified WPSs, a step-by-step review of the procedure qualification process will be covered, including tips on how to prepare the important PQR.

Day 4 (Thursday) Fabrication

This course will provide an in-depth look at the control and storage of welding consumables, stress-relief heat treatment, base metal preparation, joint dimension and tolerances and structural member dimensional tolerances, along with other topics. The significance of weld profiles and repair of defects will also be covered, along with an overview of the acceptance criteria for the different weld categories and inspection methods. Discussions on stud welding and requirements for strengthening and repairing existing structures round out this intense program.

Day 5 (Friday) Inspection

Code Week concludes with a one-day session devoted to inspection of structural steel welds. Inspector qualifications and responsibilities of inspectors and contractors will be covered. Procedures and techniques for visual, liquid penetrant, magnetic particle, radiographic and ultrasonic inspection are highlighted as a prelude to a detailed review of the inspection acceptance standards. Test method fundamentals will be covered, where necessary, to understand the more in-depth tables and criteria, along with tips on what to look for in inspection reports. Whether you are a supervisor, engineer, inspector or auditor, you will find this clear presentation a must for a better understanding of weld quality.

For further information, contact: Conferences, American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126, Telephone: 800-443-9353 ext. 223 or 305-443-9353 ext. 223, Fax: 305-443-1552. Visit the Conference Department home page via *http://www.aws.org* for upcoming conferences and registration information.

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- Development team
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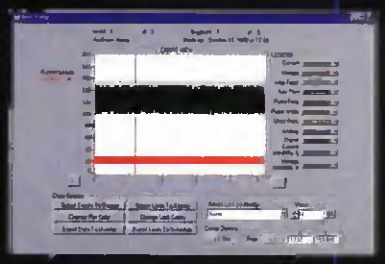
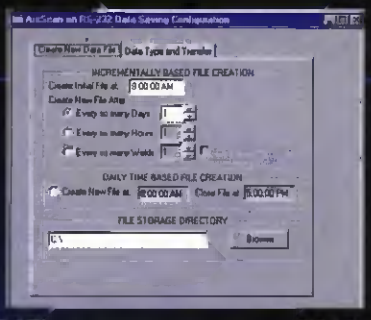


CHART VIEW



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AccuData Inc., WeldWare Inc. *Development Team

Welders Developing For Welders

Darren Barborak has a BS and MS in Welding Engineering from The Ohio State University and will receive his Ph.D. in 2000. (WeldWare)

Chris Conrardy has a BS and MS in Welding Engineering from The Ohio State University. (WeldWare)

Bruce Madigan has BS and MS degrees in Welding Engineering from The Ohio State University, and a Ph.D. from Colorado School of Mines. (WeldWare)

Todd McEllis has a BS in Welding Engineering Technology from Ferris State University. (AccuData)

Troy Paskell has a BS and MS in Welding Engineering from The Ohio State University. (WeldWare)

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Letters to the Editor

ESW Offers Good Performance

Dear Editor:

I commend you for helping the cause to reinstate the valuable electroslag welding (ESW) process as per the article titled Electroslag Welding Stands Poised for a Comeback in Bridge Construction by Mary Ruth Johnsen in the February 2000 issue of the *Welding Journal*.

To clarify a few areas, however, the process was never prohibited for compression members, nor was it the contractor/fabricator who chose not to use the process. It was the prohibition of the American Association of State Highway and Transportation Officials (AASHTO). This group is represented by the bridge engineers of each state and each has the full authority to use or not use the ESW or any other process, funded or not funded by the Federal Highway Administration, on his/her state work. They did not understand the real problem and, thus, just to play it safe, prohibited ESW on all the work, tension and compression. Tennessee, to my knowledge, is the only state that allows this process on compression flanges per AWS D1.5, *Bridge Welding Code*, paragraph 4.5. Structural steel fabricators still use the process if the work warrants its use per AWS D1.1, *Structural Welding Code — Steel*, paragraph 3.2.2.

I have always been an ally of ESW. With proper control, procedures and a skilled operator, along with 100% nondestructive testing using both radiography and ultrasound, I have supervised hundreds of electroslag welds with the present method on bridges in Alabama, Florida, Tennessee, Mississippi and Louisiana. No weld was found to be defective. However, the narrow gap improved-electroslag welding process can perform as a less troublesome method and assure good performance each time.

Rex Fronduti, P.E.
Rex Fronduti & Associates
Millbrook, Ala.
Member, AWS D1 Committee

As Mr. Fronduti correctly points out, and which was stated in the article, electroslag welding was never prohibited for use on compression members. The ban on its use for tension members had a carry-over effect, however, and its use on compression members declined.

AASHTO's role in the moratorium on the use of ESW was not mentioned in the article. We appreciate the additional information Mr. Fronduti has provided.

Mary Ruth Johnsen
Features Editor
Welding Journal

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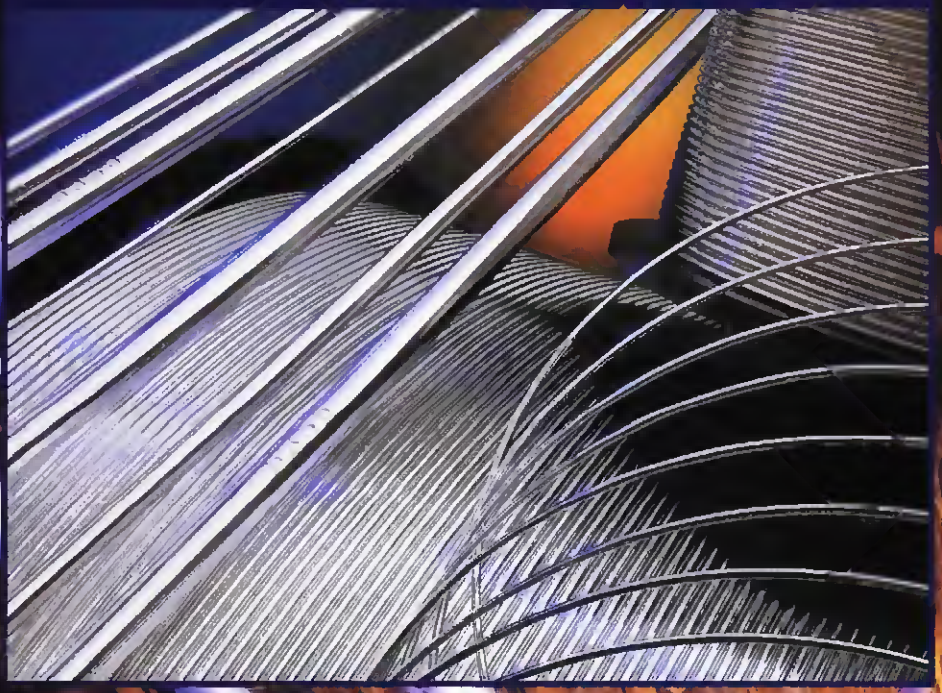

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More important, because of your enthusiasm and contributions to provide scholarships for deserving students and maintain the growth of the welding industry, you surpassed the goal by $187,000. The Foundation is proud to recognize the many companies, individuals, AWS volunteers and staff, and AWS Sections who responded to the challenge and marked year 2000 as the beginning of the next great welding millennium. You made the difference! On behalf of future welding students and the industry, THANK YOU!!!

AWS Foundation, Inc.

A Foundation of the American Welding Society

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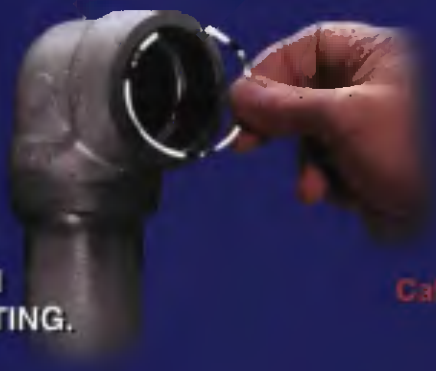

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Technology Abounds at METALFORM 2000

The staccato sound of a turret punch press was the beckoning call for metal fabricators to enter through the doors of the Nashville Convention Center and enjoy METALFORM 2000. Here they were tempted with the latest technology in stamping and punch presses, coil handlers, press breaks, tool and dies, die lifters and rollers, stackers and destackers, spinners, lubricants and electronic sensors. The premier exposition of the Precision Metalforming Association attracted 6700 attendees who viewed the displays of 306 exhibitors from Feb. 13–16 in Nashville, Tenn.

In addition to the exhibits, more than 80 technical sessions were offered during the three days. General topics covered included press technology, material handling, electronics and sensors, quick die change, lubrication, tool and die, assembly and fastening, roll forming, fabricating and welding, emerging technologies and improving the metalworking environment.

Issues with Tailor-Welded Blanks

Stanley Ream, a senior corporate project manager for Worthington Industries, made a presentation on tailor-welded blanks from a die stamping perspective. He noted that today the technology is strictly being used in the automotive industry, but its use is growing. There will be 35 million tailor-welded blanks stamped in North America in 2000, and that level is estimated to increase to 90 million by 2005.

Tailor-welded blanks offer distinct advantages for components, but they present unique problems to the metal stamping operation.

The two main processes used are mash seam and laser beam welding, with lasers dominating overall. Average length of the blank is 1.2 m and the average production per laser is 555,000 blanks per year. Presently, there are 13 suppliers of welded blanks, many of which are less than two years old.

Tailor-welded blanks offer components such as door inners the distinct advantages of higher stiffness, reduced weight, reduced set and sag, fewer stamping dies, improved fit, enhanced crash energy management and overall lower manufacturing costs, but they present unique problems to the metal stamping operation. Since the blank commonly consists of two and three different thicknesses, along with different strength levels, the die design becomes a challenge. It must accommodate the different thicknesses, it must be sensitive to gauge and blank dimensions and the blank must be more precisely positioned on the die to obtain the desired shape. Also, failure analysis becomes much more complicated because of the different strength levels. If the strength variations are too great, the blank cannot be properly formed.

Design of where the weld interface falls should take into account the stamping operation. A linear weld interface is desired and should be placed where it will not interfere with fastener locations. There is also a tendency for the weld interface to move to the thicker part in the stamping operation. The higher the ratio of thickness the greater the movement. This concern requires a well-designed, as-received welded blank and great accuracy in positioning the die. The weld should not fall in a sharp draw radius. A quality issue also arises if problems such as cracking, porosity, concavity or mismatch occur along the weld interface. Is this a stamping issue or a welding problem? Acceptance criteria developed by the Auto/Steel Partnership offer help by illustrating and describing an acceptable weld from the perspective of the stamper.

Material handling is another issue with tailor-welded blanks. Since different thicknesses make up the welded blank, the finished sheet does not lay flat. When multiple sheets are stacked, the bundle becomes lopsided. This condition makes shipping difficult. The stack must be carefully banded to the pallet or sheets may slip off or shift during transport, and once in the manufacturing facility, an automated destacker may have difficulty handling the uneven stack.

The Future of Manufacturing

George Keremedjiev, president, Tecknow Education Services, Inc., foresees new technologies on the horizon for making dies and molds. He detailed a futuristic manufacturing process known as laser engineered net shaping (LENS), which is being developed at Sandia National Laboratory.

This process uses a computer-controlled laser to precisely heat a work surface. Extremely fine powders of various materials are then transported by a nitrogen gas to the surface where they are melted by the heat of the laser. One layer at a time is produced until the desired net shape is achieved.

The advantages of this process are the production of very dense products, with no holes or porosity, and the ability to mix different materials into one object. Ceramic material can be layered with metals or different metals can be combined, such as tool steel with nickel alloys or stainless steel. The process is being refined to improve the dimensional accuracy of the final product and eliminate the slightly corrugated finish. Companies such as Eastman Kodak, 3M, Lockheed Martin and Optomec are interested in perfecting the process. Optomec, a small Albuquerque, N.Mex., company, has indicated it is working on a commercial introduction of LENS. It proposes to "grow" a variety of sample parts to demonstrate the process to potential customers.

Speculating that this may be the tooling method of the future, Keremedjiev emphasized that tomorrow's toolmaker must be computer literate, comfortable with mathematics and physics, and able to embrace new technology.

See It All Next Year

Next year the metalforming technology that is the heart and soul of METALFORM will be on display alongside the welding and cutting technology that has made the AWS International Welding and Fabricating Exposition the premier annual event in the welding industry. This combined show will exhibit under a single banner from May 6 to 10, 2001, at the I-X Center in Cleveland, Ohio. It is estimated the combined presence will attract 1000 exhibitors and more than 40,000 attendees. A single registration will offer the full breadth of metal fabricating technology on exhibit and make available attendance at all the technical sessions — *Andrew Cullison, Editor.*

News of the Industry

Laser System Welds Giant Fermantation Tanks

When Landaluce S.A., Torrelavega, Spain, needed to make long, straight, precise welds to build a 200,000-gal beer fermentation tank, it found its solution with a modified laser welding system from Prima Industrie S.p.A., Turin, Italy, the parent company of Prima U.S. in Farmington Hills, Mich.

The tanks, which are used for controlling the fermentation

A CO_2 laser welding system was developed to weld this fermentation tank, capable of handling 200,000 gal of beer. The tank measures 49 ft in diameter and is 75 ft in height.

process, are approximately 49 ft in diameter and 72 ft in height. The base structure consists of 0.2-in.-thick AISI 304 stainless steel sheet. Sheets measuring 39 ft 8 in. long x 5 ft wide are welded together and then rolled to form a half cylinder. Two halves are then welded together to form the completed cylinder; additional sections are added laterally to achieved the desired tank length. On the outside of the cylinder, 0.06-in.-thick AISI 304 corrugated stainless steel sheets are clad to the base cylinder. The corrugations have a rise of about ½ in., are 2 in. wide and 37 ft 8 in. long. The sides on each of the ten corrugations on the sheet are welded down over the base sheet to form tubes that will contain conditioning fluid to control temperature. The length of the weld to attach these sheets is more than 37 ft long and there are 11 welded joints per section, which translates into more than 400 ft of welding.

Prima adapted a Platino 1530 CO_2 laser welding system for this application. Equipped with a 2500-W laser generator and a special NC table that moves on the X axis, the setup had to hold and move the metal sheets, which are longer than the X stroke of the machine, for welding. In addition, a set of tracks was fabricated to move the parts back and forth under the laser. The standard cutting head was replaced with a welding head, and a fume extractor was attached to the head of the machine instead of the bottom of the table. In addition, a protective wall was put up on each side of the machine's safety cabin.

Excluding loading and unloading, cycle time to weld the tanks is now 1½ h.

National Engineering Honor Society Names Top Engineers and Engineering Achievements

Tau Beta Phi, the National Engineering Honor Society, recently named the top ten engineers and engineering achieve-

ments of the 20th century. Nearly 90,000 members, who subscribe to the organization's quarterly publication, *The Bent*, were asked to submit their choices of notable engineers and engineering achievements that profoundly impacted technology during the last century.

The top engineers of the 20th century named are, in order, Thomas A. Edison, Orville and Wilbur Wright, Henry Ford, Wernher von Braun, William B. Shockley, Charles P. Steinmetz, Lee deForest, George W. Goethals, Herbert C. Hoover and Hyman G. Rickover.

The top engineering achievements identified are, in order, Apollo program and moon landing (1960s), airplane (1903), digital computer (1941), transistor (1947), television (1939), Manhattan project — nuclear weapon (1945), Panama Canal (1914), integrated circuit (1959), jet engine (jet plane) (1941) and communication satellites (1962).

Tau Beta Pi recognizes engineering students of superior scholarship and exemplary character and honors eminent practitioners of engineering. Founded at Lehigh University in 1885 and now headquartered in Knoxville, Tenn., it has 220 collegiate chapters and 14 alumni chapters through the United States.

Automakers Increase Their Use of Advanced Steel Technologies

In the two years since the global steel industry unveiled its UltraLight Steel Auto Body (ULSAB), automakers have increased their use of the advanced technologies demonstrated in the ULSAB, according to the American Iron and Steel Institute (AISI). The primary technologies that have shown up in new vehicles are the use of high- and ultrahigh-stength steel, tailor-welded blanks, hydroforming and laser beam welding. These technologies help reduce weight in automobiles, which, in turn, increases fuel economy.

Prototype designs for a European C-class three-door car and a North American PNGV-class vehicle, part of the ULSAB Advanced Vehicle Concepts program.

"We see abundant technologies in the vehicles they have put on the road since we unveiled ULSAB in March 1998," Darryl C. Martin, senior director, Automotive Applications, AISI, said.

Examples of current vehicles using these technologies include the Ford Focus, which uses high-stength steel for the body

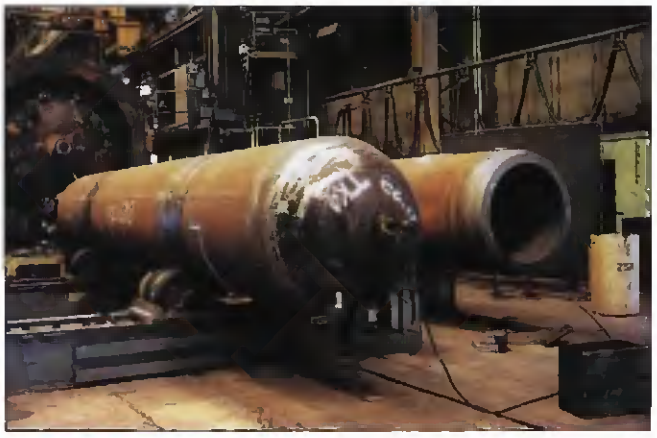
structure and exterior body panels; the Jeep Grand Cherokee, which uses nine tailor-welded blanks, four of which are in the body structure; the Buick Park Avenue and Cadillac Seville, for which General Motors uses hydroformed roof rails; and Volvo, BMW, Volkswagen and Mercedes, which all use laser beam welding in the roofs of vehicles.

The ULSAB project is continuing. The goal of the Advanced Vehicle Concepts program is to design a family of compact vehicles suitable for 2004 and beyond (see figure). According to AISI, vehicle styling influences body structure, closures, package, electrical components, aerodynamics and mass. Designers at Porsche Engineering Services' Styling Studio in Huntington Beach, Calif., developed two variations of one basic design, a European C-class and North American PNGV-class. Further information is available on AISI's Automotive Applications Committee's Web site at *www.autosteel.org*.

Nooter Fabricates Vessels for Delta IV Launch Complex

Nooter Fabricators, Inc. (NFI), St. Louis, Mo., recently delivered 14 high-pressure, gaseous nitrogen and helium storage vessels for the Delta IV Launch Complex ground support system at Cape Canaveral Air Station, Fla.

"The 300 cubic foot vessels, designed per ASME (*Boiler and Pressure Vessel Code*) Section VIII, Division 2 for 6600 lb/in.^{2}, are fabricated from 6-in.-thick SA-737 Grade C high-strength carbon steel," Mike Bytnar, NFI president, said. The vessels, which weigh more than 100,000 lb each, will be used in the purging of fuel lines before fueling the Delta IV launch vehicles, as well as to store high-pressure gases.



Nooter Fabricators, Inc., recently delivered 14 high-pressure vessels made of 6-in.-thick, high-strength carbon steel to the Cape Canaveral Air Station in Florida.

The Delta IV family of launch vehicles is Boeing's entry into the Air Force's Evolved Expendable Launch Vehicle (EELV) program. The EELV program aims to reduce space launch system costs by up to 50% from today's rate of approximately $12,000 per pound of payload to orbit.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New Products

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Portable Power Source Offers Versatility

The Champion 10,000 engine-driven generator/welding machine is suited for farming, maintenance and repair, general construction and emergency power generation applications. It is an all-in-one AC generator/DC welding machine that enables users to take their own power to a job site where electricity is not available. With its 230-A DC welding power source and 10,000 W of auxiliary power potential, it gives users the ability to weld or the power to keep needed equipment running during an electrical outage. The unit is about 3 ft long and weighs less than 440 lb. It is designed to provide a smooth arc for shielded metal arc welding, constant-current flux cored arc welding and scratch-start DC gas tungsten arc welding. The machine's front has a single welding control knob and an amp selection guide. Customers may choose between a Kohler and Onan gasoline-powered, 20-hp overhead valve engines. It has a 10-gal fuel tank and requires oil changes every 100 h of operation.

Hobart Brothers **200**
600 W. Main St., Troy, OH 45373

Interface Connects GTAW Machines to Automation Controls

The Automation Interface Connector, an external, ten-pin amphenol, connects gas tungsten arc welding machines to automation controls. Available on the Maxstar 300 DX and Dynasty 300DX, the connector is designed for plug and play with the company's alliance members, Jetline and Pandjiris. There are six features provided: an arc detect,emergency stop, pulsed lockout, start/stop, gas control and an end-of-weld sequence. Arc detect sends a signal out of the power supply indicating a valid arc condition has been established. If someone is in the way or the parts are not lined up, emergency stop immediately stops the power supply and the arc will go from weld current to contactor off; gas continues to flow. Pulsed lockout allows system integrators to connect an arc voltage control (AVC) to the connector and will lock out peak commands, so the AVC is not hunting while going through the pulsing cycle. End-of-weld sequence allows system integrators to know when the end-of-weld sequence has been reached.

Miller Electric Mfg. Co. **201**
1635 W. Spencer St., Appleton, WI 54912

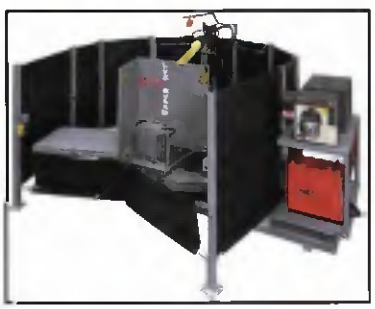
Cutting System Drive Component Offers High Transfer Rate

The Avenger 1 gantry shape-cutting system offers a transfer rate of up to 750 in./min. It incorporates Yaskawa AC brushless motors with digital drive amplifiers, coupled directly to planetary gearboxes. The selected gearbox limits maximum backlash to 5 arc minutes (0.0011 in.). The resolver used for positioning feedback is integral to the drive motor. Supporting decks have also been upgraded with thicker steel to increase the machine's stiffness-to-mass ratio.

ESAB Cutting Systems **202**
411 S. Ebenezer Rd., Florence, SC 29501

Work Cell Handles Medium-to-High Part Volume

The Versa DST is a dual-station swing table robotic welding and cutting work cell that handles medium-sized parts and medium-to-high part volumes. The unit's table dimensions are 43 x 24 in., with a weight capacity of 250 lb per table.



Common applications include automotive components, lawn and garden components and office furniture. The unit has a compact design that features a unitized base. Its common robot and positioner base means programs do not require touch-up if the system is relocated. Installation involves hooking up air and power. A safety package is included.

Genesis Systems Group **203**
8900 Harrison St., Davenport, IA 52806

Sling Provides Secure Grasp on Gas Cylinders

The BoaGrip™ gas cylinder sling is an adjustable tool for gripping, carrying and suspending compressed gas cylinders. It also complies with OSHA 1910-102(a) for safe handling of compressed gas cylinders. The sling is made of nylon, and has a sewn eye at one end and an oblong steel ring at the other. The sewn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New Products

eye fits through the ring to form a lasso. The sling's inner surface is lined with polymer grippers. When the sling is

slipped over a cylinder and pulled tight, the grippers are forced onto the cylinder's surface, holding it tight and allowing it to be lifted onto devices such as welding or cylinder carts. An extension bar on the sling's steel ring prevents it from binding or bunching when pulled. Typically, a worker can grasp the cylinder cap with one hand and use the other to hold the sling. The sling adjusts to accommodate cylinders 4–14 in. in diameter.

Safe Shop Tools, Inc. 204
P.O. Box 4206, Missoula, MT 59806

Boiler Beveling Machines Are Portable

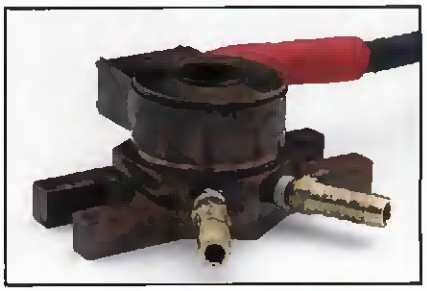
The company's boiler-tube beveling machines offer reduced size and weight. They prepare for welding boiler tubes from 0.69-in. inside diameter to 4.5-in. outside diameter, and up to 0.500-in.

wall thickness. It has minimal side clearance for use in tight boiler areas.

The E. H. Wachs Co. 205
100 Shepard St., Wheeling, IL 60090

Sensor Monitors Weld Force Currents

The platen-style WeldThrough Sensor monitors and fires weld force current at preselected force limits while si-



multaneously monitoring secondary current and cooling water temperature for further quality control. This version of the multifunction sensor is designed specifically for projection welding applications and measures welding force, current and cooling water temperature during each weld. The platen style matches the hole pattern of the standard RWMA platen electrode holder and includes standard water cooling ports. The sensor can replace existing electrode holders on many projection welding systems and, integrated with appropriate

instrumentation, can provide relay contacts to control the weld process or provide downloaded data to track process parameters.

Sensotec, Inc. 206
2080 Arlingate Ln., Columbus, OH 43228

Clamp Designed to Hold On in Tight Spots

The Strong Hand cantilever clamp is designed for clamping in tight areas.The screw assemhly is located on the back of the clamp, away from the work area, for clear access. Designed for flexibility in welding applications, the screw assembly can slide off the clamp arm and be reversed for either pushing or pulling action. The clamping pad pivots freely. An optional V-shaped clamping pad provides extra gripping of round workpieces. All clamps are replaceable. It is made of heat-treated steel with a nickel-chrome plating that resists contaminants. It is available in 12-, 24- or 40-in. capacities, with clamping pressures of 1850 lb.

Good Hand, Inc. 207
720 S. Vail Ave., Montebello, CA 90640

Stud Welding Machine Features Multi-Gun Capability

The ABC stud welding machine has multi-gun capability as an optional feature. It allows the user to set up as many as four guns. Users can welding up to

four different sizes and types of studs. The unit measures 26.9 x 25.9 in. The company offers three-phase units of 1200 or 2000 A. Users can upgrade as needed.

Image Industries Inc. 208
382 Balm Ct., Wood Dale, IL 60191

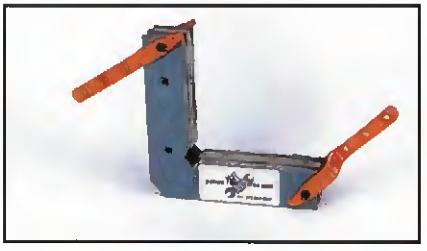
Regulator Designed for Noncorrosive Acetylene Service

The Model 202-510A single-stage pressure regulator is constructed of brass and is recommended for noncorrosive acetylene service. The regulator features a neoprene diaphragm that permits accurate delivery pressure settings. An outlet needle valve provides flow control while a sintered metal filter in the seat assembly traps foreign particles.

Scott Specialty Gases 209
6141 Easton Rd., Plumsteadville, PA 18949

Positioners Holds Magnetic and Nonmagnetic Material

MagSquare™ positioners, through creative use, can hold both magnetic

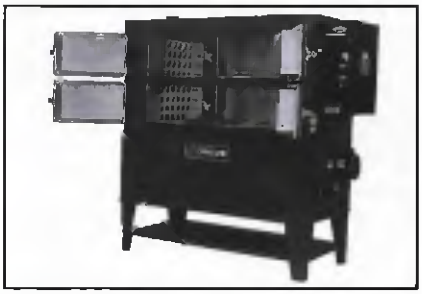


and nonmagnetic material. By sandwiching plate steel, aluminum or stainless between the double-L-shaped magnets, the positioners effectively hold all types of material at a 90-deg angle. The positioners require no power and feature up to 245 lb of pickup holding power, depending on the model. They are available in a variety of sizes and configurations.

DetroitToolWorks.com **210**
37682 Radde St., Clinton Township, MI 48036

Batch Soldering Oven Features Extended Chamber Width

Model No. 596 oven is an electrically heated cabinet oven used for soldering parts in fixtures. The unit features an extended chamber width and four separate front-access doors for loading/unloading of the 46 x 20 x 26-in. workspace. Total installed capacity of 15 kW in Inconel®-sheathed tubular heating elements furnish temperatures

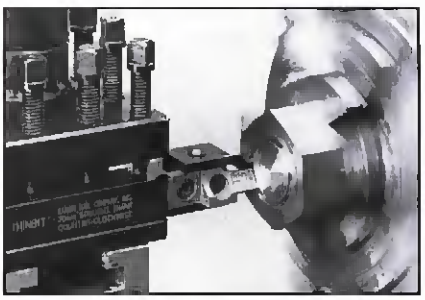


up to 650°F in the aluminized steel interior. Horizontal air flow across two metal shelves processes the workload. The four front doors, each with a 20 x 11-in. opening, permit independent access to a portion of the workpiece. A side-mounted control panel houses the indicating temperature controller and manual reset excess-temperature controller. Independent pilot lights indicate when the blower and heaters are energized.

The Grieve Corp. **211**
500 Hart Rd., Round Lake, IL 60073

Face Grooving Tool Inserts Used for O-Ring Applications

LITTLEBIT® face-grooving and shoulder-face-grooving inserts, part of the THINBIT line, are available in a variety of sizes. All inserts are available in widths for common O-Ring applications



— 0.30, 0.50, 0.62, 0.90 and 0.125 in. — in either DURA-MAX® 2000 or 5000 carbide. The face-grooving inserts come with a major diameter of either 0.300 or 0.750 in. in a counterclockwise rotation. The shoulder-face-grooving inserts have the same major diameters and are available in either a right-hand or left-hand orientation with a counterclockwise rotation.

Kaiser Tool Co., Inc. **213**
3620 Centennial Dr., Fort Wayne, IN 46808

Engine-Driven Power Source Offers Arc Performance

The Ranger 250 commercial, engine-driven welding machine/generator offers arc performance with Chopper technology. This technology controls the DC welding output to create a smooth arc, easy starts, low spatter and good bead appearance, according to the company. The unit is housed in an enclosed engine case for increased safety. In addition, a flip-down door hides less frequently used controls to

improve the overall appearance of the machine. The 250-A, DC multi-process, gasoline-driven unit can be used for general-purpose shielded metal arc welding (SMAW) and pipe SMAW, gas tungsten arc welding, cored wire, gas metal arc welding and arc gouging up to 3/16 in. in diameter. It offers 8000 W or 120 V/240 V AC-generator power for powering tools, lights and plasma arc cutting units. The unit comes with a choice of engines from Onan and Kohler.

The Lincoln Electric Co. **212**
22801 St. Clair Ave., Cleveland, OH 44117

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The 24-ft-tall bronze sculpture, **Il Cavallo,** *is a modern-day interpretation of the sculpture Leonardo da Vinci designed and planned to build for the Duke of Milan. Here, workers position the head and neck section in preparation for bolting from the inside and then welding onto the body prior to its unveiling in September in Milan.*

The Great Master's Horse Returns Home after 500 Years

Welding played an important role in producing a modern version of Leonardo da Vinci's unfinished masterpiece

In the same tradition of international goodwill as France's gift of the Statue of Liberty, the United States recently presented Italy with *Il Cavallo*, the world's largest bronze sculpture of a horse—Fig. 1. The gift honors the Italian people for 2500 years of cultural heritage; recognizes the horse as a bearer of movement and messages for centuries; encourages curiosity, imagination and creativity in youth; and commemorates Leonardo da Vinci, the Renaissance's greatest universal man. To fully understand the significance of *Il Cavallo* (Italian for "the horse"), its history must be traced back more than 500 years.

In 1482, the Duke of Milan commissioned Leonardo da Vinci to design the world's largest equestrian sculpture. Da Vinci used his keen grasp of animal anatomy (Fig. 1) to design and produce a 24-ft 6-in. clay model of his planned bronze sculpture.

Fig. 1 — Leonardo da Vinci made many sketches of horses in preparation for creating Il Cavallo (Windsor, RL 12319 r).

Based on a story from Miller Electric Mfg. Co., Appleton, Wis.

Fig. 2 — The sculpture was unveiled at Milan's Hippodrome Cultural Park on September 10, 1999, exactly 500 years from the day da Vinci's original model was destroyed.

But on September 10, 1499, France invaded Milan and French soldiers destroyed da Vinci's clay model by using it for target practice. The bronze allotted for the sculpture was reassigned for making cannons, and the Duke's commission was dissolved. Da Vinci was reported to have wept on his deathbed for his unfinished masterpiece.

Charles Dent, a retired airline pilot, read the story about da Vinci's horse in an article in *National Geographic* in 1977 and conceived the idea to "give Leonardo his horse." Dent founded the nonprofit organization Leonardo da Vinci's Horse, Inc. (LDVHI), and worked with sculptors, art historians, da Vinci scholars and equine experts to produce a modern version of da Vinci's dream. The sculpture was unveiled in Milan on September 10, 1999, exactly 500 years from the day da Vinci's original model was destroyed — Fig. 2.

"The whole project is a beautiful concept," Peter Homestead said. Homestead is president of Tallix Foundry, Beacon, N.Y., the art foundry that produced *Il Cavallo*. "It is a beautiful idea to do a modern interpretation of something the great master, Leonardo da Vinci, never had a chance to see to completion."

To produce *Il Cavallo*, Tallix worked from a design by American artist Nina Akamu. Once an 8-ft (2.4-m) model was produced, it was put on an enlarging apparatus that mechanically worked the 24-ft clay model to scale. Working the entire full-size model took one year.

Molding and Casting

A "mother mold" of the horse was made by spraying the model with liquid rubber mold material and then applying a half-inch layer of polyester resin and fiberglass to the rubber coating for a sturdy backing. When it hardened, the rubber sections were removed.

Most of the horse was sand cast. Sand casting involves making positive plaster castings from the mother mold and placing them, one at a time, in an 8-ft steel molding box. Next, a sand and binder mixture is packed around the section. Once the mixture has hardened, the sides of the molding box are separated and the plaster is removed to create a negative image in the sand. The molding box is closed again and molten bronze (at about 2000°F [1093°C]) is poured in through pour spouts. When the bronze has cooled, the sand mold is broken and the result is the bronze casting.

Lost wax casting was used on the more intricate areas, such as the mane, tail and face, to pick up small details. The lost wax casting process starts by coating the rubber molds in wax to make wax replicas of the original model's parts. The wax parts are dipped into a slurry ceramic shell solution and coated to ⅝ in. (15.87 mm), which hardens into a mold. To remove the wax, the mold is placed in an autoclave, baked at 1350–1450°F (732–788°C), and the wax is burned out. Then the mold can be filled with bronze.

The materials used in casting and molding may have changed, but the methods have remained somewhat unchanged since da Vinci's time. Although Leonardo planned to cast the entire horse in one piece, experts today say it would have been impossible because bronze is difficult to keep at constant temperature while it flows into the many crevices of a large mold. Tallix's experience in large metal sculpture dictated casting the sculpture in 60 pieces, all about 4 ft square (1.2 m) and comprised of ¼- to ⅛-in.-thick (6.3- to 9.5-mm) silicon bronze.

Assembly in the Foundry

The castings were matched, tack welded together and then gas metal arc (GMA) welded on the inside of each joint using Deltaweld® power sources and XR™-A push-pull wire feeders from Miller Electric Mfg. Co., Appleton, Wis. The wire feeder was chosen because it could reach the most difficult places within *Il Cavallo*, sometimes up to 30 ft (9 m) from the power source.

Tallix welders used 0.045-in.-diameter (1.14-mm) silicon bronze wire (ERCuSi-A per AW5/5FA A5.7) at traveling speeds of 60 in./min (1.5 m/min).

"I'll bet we used 500 to 600 lb (225 to 270 kg) of wire, with a total of about one mile of welds," Homestead said.

Gas tungsten arc welding (GTAW) was used on the external sides of the joints where cosmetics were more important — Fig. 3. Gas tungsten arc welding gives a more attractive weld because it produces less spatter and doesn't warp or distort the metal. Tallix used Miller Syncrowave® 250 GTAW machines and 1/16- to 3/32-in.-diameter (1.58- to 2.38-mm) silicon bronze (ERCuSi-A per

Fig. 3 — Gas tungsten arc welds were used on the outside of the sculpture for cosmetic reasons.

Fig. 4 — A welder uses the GMAW process to attach the stainless steel and titanium pole fitted inside two of the sculpture's legs to steel plates embedded in the concrete pedestal on which it now stands.

AWS/SFA A5.7) filler metal.

The welds were finished by a process called chasing, which blends the welds to the "rough rake" texture of the sculpture and prepares the surface for the patina (the chemical that colors the bronze) and wax.

A structural engineer analyzed the sculpture and set structural specifications based on loads from natural forces such as wind and earthquakes, as well as the structure's own weight load. From those specifications, an armature of Type 304 stainless steel was designed to support the sculpture from the inside. The 3-in.-diameter (7.6 cm) armature tubing was cut with a plasma arc cutting machine to created a "ribbing" that fit the exact curves and dimensions of the horse. To gas metal arc weld the armature to the bronze skin, Tallix used 0.045-in.-diameter ERCuAl-A2 aluminum bronze wire.

The two legs on which the sculpture rests were each fitted with an 8-in.-diameter (20.3-cm), 1-in.-thick (2.54-cm) stainless steel/titanium pole that extends 18 in. (45.7 cm) below the hooves and was eventually GMA welded to steel match plates embedded in the concrete pedestal in Milan — Fig. 4. The poles reinforce the 15 tons of weight put on two legs — 12 tons from the bronze skin, 3 tons from the armature.

Once the sculpture was completed, it was unbolted at the joints connecting the seven main parts (head/neck, body, four legs and tail) and flown to Milan for final assembly at the Hippodrome's Cultural Park. Three welders, a finisher and a patina worker from Tallix traveled to Milan to begin the one-week assembly on *Il Cavallo*.

When they arrived, the same power sources and wire feeder they had used in the United States were waiting for them, provided by Miller Europe, which has facilities in Milan.

"We wanted to be sure we were getting the same weld quality and performance in Milan that we had in the foundry, so we requested the same models we had at home," Homestead said. The same ceramic cups, tungsten electrodes and wire that had been used previously was also supplied.

Assembly in Milan

To assemble the sculpture, the horse's body was set on its side and the four legs were bolted and then welded on. Next, the body and legs were lifted by a crane, placed upright and set on the concrete pedestal.

The head and tail were lifted by crane, positioned and bolted on from the inside before being welded onto the body (see photo on page 44). Another stainless/titanium pole reinforced the tail. Once all inside welding was completed, the trapdoor on the horse's belly was welded shut and finished. To complete the project, the pedestal received a white marble facade.

Since its unveiling, *Il Cavallo* has received notice from people all over the world, including travelers, families and school children. To everyone involved in the making of *Il Cavallo*, including the artists, the LDVHI board and the Tallix crew, it is much more than just a sculpture.

"In the future, our culture will be studied through the sculptures and artifacts we produce today," Homestead said, "just as cultures have been studied by their art throughout history." ◆

Chicago: There's a Whole Lot of Welding Going On

A wealth of projects, especially in construction, should keep Chicagoland welders and welding-related businesses extremely busy

BY MARY RUTH JOHNSEN AND TIM HESTON

Fig. 1 — Frank O. Gehry's contribution to Millennium Park is a massive music pavilion of stainless steel sheet with a trellis of structural steel pipe over the audience.

Fig. 2 — The thick-plate, fitup requirements and stiffness of the double-curve shape required for these gas storage containers means precise components must be shipped to ensure high-quality field welds.

Hog butcher for the world,
Tool maker, stacker of wheat,
Player with railroads and the
nation's freight handler;
Stormy, husky, brawling,
City of the big shoulders.

This image of Chicago that poet Carl Sandburg evoked in 1916 remains true today. People, raw materials, finished goods and ideas have moved in and out of the United States' third-largest city throughout its history. The metropolitan area — often referred to as Chicagoland — serves as a major shipping port and an important rail, highway and air transportation hub.

The construction projects taking place in Chicago this year reflect its image and the city's place as a commercial, financial, communications and cultural center. Projects currently in production or under consideration will have Chicagoland welders working to revamp local landmarks or construct new ones, shore up the city's infrastructure, refine and transport natural resources and showcase technology.

Chicago will be the center of the welding world when it hosts the AWS International Welding and Fabricating Exposition this month, but welding will be central to the success of many projects in Chicago for years to come.

Curvaceous Fabrication

In a city long praised for its architecture — the John Hancock Center, the Sears Tower, the Civic Opera House — architect Frank O. Gehry is about to add a radically different landmark.

Gehry's $15-million music pavilion is to be the focal point of Millennium Park, a project estimated at $250 million. The new park will connect to the existing Grant Park on the city's lakefront.

The curvaceous band shell's skin (Fig. 1) will be made of thin-gauge stainless steel. Designed for orchestral performances, the shell is 300 ft wide. According to designers, the huge size is to match the huge seating area — 4000 people in chairs, 6000 more on the lawn. "When you're sitting 600 ft away from the stage, the opening looks quite small," said Craig Webb, senior design engineer at Frank O. Gehry and Associates, Santa Monica, Calif. "So, the metal surrounding [the stage] is essentially a proscenium wall that tries to deal with the scale of the whole venue, and it gives the orchestra more presence."

The most intricate welding will not be in the band shell, but in the trellis, a lattice of pipes curving over the permanent chairs and the lawn. The pipes will hold carefully placed speakers, part of the pavilion's state-of-the-art sound system. They will be of structural steel and are likely to be coated with a high-gloss auto-body-type paint.

Together with Skidmore, Owings & Merrill LLP in Chicago, Gehry's designers are considering fabrication and erection options. Though exact processes have not been determined, the pipe connections will be fully welded.

"It is likely the inner sections [of the trellis], which will essentially receive pipe from four directions, will be shop fabricated," Webb said. The pieces will be brought on site, and the structure will be shored as it's erected and welded. A typical weld would be for two equal-diameter pipes crossing each other in plane, each 60 to 70 ft long. One pipe would be coped, precisely fitted and welded to the other. "We'll end up with a very clean intersection," Webb said.

The greatest challenge, though, will be bending the pipes to the extremely wide radius required for them to rest on 12-ft concrete pylons at either end of the lawn, 300 ft across. A span this long requires heavy pipe, up to 20 in. in diameter with almost a 1-in. wall thickness. Diameters will gradate down to 18 and 16 in., depending on the stresses involved.

A bending machine can easily work with short-radiused pipe, running the pipe out and then grasping it with a mechanical arm fixed at a particular pivot point as it's being extruded. But the trellis pipes have extremely wide radii, and "there are no 400-ft-long arms" that can bend them, Webb said. So, engineers and designers are considering other advanced processes, including induction bending, which differentially heats and induces a bend. According to Webb, there are quite a few fab shops with the technology that are interested in the job.

Except for two trellis pipes that connect to the proscenium, the band shell is structurally independent. Shapes for the shell will be cut based on an advanced three-dimensional computer model: detailers will work directly from the digital wire frame. "It's a very precise process," Webb said. "We've been through this process with seven or eight buildings already, and the accuracy with computers is really high."

The bent stainless the audience will see will be thin, 14–22 gauge (the exact thickness has not yet been determined). Behind the stainless sheet will be subframing, possibly aluminum

MARY RUTH JOHNSEN is Features Editor and TIM HESTON is Assistant Editor of the Welding Journal.

Fig. 3 — A model of Richard Hunt's Midway, *to be placed outside the entranceway to Midway Airport's new terminal.*

plate (again, to be determined) cut with a CNC machine, and behind that the wide flange shapes of the roof trusses, cantilevering off the proscenium line a full 100 ft. That makes for an extremely dramatic structure.

"Chicago is one of the greatest cities in America for architecture" Webb said. "And we think the pavilion will be a significant contribution, adding to the incredible heritage of buildings that is already there."

The End of the Line

What has been called the largest construction project in North America for 1999–2000 — the Alliance Pipeline system — terminates at the Aux Sable Liquid Products plant in Channahon, Ill., about 50 miles southwest of Chicago. Currently, about 750 workers, including approximately 125 welders, are constructing the plant, which has an estimated direct capital cost of $365 million. This new natural gas liquids extraction and fractionation facility will initially process up to 1.6 billion cubic feet of natural gas per day, removing from the gas stream up to 40,000 barrels of ethane, 19,000 barrels of propane, 8000 barrels of butane and 3000 barrels of pentanes plus (also called natural gasoline) every day.

There are two main areas where welding is being used to construct the plant, which is essentially a natural gas refinery. First, there's plenty of piping to transport the gas all around the plant. Second, the site includes nine spherical storage containers.

Morrison Knudsen Co., Inc., serves as construction manager for the project. Phillips Getschow Co., Joliet, Ill.; Borg Mechanical Contractors, Inc., Hillside, Ill.; and Morrison Construction Co., Hammond, Ind., are handling most of the pipe welding. CBI Services, Inc., a subsidiary of Chicago Bridge & Iron Co., is building the nine storage containers.

According to Hans Zickmantel, construction manager for Aux Sable Liquid Products LP, the facility will contain piping in a wide variety of sizes, from small-bore up to 36-in. pipe for the high-pressure lines, and up to 54 in. for the main cooling water lines. Since the piping system contains many configurations, and for economic and quality reasons, Zickmantel said, most is prefabricated in the shop in segments sized conveniently for shipping and then welded together on site.

Shielded metal arc welding (SMAW) is used for the on-site welding, mostly because it works well for all-position welding. The piping is primarily stainless steel and high-yield carbon steel. Although no exotic materials are used, Zickmantel said, the job requires skilled workers capable of welding on pressure pipe in all positions.

The largest weldments at the facility are the nine spherical storage containers — Fig. 2. Dennis Olsen, CBI's project manager for the Aux 5able job, said four spheres will store propane, four butane and one pentanes plus. The shell of the 69-ft-diameter propane containers is 5A 738 Grade B steel with a 2-in. wall thickness. Design pressure is 250 lb/in.^{2} and capacity is 30,000 barrels. The four butane containers and the pentanes plus container are built of 70 ksi SA516-70 steel with a ⅞-in. wall thickness. The butane containers are 54 ft 9 in. in diameter, hold 15,000 barrels and have a design pressure of 85 lb/in.^{2}; the 20,000-barrel-capacity pentanes plus container is 60 ft 6 in. in diameter and has a design pressure of 15 lb/in.^{2}.

Olsen said 22 production welders are working at the Aux Sable site, as well as several other qualified welders for fitup and miscellaneous attachments. All welders are qualified to ASME *Boiler and Pressure Vessel Code* Section IX.

The shop receives the plate from the mill in the as-rolled condition and it is cold formed to the double-curved (spherical) shape. "For 2-in.-thick, high-strength plate, we utilize our 1500-ton press with specially made dies," Olsen explained. "For ⅞-in.-thick steel, we use our 500-ton press."

The plates are then cut to the proper shape for final assembly. "At this point, the column stub sections are attached," Olsen said. "We also shop install the manways and larger fittings to the appropriate plates for each vessel. The shop will postweld heat treat all plates with large weld attachments prior to shipping."

The sections are delivered to Aux Sable in pieces as large as can be legally shipped by truck and then welded using automatic submerged arc welding (SAW). CBI uses a Lincoln LT7 tractor with twin wire feed. This is the tricky part. One of the limitations of automatic SAW, Olsen said, is that welding must

take place in the flat position. The curved sections must be kept within 5% of level and the assemblies for the propane tanks weigh approximately 60,000 lb. CBI solves the problem by using two tilt tables in the field to keep the assemblies in the proper position, Olsen said.

After the field crews fit the plates together in their final position and do the welding, the field joints are radiographed to inspect for defects. Any defective welds are corrected.

The field work wouldn't be successful without high-quality work from the shop crew, Olsen said. "Due to the thickness of the plate, the code requirements for weld joint alignment and the stiffness of the double-curve shape, we depend heavily on the expertise of the shop personnel to deliver high-precision shapes to the field."

Fig. 4 — Fitup of the pipe components and coordination between the fabricator and erector were key to successfully building the entrance to the Lucent Technologies complex in Lisle, Ill.

Art at Midway

Chicago is an aviation hub, which is why the city's Department of Aviation is heading the largest public works project in Illinois — the $761 million Midway Terminal Development Program. A new terminal and concessions area, to be located in front of the existing terminal building, is expected to open during the first quarter of 2001. The entire program, which includes a new 41-gate concourse building, is slated for completion in 2004.

"When I was a kid, my family and I used to drive out to the airport and watch the DC-3s take off and land," said sculptor Richard Hunt, an unconventional, but by no means less important, contributor to welding and fabricating at the new terminal. Fifty years after watching DC-3s, he's leaving his own distinct mark just outside the entranceway to the new terminal.

Titled simply *Midway* (Fig. 3), Hunt's abstract sculpture represents birds and winged flight forms from nature and man vs. technology in the quest for flight.

Hunt chose gas metal arc welding (GMAW) for most joints on *Midway*. "Sculpture should carry a symbolic message to viewers, so the premium here is on individuality and the creative fusion of ideas within a form," he said. When he and his assistants weld, it's a creative pursuit, not a drive for efficiency. "If you spend a lot of time welding this complex structure, spend a little more time grinding, polishing and highlighting parts [to make the surface varied], that's all part of the image, and it increases its value to the end user. It's a meaningful and worthwhile way of spending time."

A Chicago resident, Hunt has many works standing in and around city limits, including *Winged Forms*, welded bronze outside the Amoco Building Plaza; *Jacob's Ladder*, welded bronze outside Carter Woodson Library; and *Pillar*, welded Corten steel outside Michael Reese Hospital.

Midway, which will be made of 306L stainless steel, is Hunt's largest to date: 35 ft tall, 28 ft wide and 15 ft deep. Most welds will be made from the inside. Because of its size, the artwork will have to be welded in three sections at the artist's studio, then field welded at its resting place. Tentative scheduled completion is in 2001.

As with most of Hunt's sculptures, sanding and grinding is the most delicate part of fabrication. "It's where I give *my* characteristics," he said. This piece should appear seamless. Because of its size and location, there's a safety factor involved. The Federal Aviation Administration has instructed Hunt not to polish too much because it may reflect sunlight that could distract pilots.

Hunt will start grinding with 50–60 grit discs, then 80, all the way down to course, then fine pads. "I'll leave it at that," he said. "It's not going to have too high a polish."

The stainless steel sheets will be between ⅛- and 3/16-in. thick. Hunt and his assistants will manually cut the sheet with a plasma arc cutting machine into sections roughly 6 ft wide and 12 ft tall. They will be bent, rolled, shaped and then welded, all around internal bracing.

"The specifications for this sculpture will make it beautiful — or at least aesthetically pleasing — long lasting and low maintenance," he said.

A Home for Techies

When communications giant Lucent Technologies opens the new section of its Lisle, Ill., complex next year, it will provide a spectacular showcase for the skill of welders. Welded structural pipe supports the entrance to the building (Fig. 4), a glass-enclosed atrium designed to resemble a satellite dish. Two five-story buildings flank the entranceway.

Fitup was definitely the most challenging aspect of this job, agreed Horst Peppa, president of Chicago Ornamental Iron Co., Melrose Park, Ill., the structural steel fabricator for the project, and Robert A. Fortino, project manager of Area Erectors, Inc., the company that did the field erecting.

"The special challenges for this project were many given the fact that an all-welded building of this type has very little margin for error, so plumbness and deflection had to be monitored continuously," Fortino said. "Also, there were the usual problems with rigging and handling large, odd-shaped pieces."

The atrium's drum-shaped roof is 115 ft in diameter. It is tilted 45 deg, creating an elliptical-shaped drum 115 ft x 86 ft. At the low end, it is 35 ft high; at the high end, 122 ft. The roof is also concave, with the depression about 10 ft. The roof is supported by columns around the circumference of the building that attach to a spider's weblike network of members — Fig. 4.

"Since the roof is round," Peppa said, "that forces the building to be elliptical in shape. So the columns are set on an elliptical basis so they match the round roof. And the Vierendeel trusses that connect each of the columns are then all different radiuses to make up the elliptical shape." Vierendeel trusses have no diagonal members, but instead rely on bending in the horizontal chords and vertical posts for strength.

The pipe used for the project was Grade 50 steel in sizes ranging from 6 to 18 in. in diameter and with wall thicknesses from ⅛ to 1¼ in. Eighteen welders worked in the shop at Chicago

Fig. 5 — Structural steel work for the Stevenson Expressway.

Ornamental Iron fabricating as many of the components as possihle prior to their being shipped to the site, Peppa explained. Welders used semiautomatic gas metal arc welding with straight CO_2 as the shielding gas and ER70S-3-NC filler metal. Semiautomatic GMAW was used "because the bevels and angles were all too weird to use automatic machines," Peppa said.

Since fitup was crucial, Peppa said, his company tried to do as many of the complex weldments in the shop as possible. "We looked at prefitting everything ahead of time and then making cuts to reduce the complexity of the welding in the field," he said. "We didn't want to get into compound welding out there, just straight pipe welding. In other words, a straight butt (joint) weld."

"The fabricator did an excellent job," Fortino, of Area Erector, said. "They made it much easier for us." Still, the job required more than 8000 hours of welding out in the field, he said. Area had up to eight, two-person welding crews working at a time.

Most of the joints were beveled at 45 deg with backup bars for full-penetration welds. There were also many partial penetration welds. Very little SMAW was done on the field welds, Fortino said; instead, the company mostly used flux cored arc welding. Fortino's company also erected the approximately 3500 tons of structural steel for the two five-story buildings.

Chicago Ornamental Iron received the contract for the atrium in March 1999 and began shipping pipe components to the field in September. While the structural steel work for the building itself is complete, the company is working on the spiral staircase and handrails that will go inside the atrium. The project should be ready for occupancy early next year.

Bridges and 'Dead Squirrels'

Those most familiar with the Stevenson Expressway (Interstate 55) are the commuters who endure the daily construction delays. "We're down to 60% capacity," Rick Young of the Illinois Department of Transportation (ILDOT) said.

What the disgruntled drivers may not realize is the true magnitude of the massive reconstruction they're driving through. About half of the 4.5-mile-long construction zone is bridge. The total project, including outbound and inbound lanes, consists of about 20 million lb of structural steel (Fig. 5), most of which is AASHTO M270M/ASTM A709M Grade 345 (Gr. 50). These are big pieces, too. "It was a challenge getting some of these beams to the job site," Young said. Rolled beams up to about 110 ft and plate girders nearly 120 ft long were delivered to the conjested urban area by truck. Some girders have an overall depth of 11 ft.

At peak construction this summer, more than 300 workers will be on site. Not many welders will be among them, though. Most welding was performed at Industrial Steel Construction (Hodgkins, Ill., and Gary, Ind.) and PDM Bridge (Eau Claire and Wausau, Wis.). Automatic submerged arc welding was used for most of the plate girder fabrication. Stiffeners, connection plates, cross frame, diaphragm and bearing welds included some gas-shielded flux cored arc welding (FCAW-G) and a limited amount of SMAW, depending on the shop's preference.

Utilizing existing substructure foundations limited many spans to those suitable for rolled beams. "We ended up with almost every common W920 (W36) beam in the AISC manual," Jon Edwards, who supervises weld inspection for ILDOT, said. Though most of the welding on plate girders requires automatic submerged arc, different processes may be permitted for plates welded to beams. For small beams, ILDOT allows semiautomatic submerged arc welding or other processes, such as SMAW. "Depending on the situation, an opposed-head submerged arc machine may not be practical for installing connection plates. So, on a shallow beam, we may allow manual methods," Edwards said.

One of the project's most structurally complex sections is the single-point urban diamond at Damen Ave., a six-lane road going over the eight-lane interstate. Ramps come up from the outside edges of the interstate to the road above. Each ramp flares inward (toward the interstate) and outward, like a trumpet bell, and the inward flares intersect over the middle of the interstate. Project engineers jokingly call it the "dead squirrel interchange," because the drawing resembles the flattened animal with front and rear legs extended to the sides.

PDM is performing full shop assembly for the flares. "It takes an area about the size of a football field for the assembly of each flare," Edwards said.

Another complex structure is the bridge over the Des Plaines River. "That bridge is on a 1900-ft-radius curve, and also on a 57-deg nominal skew," Edwards said, "so it's closer to paralleling the river than crossing it. This resulted in skews up to 74 deg between girder centerlines and the ceterlines of bearing at one abutment, or being only 16 deg from parallel. The skew and curvature effects combined to require some cross frames from hell, with eight 1-in. A325 bolts at each end of the interior cross-frame angles." And there's a lot of SAW for the connection plates.

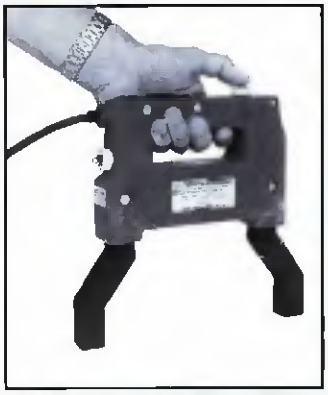
The project is in two phases. Last year work was done on the inbound lanes; this year it's the outbound. Scheduled completion for the second phase is October 31, and construction is ahead of schedule.

Developing the Windy City

From huge spheres to wide radiused members to millions of pounds of structural steel to artwork, Chicago is a city welding helps raise. Because of all the work, the union halls stand near empty. Everyone is out making a living, building the foundation for Chicago's big shoulders. ◆

PARKER

MAGNETIC PARTICLE INSPECTION INSTRUMENTS



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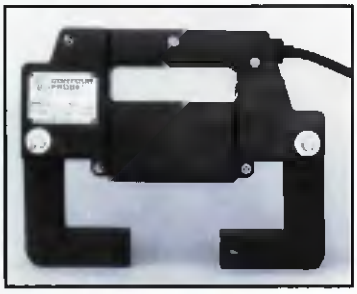

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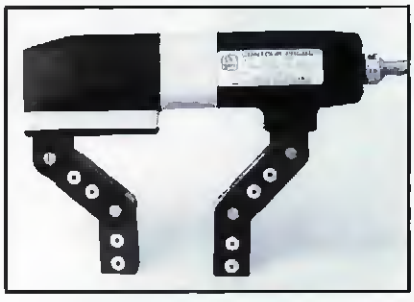

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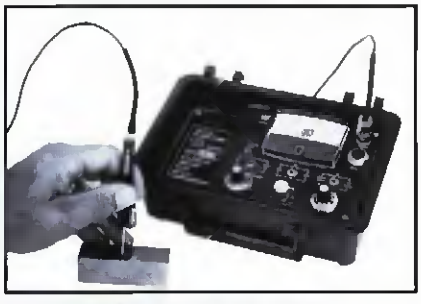

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Robotic Arc Welding Is Off and Running at Caterpillar

Fig. 1 — Robotic arc welding is a routine operation in Caterpillar plants around the world.

Robotics has frustrated hundreds of companies throughout the world, but here is one company that has worked extra hours to master the technology

BY BOB IRVING

Many experts have long regarded Caterpillar Inc., Peoria, Ill., as not only the largest but perhaps the wisest user of arc welding technology in the world. So it is no surprise Caterpillar was in on the ground floor when robots were first introduced to arc welding. In the early years, which started almost 20 years ago, there were growing pains. There was a huge amount of research into robotic arc welding at the Caterpillar Manufacturing Development Center in East Peoria, Ill., and developments in advanced robotic systems continue today at the Tech Center in Mossville, Ill. The original spadework has paid off to the extent the company now has several hundred robots in operation throughout its plants worldwide specifically engaged in arc welding. Why all this effort? What was the goal?

Howard Ludewig, project manager, welding engineering, answered both questions quickly and to the point: "Quality, productivity and environmental impact."

There was a time not too many years ago when welders wielding semiautomatic guns performed most of the welding operations in a typical Caterpillar manufacturing plant. Most of the welds were made with flux-cored wire. Today, most of the welders have become robot operators or have moved to other jobs. Robotic arc welding systems now make the welds the welders produced in the past — Fig. 1. Nowadays, the welds are made mostly by solid, not flux-cored, wire. Things are quiet. The plant area is clean. It's not unlike an aircraft plant in that respect.

A Welder Shortage

To continue the way they had been doing things, Caterpillar would have needed a huge number of qualified welders. Not enough welders were available to do what had to be done. Automatic welding, especially robotic welding, seemed the logical answer. Handled properly, it could result in great improvements in weld performance Caterpillar engineers estimated.

Over the years, Caterpillar has played an important role in advancing robotic technology from its simple single-axis be-

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Fig. 2 — The first robots Caterpillar used in production were hydraulic robots, some of which are still in operation. Eventually they will be replaced by state-of-the art electric robots.

ginning to the point where the designers of the equipment and the designers of the manufacturing process work together to optimize their process before the first arc is ever struck. So, it's no longer just a case of making acceptable welds. The welds also contribute to the betterment of the entire structure being manufactured.

Generally, Caterpillar is moving away from flux cored arc welding, a technology the company played a major role in developing years ago, and toward small-diameter solid wire welding. One reason especially important in robotics is the straightness of the wire when it emerges from the gun. According to Caterpillar engineers, the solid wires they are using come out straight, while flux-cored wires sometimes come out slightly bent. This can cause misalignment of the wire in the weld joint when vision is used. Not all of the vision systems can handle these misaligned wires. The change in filler metals is away from flux-cored wire to solid wire. Some metal core filler metal is used in the more demanding applications.

The welding procedures are designed to eliminate the need for preheat. Using small-diameter wires, there are often dozens of weld passes, which minimizes the amount of heat input into the weld.

Greg Kimberly, development project engineer in welding engineering, Caterpillar Technical Center, Mossville, Ill., was first introduced to robotics at the former Burlington, Iowa, plant in 1983. He continued working with robots when he moved to the East Peoria plant.

Simple at the Start

"In the beginning, the robots were quite simple," he said. "There were no servo-controlled positioners, for example. The first two robots we had were operated by a controller, but they had a double-ended positioner and Gemco switches for positioning. The robots performed well, but the switches were not as accurate as we wanted. Repeatability was acceptable with the robots but not with the positioning equipment. We had to do a lot of touch up on the robot programs."

These early robots were used in production mostly for making fillet welds and some small groove welds. They were purchased for use in production, not for research. Looking back on it, Kimberly said, those early robots represented a new technology searching for an application. At first, the applications they did find were mostly small parts, such as brackets. These were all low-volume applications.

"We then started to weld belly guards," Kimberly recalled. "And, while we were doing that, a number of hydraulic robots (Fig. 2) were being installed on bogie assembly lines. This was all being done at a time when our company was shifting from oval track tractors to the L series or triangular tracks."

Unlike the oval tracks, the L series had movable undercarriages with eight bogies per tractor. This new design required welding on the bogies and other heavy components, which had not been required on the oval tracks. As a result, hosts of welders were used in the manufacture of these bogie assemblies.

The Redeployment

"The decision was made to redeploy 12 hydraulic robots that had been in use at our Mentor, Ohio, plant to East Peoria," Kimberly said. "These were the first robots we had in arc welding. But there were problems keeping the oils clean. There was concern that the seals might break down and the particulate from the seals might infiltrate into the hydraulic fluid. Because of that, we chose a path where dedicated repair personnel were trained to work on the robots. The same individuals were also involved in the improvements that were going on continually."

But some things happened during the period when hydraulic robots were in vogue that really helped robotics in general. At first, the engineers worked with positioner manufacturers in order to change from traditional positioners to the new "skyhook" positioners that featured L-shaped arms. By the time electric robots started to replace hydraulic robots in 1983, these kinds of positioners were in place on rotating platforms. This setup enabled the operator to load one assembly while the robot was working on another.

The positioners on earlier vintage robot cells are only capable of 1½–2 rpm movements. Today's positioners are capable of movements in the 10–12 rpm range. This higher speed is necessary because of today's streamlined design. Instead of square corners, they are now rounded off. Weld joints are now curved, rather than straight. Coordinated motion is required to make those types of welds. So now the positioning equipment is driving the improvements in a robot cell. On Caterpillar's original bogie line, single-axis positioners were used, but they would only turn in one direction. That's when the skyhook positioner came into play, now five-axis positioners are in use.

"We had this expensive piece of equipment and we wanted

to keep it busy," Kimberly said. "For economic reasons, we wanted to have the next part ready once the robot had finished welding the present one."

Positioning equipment for these large fabrications can cost as much if not more than the robot itself. When Caterpillar migrated from hydraulic to electric robots, the electric robots had a number of auxiliary axes. In the end, five electric robots replaced twelve hydraulic robots, but did the same work. This was achieved by improving the positioning and by placing the positioners on turntables.

Improved accuracy in the electric robots with servo-controlled positioning equipment was a big factor in both the reduction of the number of robots and the personnel needed to service the robots.

Fig. 3 — The first vision systems employed in robotic arc welding lines at Caterpillar were actually designed and built by Caterpillar engineers. Some of these systems are still in use.

Momentum in Modernization

By 1989, the transition to electrics was fairly complete. There are still a few hydraulic robots operating in various plants, but they will be eventually replaced.

Caterpillar management found three main reasons for using robots. One is improved weld quality, providing better structural performance. The second reason is an improved environmental impact. Third, but not least, is the manufacturing cost reduction. Back in the '70s, they were saying, "Hey, we've got this robot. How can we put it on welding?" Now they're saying, "How can we use this robot to make this part work better?" There has been a deliberate shift in strategy, Ludewig said, but it is what will drive his company's use of robots in the future. So, the question is now: How can the robot be best used to control welding to the point it can improve the performance of a structure?

How can robots reduce manufacturing cost? Suppose you have a job calling for the welding of 100 assemblies per day. Without robots, you find you can only weld 10 per day conventionally. So you need 10 fixtures, and no two fixtures will ever be alike. With a robot, you can weld all 100 assemblies in one day, and you can do it with one fixture. Every job will be identical. There will also be a tremendous reduction in floor space.

"We can do all of that," Ludewig said, "including process design and robot programming, before the robot is even on the shop floor. It makes the operation much more agile."

In addition to its plants in the United States, Caterpillar manufactures in plants in Mexico, Brazil, Belgium, France, United Kingdom, Australia, Russia, China and two plants in Japan. At one time, the general office provided guidance to all of the manufacturing operations. Caterpillar is now organized into business units. The parts are the same within a business unit no matter where in the world they are made, but the welding systems may differ because each plant deals with vendors within its geographic location. Continual communication among business units is essential to maintain the high quality related to robotic welding.

The Importance of Vision

Another important technology that placed robotic arc welding on the map was vision systems. At Caterpillar, the designs call for the use of robotics to weld a wide variety of groove and fillet welds. Many of these welds are used to join plate to castings, which brings up the question of fitup due to varying degrees of consistency. When hydraulic systems were used, the robots did exactly what they were told but, unfortunately, did not handle the variation in the parts very well.

To overcome that problem, Caterpillar's next step was a concerted effort to become more "control wise" with the robots. First, through-arc tracking was studied. While found to be fine for tracking the welds, it did not provide the information really needed. The main pursuit soon became "fill/adaptive welding," not just joint tracking, but proper joint fill as well. Caterpillar engineers then built their own vision system, the first vision system used for robotic arc welding at Caterpillar. Somewhat larger than the more current vision systems, the first Caterpillar-developed system was installed on a new robotic system and placed into production — Fig. 3. Then, in 1989, Caterpillar started to purchase vision systems that were part of newly purchased robotic equipment. The two most widely used systems were the Meta and Oldelft systems from Europe. During this same period, experiments were conducted on several off-the-shelf cameras from U.S. companies. One such camera could calculate how many passes would be needed to complete the weld. But a problem in dealing with much of this high-tech equipment was that years later the companies that had made it were either no longer in business or had discontinued making that particular line of product.

The machines installed in 1988 and 1989 are being looked at for replacement. The robot arms are fine, but much of the electronics associated with the cells is obsolete. Items such as keyboards, teach pendants and memory boards are becoming hard to find and are no longer supported by the manufacturer.

The East Peoria Plant

Some say the most advanced production systems in heavy fabrication can be found in Caterpillar's East Peoria plant. There, the track-type tractor is the building block of manufacturing. Rod Wickert, weld engineering supervisor, Track-Type Tractors Div., said the plant has 56 robots and plans are in place to upgrade this technology in the future.

Fig. 4 — The newest robotic system to arrive at the East Peoria plant is definitely state of the art. It will be used to evaluate different processing techniques, and is expected to result in further cost reduction and better robot utilization.

The engineers in the Track-Type Tractors Division were probably pioneers in laser vision. It was all very high tech when it was first introduced onto the production lines. Before long, as many as four different vision systems were operating at one time. Most prominent in the plant at this stage were the Meta and Oldelft systems developed about ten years ago. "We now have close to 35 vision systems operating today," Wickert said. "No one else has that number. There are some techniques to making vision systems work in production," he added. "One of the most important is dedicated support. You have to have the ability to fix vision systems internally. Our philosophy ten years ago was one man/one robot. It worked inasmuch as we were able to streamline the work force, eliminate the smoke from the semiautomatic welding operations and make money for the company.

"But if you want to go with vision," Wickert said, "you must have that dedicated support that will provide you with the ability to fix the vision systems internally."

Rather than continue sending equipment to the original manufacturer in Europe for repair, Caterpillar's Track-Type Tractors Div. went into the repair business. The entire repair operation was set up internally.The workers were given factory training so they would be able to repair all of the vision systems used at the plant, including the new cameras from Servo-Robot. Five electricians, in fact, have been trained exclusively to repair the cameras, teach pendants and printed circuit boards used in different vision systems. In the repair room, many of the mechanical adjustments or alignment procedures have to be tended to. The work is all very delicate.

The robots currently in operation at the East Peoria plant are either equipped with vision or through-arc systems, but not both. The company is now taking the next step. It is the new Kawasaki robot (Fig. 4) is being installed on the shop floor. It has a Servo-Robot camera on it with touch sensing — all the technologies in one machine. This technically advanced robot will be used to evaluate different processing techniques. It is expected to result in further cost reduction and better robot utilization. "It is hoped this robot will change how we do robotics in the future," Wickert said.

Questions about Alignment

One thing driving the use of technology in the East Peoria plant is the welding of castings. Part fitup along with the variability of the casting causes large joint variations that require sophisticated tracking technology.

There are questions that arise when working with castings. Will the weld joint move slightly because of thermal distortion? Is there a variability from one part to another? If not handled properly, those kinds of situations could lead to variation in the weld joint. Wickert said several tracking methods can be used here.

One method is touch sensing, which locates parts and makes the appropriate offset to compensate for the variation. A calculation is then determined and the weld is made.

Another method in use at the plant is through-arc joint tracking, which uses arc current and weaving to determine the location of the joint. This information is then fed into the robot controller for path offsets and a correction to location, if necessary. This keeps the wire in the joint even if the wire comes out differently from time to time.

The third and most sophisticated approach is with cameras. The camera uses either a compact or helium-neon (He-Ne) laser beam to produce a stripe across the weld joint while it scans. As it scans, a camera sees the reflection of the stripe and produces a profile of the weld. With software, the profile is measured; both the width and depth of the area are calculated. This information is used to determine weld schedule and travel speed and provide a truly adaptive process.

Because of their age, most of the robots at East Peoria are being looked at for replacement. Some of the through-arc joint tracking machines have already been replaced with newer FANUC systems. Most of the current vision systems are FANUC robots with Meta vision systems. There are a few remaining Cincinnati Milacron robots with Oldelft vision systems.

A Look at the Decatur Plant

The company's plant in Decatur, Ill., is where all models of off-highway trucks, motor graders and wheeler tractor scrapers are built. The new 60-ft-long (18.3-m) model 24H motor grader is built in this plant. Another huge new product manufactured in Decatur is the 1.3-million-lb (590,000-kg) model 797 truck used in open pit strip mining operations.

According to Mike D. Younker, manufacturing project specialist, fabrication process engineering, there are 17 robotic systems at the Decatur plant — all of them big. At present, he said, there is one robot for the wheeler tractors, ten for the motor graders and two for the truck lines. "We have an automation strategy in place where we will eventually automate all of our truck frame lines."

The welding equipment used to build the 797 mining truck (Fig. 5) is the largest of its type in any Caterpillar plant. An ABB robot system, the equipment stands 26 ft 4 in. (8 m) high. Pilot models of the equipment were run in the spring of 1999. Production has now begun. There are two robots in this cell. They are both on rotating, traveling columns. It's an 11-axis machine; 6 axes are on the robot. During a visit to the plant in January, the company said an offline programming system from Deneb Robotics had just been delivered. In time, the engineers plan to use this system on the 797 truck operation.

With off-line programming, the engineer can look at a whole process in a different way. The process designer, in fact, can look at the assembly in three dimensions. Where there is re-

stricted access, the designer can redesign to eliminate it. The requirements of the engineering process are immediately and completely transferred to the shop floor. Kimberly said, "We in engineering know exactly how the part is going to be processed in the shop. We know the order in which the welds will be produced. We know what the distortion will be and what the residual stresses will be, and we can design accordingly. There will be no variation from all of that."

The vision system on the equipment used to weld the 797 mining truck is provided by a Servo-Robot camera that has been operating for about a year without needing any repairs. This is the only vision system in the Decatur plant. Caterpillar plans to add six more of these systems to its Decatur operations.

Fig. 5 — The robotic welding equipment used to build the 797 mining truck at the Decatur plant is the largest of its type in any Caterpillar plant.

"Robotic welding gets more of our employees out from under the hood and gives them a chance to focus on other critical areas in our manufacturing environment," Younker said. "Our manufacturing environment is much more 'high tech' than in years past. Gone is the perception that working in a factory is dirty, unpleasant work. On the contrary, students are continually amazed when they visit a plant such as Decatur or East Peoria. They are impressed at how clean and bright the manufacturing areas are. This helps us to attract the manufacturing professionals we need. The welder of today needs to understand high-tech robotic welding systems and how these systems interact with other manufacturing systems elsewhere in the plant."

Welding Requirements

In the 797 truck operation, solid wire is used. The welding wire is unreeled from 1200-lb (544-kg) spools. The parts to be welded are mostly castings in thicknesses up to 60 mm (1.8 in.). Thirty to forty passes are required to complete each weld. Inspection is visual and by ultrasonics.

The improvements in robot systems are also making their mark at Decatur. In the welding of motor grader components, five robots had been used in that operation. Two robots of more advanced design now do the same work. In still another production line, two new, more advanced robotic systems are doing 300% more welding than had been achieved previously when four robots were in service.

The Decatur plant has also installed a training robot from ABB Robots for use in training workers to be robot operators. Many of these operators are former welders.

Future Trends

Today, Caterpillar fabrication plants are successfully using advanced robotic arc welding systems that are rugged enough to meet the most demanding applications. Future robots will be agile and flexible enough to meet rapid response demands of future customers.

At the Tech Center, the engineers are evaluating the potential for robotic laser beam welding. To do this, they have a Haas YAG laser from Trumpf of Germany. Time will tell whether this newer technology will find a place on production lines in Caterpillar plants. CO_2 laser cutting is already being used. ◆

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Company Embraces Automatic Laser Gas Supply System

An assist-gas distribution system helps a company save money

BY FRED STEELE

If a company could deliver high-pressure gaseous nitrogen to its lasers more efficiently and for less money, it would, of course, be interested. Precision Laser Manufacturing (PLM) of East Peoria, Ill., certainly was. The company was able to reduce its overall gases and labor costs by 30% while increasing its efficiency, safety and quality.

PLM is a contract laser job shop specializing in laser processing services such as laser beam cutting, laser beam welding, engraving, cladding, heat treating and tube cutting. The company has three CO_2 lasers of varying capacities: a 2- and a 2.2-kW laser and a 3.5-kW laser with a cutting capacity of $^3/_4$ in. (19.05 mm).

The company's location, coupled with its unique scheduling system, gives it the flexibility and capacity to handle small-volume prototype work as well as medium- to- high-volume production quantities. Fabrication is a key element in Peoria. Several large manufacturers of heavy earth moving and agriculture related equipment are headquartered there, and many companies that supply these large manufacturers with outsourced products operate within a 30-mile radius.

Gases Used in a CO_2 Laser

There are three different types of gas applications in a CO_2 laser: lasing gas, assist gas and beam path purge gas. Lasing gas, typically supplied in high-pressure cylinders, is used to create the laser beam itself. Assist gas (Fig. 1) blows away the molten metal created by the heat of the laser beam. Beam path purge gas provides a low-pressure positive

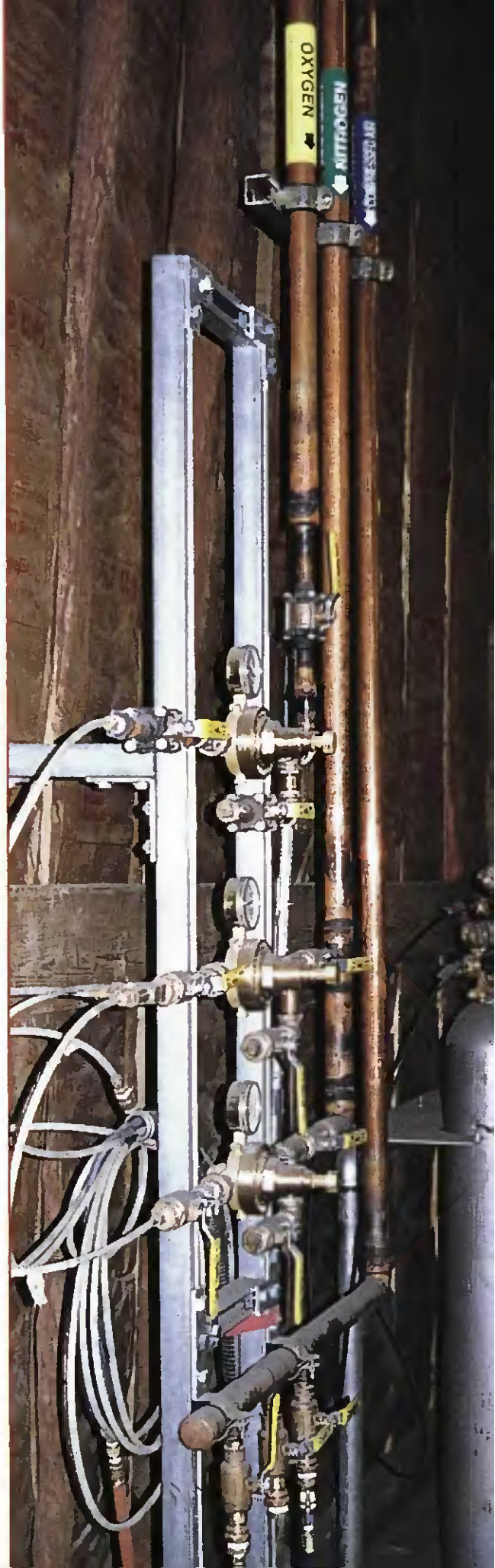

Fig. 1 — The laser assist-gas distribution piping at Precision Laser Manufacturing.

FRED STEELE is Fabrication Specialist at BOC Gases, East Peoria, Ill.

Fig. 2 — PLM's bulk liquid storage tanks.

Fig. 3 — PLM's skid-mounted system employing two small high-pressure liquid cylinders.

pressure purge on the beam path that keeps out atmospheric gases.

The assist and beam path purge gases are particularly important. A CO_2 laser uses assist gas, either oxygen or nitrogen, for cutting. When cutting mild steel, oxygen is typically the assist gas; for stainless steel, it is usually nitrogen.

PLM needed a way to cost effectively deliver oxygen at low pressures (less than 250 lb/in.^{2}) and deliver nitrogen at high pressures (up to 400 lb/in.^{2}).

Instead of air from a compressor, PLM also uses nitrogen for its beam path purge gas. With the nitrogen purge, the company is assured no moisture or hydrocarbons[1] are introduced into the beam path. This is due to the inherent "cleanliness" of nitrogen. Although nitrogen costs more than compressed air, the cost is outweighed by the savings realized through less maintenance and cleaning of mirrors and other components. Additionally, when using nitrogen to purge the beam path, the quality of the beam cannot be negatively affected by impurities.

The assist gas is used at much higher flow rates and pressures than the beam path purge gas. When laser beam cutting mild steel with an oxygen assist gas, an oxide coating can form on the cut edge. This oxide coating makes postcut painting and treating difficult as paint will not adhere to the oxide surface. The potential for oxide coating has also made laser operators look more carefully at cutting mild steel with nitrogen — the downside being slower cutting speeds and much higher pressure (150–450 lb/in.^{2}) and flow requirements.

1. Moisture and hydrocarbons (oil mist) are inherent in air from a compressor system, and they must be filtered, which requires maintenance. Nitrogen is inherently "dry," meaning the moisture levels are extremely low (in bulk liquid nitrogen, the moisture level is ~1.5 ppm), and the hydrocarbons are also extremely low (~1 ppm).

Gases Supply Methods

There are three primary methods of delivering gases in quantity: bulk liquid tanks, portable liquid dewars and cradles.

Bulk liquid tanks are permanently installed on site and vary in storage capacity from 500 to 11,000 gal (1892.5 to 41,635 L). Liquid bulk is the most cost-efficient method of purchasing gas. In a bulk liquid tank, the liquid product is pushed through a vaporizer that phases the liquid into gas. This method of gas delivery is well suited to high flow rates because the capacity of external free-standing vaporizers can be matched to the company's need. Additionally, no labor is required as these tanks operate automatically. The downside is the pressure available. Typical bulk-liquid storage tanks have a maximum allowable working pressure of 250 lb/in.^{2}. PLM needs pressures of up to 450 lb/in.^{2}.

Portable high-pressure liquid dewars are relatively small and do not require much floor space. They also meet the need for high-pressure withdrawal. Unfortunately, they cannot maintain the high flow rates required because they must transform the liquid to gas. Another negative is the labor needed to move these vessels within the plant, monitor their status and connect and disconnect them to the system.

Cradles are typically 12 high-pressure cylinders connected to a common header to which a pressure regulator is connected. Cradles meet the requirement for high pressure and flow rates. The downside is their size and weight, about 2000 lb (900 kg). Their cost is also higher than liquid. As with the portable dewars, handling and movement within the plant utilizes labor. Cradles also occupy floor space, and cradles with residual gas product are often sent back to the supplier.

Oxygen Delivery

Because pressures for cutting mild steel using oxygen would be in the area of < 200-lb/in.^{2}, PLM converted to a bulk liquid storage tank — Fig 2. A mode change analysis worksheet was created that analyzed the cost of labor, product, and cradle and dewar rental vs. the proposed bulk product and facility fee. The analysis also showed when the payback occurs for PLM's initial startup costs, such as the concrete pad, fencing around the bulk pad and piping the plant. The savings on oxygen would be approximately $11,000 a year.

Nitrogen Delivery — The New Solution

The company's supplier, BOC Gases, provided a laser assist-gas system that uses a standard low-pressure (250 lb/in.^{2}) bulk liquid storage tank connected to a skid-mounted system employing two small, 200-L (52.84-gal), high-pressure liquid cylinders (Fig. 3) connected to a switchover mechanism and piped to a free-standing vaporizer; from there, the gas is piped into the plant.

The system basically functions as follows: The liquid from the bulk tank fills the liquid tanks, one of which is the primary tank, the other the reserve. When the primary tank reaches a preset lower level, it switches over to the reserve tank, and the bulk tank then refills the primary tank. The process then repeats itself as the reserve tank is depleted. Thus, the system allows for a continuous, uninterrupted flow of product, with no intervention necessary from the user.

In PLMs' installation, a modem device monitors the liquid level in the bulk tanks (along with the oxygen in the oxygen bulk tank) and deliveries are sched-

uled based on the information received through the modem device.

A mode change analysis worksheet was also done to justify the initial startup costs. The nitrogen system would save PLM approximately $6000 a year and solve all the problems inherent with previous methods of supply (movement of the cradles and portable liquid cylinders, the floor space this occupied, etc.).

Piping/Pressure Regulation

The way to set up these two bulk systems at PLM was to set the pressures entering the plant at the highest they would use and reduce/regulate the pressure at the various use points. For instance, the beam path purge uses nitrogen at 80 lb/in.^{2}, while the same laser cutting stainless might use nitrogen at 400 lb/in.^{2}. A tee at each station was designed with two line regulators to allow for independent control of pressure. The oxygen pressure varies with the thickness of plate, so a line regulator is used to adjust the final line pressure.

PLM needed a way to cost effectively deliver oxygen at low pressures and deliver nitrogen at high pressures.

Key Benefits

Essentially, the installation allowed for a "tap water" situation in that when the company needed the gas, it was ready and waiting, and no employee intervention was necessary. With the lower cost of gas from bulk liquid and fewer invoices to pay, the company ultimately saves money. ◆

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Survey Reflects Stability in Welding Equipment Industry

An industrial market survey conducted globally shows that while some market segments are on the decline, others are poised for growth

BY ANDREW CULLISON

In 1999, a study of the welding industry was conducted by Frost & Sullivan, a company that has been doing market research for more than 30 years. The 300–400 industry studies done every year by the company are used for marketing strategy, by financial institutions and venture capitalists, and to help new companies entering the market.

This particular study, which took six months to complete, is part of an update to a similar study on the welding industry done six years ago. The information was gathered from interviews conducted with 50–60 companies chosen because a variety of sources identified them as playing a major role in some segment of the welding industry. The companies are located worldwide.

The majority of facts and figures presented in the report comes directly from the companies themselves, with additional information taken from Dun & Bradstreet reports, Frost & Sullivan internal data and various external sources.

Sanjeev Bhaskar, the lead analyst on the project, expressed confidence in the numbers. His background, which included six years working in the welding industry, added to this confidence. "With my experience, I have a basic understanding of the industry, which helped in getting the right information and interpreting the data," he said.

Segments of the industry that were investigated are as follows:

- Arc welding equipment
- Gas welding and cutting equipment
- Resistance welding equipment
- Electron beam welding equipment
- Laser beam welding equipment
- Ultrasonic welding equipment
- Welding electrodes and filler metals.

The full study is an extensive report of more than 200 pages covering the overall industry and its individual segments. Market trends and forecasts to the year 2006 are presented, as well as key issues driving each product segment and the major restraining factors that might hamper the growth of these segments. The report can be purchased.

A brief summary of the survey is presented below. The compounded annual growth rate stated is growth averaged over the forecast period from 1999 to 2006.

Analysis of Market Segments

Arc Welding Equipment

In 1999, this market was worth $2491.4 million, and it is projected to grow to $3009.8 million by the end of 2006. It is generally considered a mature market with any growth in one welding process usually coming at the expense of another process in this market segment.

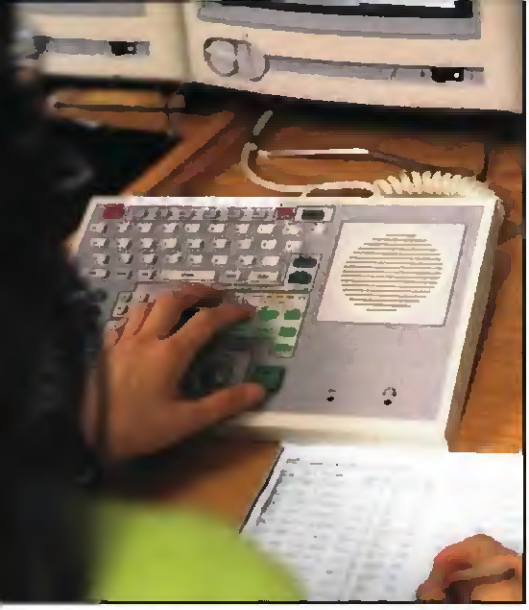
A factor that could drive growth is an increase in the worldwide investment in infrastructure, with a shift into using less concrete and more steel in the construction of that infrastructure. The market is expected to grow at a 2.2 to 3.3% rate during the period 1999–2006. A factor inhibiting growth is the increasing use of plastics and other synthetic materials in products that previously required arc welding for their fabrication.

Gas Welding and Cutting Equipment

The outlook for oxyfuel welding indicates a continuing decline in use with an overall compounded annual growth of only 0.8% projected. The oxyfuel cutting market is performing better with growth forecast at 3.2%. The overall market for 1999 was $1401.0 million. That figure is expected to increase to $1642.7 million by 2006 with a compounded annual growth rate of 2.3%.

The oxyfuel process has low equip-

ANDREW CULLISON is Editor of the Welding Journal. *Information on purchasing the report can be obtained from Cara Shevlin, at (210) 348-1018.*



ment cost, portability and automation in cutting on its side, but the slow manual welding operation and a diminishing work force trained in the oxyfuel process are contributing to its limited growth.

Resistance Welding Equipment

The outlook for resistance welding equipment is encouraging. The 1999 revenues of $1013.0 million are estimated to grow to $1382.1 million by 2006, with a compounded annual growth rate of 4.5% projected.

Factors favoring this market are a healthy automotive industry, environmental friendliness of the process and low-cost operation.

Presently an overcapacity in the radiator industry is slowing new equipment investment in that segment, especially in Europe. The pressure to reduce weight and cost in the manufacture of many products leads to the search for alternative nonmetallic materials, which may impact the use of resistance welding.

Electron Beam Welding Equipment

Although electron beam welding has remained stagnate over the years, it still remains the process of choice for certain applications. The total equipment revenues for 1999 were estimated at $52.6 million, but a forecast of $68.2 million in 2006 is promising.

Contributing to the projection of revenue growth are the faith and confidence shown in the process by the automotive and aerospace industries for specific applications and the need to replace or refurbish aging equipment.

Inhibiting widespread use are the high equipment costs and competition from faster production processes.

Laser Welding Equipment

The laser welding equipment industry is experiencing market strength. Revenues for laser welding equipment are projected to have good growth into 2006. With revenues in 1999 at $274.9 million, the estimate for 2006 is $505 million, reflecting a compounded annual growth rate of 9.1%.

Flexible manufacturing systems, material processing capabilities, improved equipment reliability and easy integration into production lines are all factors that contribute to growing demand. On the other hand, high initial cost, lack of awareness by end users of the capabilities and benefits of the process, and shortage of trained operators are restraining growth.

Ultrasonic Welding Equipment

The market in 1999 generated $333.0 million in ultrasonic equipment sales, and the forecast for 2006 is a healthy $629.1 million. This process is used to weld both plastic and metal components. The major growth is projected to be from plastic's side, but metal applications might also be on the rise. A growth rate of 6 to 9% is estimated for this process.

A factor promoting the use of this process is resistance to the use of adhesives for thermoplastic joining. Also, the demand for cost reduction may lead manufacturers to use more plastics in components.

Welding Electrodes and Filler Metals

The largest revenue-producing segment of the welding industry is from electrodes and filler metals. Revenues in 1999 were $5.69 billion, but the growth rate for this segment has been declining. The forecast for 2006 is $6.16 billion in revenues. The compounded annual growth rate is projected at only 1.1%.

Factors working against strong growth are the development of new materials that require little or no filler metals in their joining and the slowdown in the economies of Pacific Rim countries. Also, the demand for productivity in manufacturing has led to implementing joining processes and systems that put a premium on efficiency, which means less weld metal deposited.

Conclusions

The market for welding equipment, electrodes and filler metals is mature; it is very stable due to its central importance to metal fabricating all over the world. There is demand for products in both developed and developing countries, and the total market was $11.25 billion in 1999.

Recent softness in the European economy and the economic downturn in Asia have affected market growth, but there are signs of economic improvement on those continents. At present, it appears the economy of North America will remain healthy, but the next decade will require innovation from the welding industry to encourage strong growth in sales.

Major companies have tried to blunt the cyclical nature of the industry and to spur growth through mergers and acquisitions. 5ome have succeeded, but others have failed.

Overall, the prospects for the welding industry look healthy, but growth will be slow. The total revenues are forecast to reach $13.39 billion by 2006, with a compounded annual growth rate projected at 2.5%. ◆

Practical information for welders and others involved in welding and its allied processes.

Dynamics of the Electric Arc

A low-voltage, high-current electric arc is the common heat source for fusion welding. The welding arc consists of a sustained electrical discharge across a gap between two poles, commonly an electrode and a base metal. The arc's stability, energy, temperature and spectral emission are significantly affected by the pole materials, the gases in the gap and current level. The two standard categories for welding arcs are one pole a nonconsumable electrode, or one pole a consumable electrode. The nonconsumable pole in arc welding is commonly made of a tungsten material. The composition of the consumable electrode varies, for not only is it the source of the electrical discharge but it also provides filler metal to the weld joint.

The common configuration for a welding arc can be visualized as a round column between the poles, somewhat constricted at the electrode end and more broad at the base metal — Fig. 1. The column consists of two hazily demarcated zones: the outer mantel and the inner plasma.

The highly ionized gases and solids in the plasma offer the main path for the current and generate the area of greatest heat. The temperature in the arc depends on current level, but the type of matter forming the plasma can also influence temperature. An arc can be maintained with very low current levels, but typical arc temperatures range from 5000 to 30,000 K. Equipment designed to take special power loading or constrict the plasma can generate heat in excess of 30,000 K.

Ionization takes place when electrons are removed or added to the outer shell of an atom, changing its electrical state from neutral to charged. An atom becomes positively charged when electron(s) are removed from it, and negatively charged with the addition of electron(s). Atoms that have electrons removed or added are called ions. In Fig. 1, electrons from the power source flowing from the tip of the electrode (cathode) are attracted to the base metal (anode) where they release heat on impact. The electrode attracts positively charged ions.

The temperature in the mantel is not as high as in the plasma. Metals that may have vaporized in the plasma may condense in the mantel, leaving very light metal oxide deposits adjacent to the weld after passage of the arc.

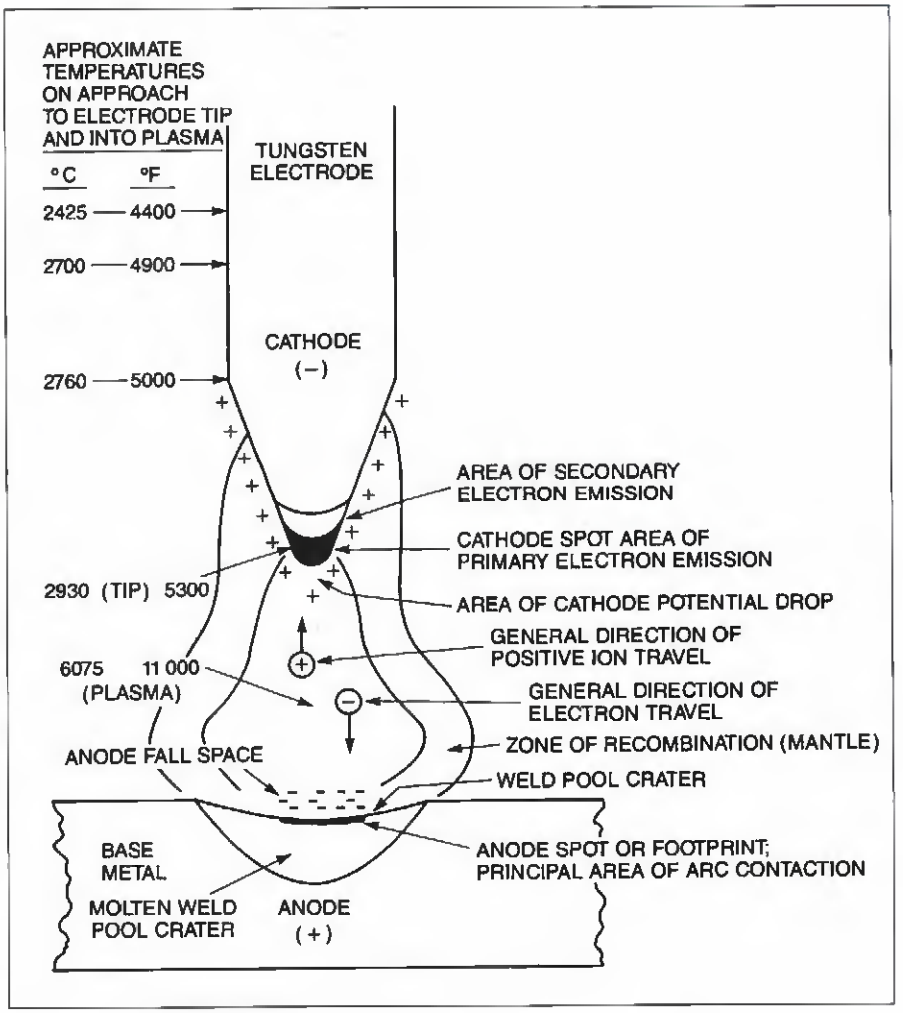


Fig. 1 — Illustration of a nonconsumable electrode operating on direct current electrode negative. Current flow and typical temperatures are shown.

Excerpted from Welding Metallurgy *Vol. 1, 4th Edition.*

Pinch Effect of a Consumable Electrode

The use of a bare steel rod as a consumable electrode was first recorded in 1881. There was difficulty in initiating the arc, but its operation gave promise for future development. The introduction in 1907 of a steel rod covered with fluxing ingredients brought a much needed improvement in arc stability and weld quality. It was learned that by manipulating the ingredients in the covering that a variety of things could be accomplished with the arc, not the least of which was the control of the way the molten metal transferred from the electrode to the base metal.

The variety of forces that affect the transfer of molten metal have been studied extensively through the years. In addition to flux composition, the types and mixtures of shielding gases used with flux cored and solid welding wires have also been found to play a major role in the nature of the transfer.

One of the dynamics of the transfer is called the "pinch effect." The supersonic movement of electrons and ions in the arc plasma gives rise to a magnetic field around the arc column. As seen in Fig. 2, when a metal droplet forms at the tip of the electrode, this magnetic field acts as a squeezing force, constricting the molten metal at the tip of the electrode. Then the magnetic forces acting perpendicular to the constriction pinch off the droplet and propel it to the base metal.

Pressure from gases formed during the rapid heating of the metal at the electrode tip and the density of current passing through the "necking" part of the droplet may also assist the propulsion of the molten metal. The force of the plasma stream then accelerates the droplet to the base metal.

The surface tension held by a liquid acts to hold the metal droplet as it enters the weld pool. Of course, solidification of the molten metal must be accelerated through a combination of current control, technique and electrode formulation to counteract gravitational forces when welding out of position.

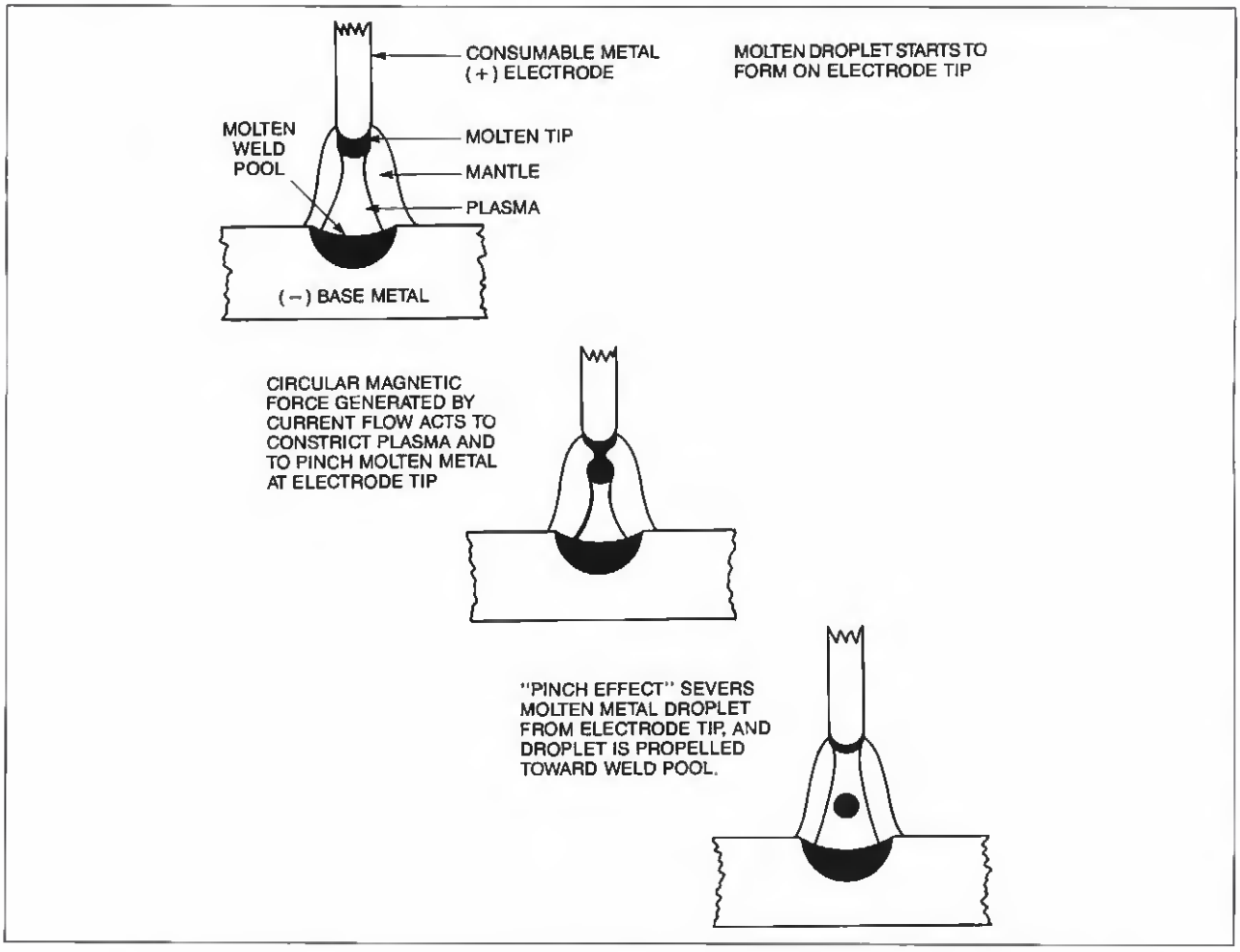


Fig. 2 — Illustration of the pinch effect of a consumable electrode using direct current electrode positive.

81st ANNUAL AWS CONVENTION & INTERNATIONAL WELDING & FABRICATING EXPOSITION

The Best Fabricating EVENT of the year

Days and Hours

The 81st Annual Convention begins Tuesday, April 25, and continues through Friday, April 28. Hours are 9:00 a.m. — 5:00 p.m. The Official Opening of the International Welding and Fabricating Exposition is scheduled for 8:15 a.m. on Wednesday, April 26. AWS Expo hours are Wednesday and Thursday from 8:30 a.m. to 5:30 p.m., and Friday, April 28, from 8:30 a.m. to 1 p.m.

Registration Hours

On-site registration at McCormick Place will be from Tuesday, April 25 through Thursday, April 27, 7:30 a.m. to 5:30 p.m., and Friday, April 28, from 7:30 a.m. to 1:00 p.m.

American Welding Society

Society Activities

Membership

Registration fees for the full Professional Program and identified continuing education offerings include a one-year membership in AWS. AWS member benefits are activated immediately and attendees are encouraged to shop the AWS Book Store and use their new 25% discount.

Tuesday, April 25

Opening Session
9:00 a.m. - 11:00 a.m.

The 81st AWS Annual Convention begins at 9:00 a.m. The AWS Annual Business Meeting includes the President's Report and the induction of the 2000 Class of AWS Fellows, and is open to all AWS Members.

Comfort A. Adams Lecture
11:00 a.m. - 12:00 noon

Named after AWS Founding Father and First President Comfort A. Adams, this lectureship is one of the most prestigious recognitions that can be bestowed within the industry. The 2000 Comfort A. Adams Lecture is being presented by **Dr. Tarasankar DebRoy,** a professor of materials sciences and engineering at Pennsylvania State University. Dr. DebRoy is internationally known for his work on transport theory and chemical processes associated with arc and laser beam welding. An AWS Fellow (Class of 1999), Dr. DebRoy has also contributed to the understanding of weld metal geometry, chemical composition and structure. He currently directs projects for the U.S. Department of Energy and the Office of Naval Research, among others.

The 57th lecture in the Adams series is titled "**Computer Modeling — A Path to Understand the Science of Welding.**"

Get Acquainted Luncheon
Sheraton Hotel
12:00 noon - 2:30 p.m.

Want to know the low-down on the guest sitting next to you at this special function? Then join in with other AWS Convention-goer spouses for a sensational lunch and learn the secrets only astrologers can reveal. Several of these mediums will be on hand to give individual readings and answer questions you may have on "the sight."
$30. Please use registration code 102.

AWS Officers' Reception
Sheraton Hotel
6:00 p.m. - 7:30 p.m.

This stylish annual party is attended by both AWS Members and nonmember Expo-goers alike and is a great way to kick off the week-long convention. Meet the AWS Officers, new friends, new Members and new prospects in an elegant setting. Cash bar, complimentary hors d'oeuvres buffet. Evening business attire, please.

Thomas Lecture
1:30 p.m. - 2:00 p.m.

Mr. Frithjof Zentner of NAS-DIN will be this year's Thomas Lecturer. Mr. Zentner's involvement and expertise in the field of welding spans many years. He has been employed at DIN e. V. (German Institute of Standardization) for almost 40 years and is responsible for the coordination of National, European and International Standards in the field of welding and allied processes. He has been actively involved in the IIW since 1970 and currently leads the department of welding (NAS) at DIN. In addition, Mr. Zentner is the Secretary of several European and ISO Standards Committees. His lecture is titled, **"Connections and Results of European and International Standardization in the Field of Welding."**

Wednesday, April 26

Opening of the 2000 AWS Expo
8:15 a.m. - 8:30 a.m.

A short, symbolic ceremony has evolved into a spirited, exciting event that sets the mood for Expo-goers about to enter a welding and fabricating equipment extravaganza. Hosted by incoming AWS President **L. W. Myers.**

Free Seismic Session for East-of-the-Rockies Engineers

Cosponsored by AWS and AISC

10:00 a.m. - 11:30 a.m.

Steve Ashton, the assistant director of education for the American Institute of Steel Construction (AISC), is presenting significant information on two important issues for low seismic-prone areas: lateral framing systems and new filler metal toughness requirements in static application.

Ashton, a professional engineer (PE), has worked both at a desk, as a structural engineer for Burns & McDonnell, Kansas City, Missouri, and with his hands as a fabricator for Egger Steel — so he'll be delivering the kind of straight talk you need on the following:

- Seismic and code information that applies to lateral-load-resisting systems in low-seismic regions
- The underlying concepts and details for braced frames and moment frames
- What's behind these code provisions and what you can expect to be working with
- The new AISC requirements for the use of filler metals with specified toughness

Thursday, April 27

Prayer Breakfast
7:30 a.m. - 8:30 a.m.

Get together for fellowship and inspiration as Dr. Terry Nelson-Johnson and Kate DeVries address the topic "Are You Grounded?" Some have referred to God as "the ground of our being," a phrase which should strike a chord with welding professionals. Kate and Terry will ask you to consider the question: "Am I sufficiently grounded in a reality that will help me meet life's challenges?"

Dr. Nelson-Johnson is director of Community Formation at Old St. Patrick's Church in Chicago. His dynamic style has made him a popular speaker on a national level. Ms. DeVries is the associate director of the Young Adult Ministry Office for the Archdiocese of Chicago.

$20. Please use registration code 116.

Plummer Memorial Educational Lecture
9:00 a.m. - 10:00 a.m.

This award recognizes outstanding individuals in the academic community and was installed to reflect the contributions of AWS President and Executive Director Fred L. Plummer. **Edward R. Bohnart**, president, Welding Education and Consulting, Winneconne, Wisconsin, and AWS Past President (1995 - 1996), will present "**Skill Standards: Are We Raising the Bar or Promoting Mediocrity?**"

AWS 2000 Education Program

sponsored by the AWS Education Committee

E1 Training Trends
10:00 a.m. - 12:00 noon

A. Cultural Differences in Welding Training: An American Instructor in Mexico
Dr. Angie Hill Price, assistant professor, Texas A&M University, College Station, Texas

B. What Makes a Successful Welder? A Four-Year Tracking of 300 Welding Careers
J. Wayne Western, instructor, Ogden-Weber Applied Technology Center, Ogden, Utah

C. How AWS is Furthering the Joining Sciences through its Foundation and the National Educational Scholarship Committee
Nancy M. Carlson, Consulting Technical Specialist, Idaho Falls, Idaho

D. S.E.N.S.E. Program Update
A. J. Badeaux, instructor, Crossland High School, Temple Hills, Maryland

73rd AWS Awards Ceremony
12:00 noon - 2:00 p.m.

The first AWS award, the Samuel Wylie Miller Memorial Medal, was presented to Comfort A. Adams in 1927. As the Society, and the industry it serves, has grown, so has the need to recognize outstanding scientists, engineers, educators and researchers. Join an assembly of distinguished award presenters, recipients and guests for a well-paced ceremony and fine dining.

$30. AWS Members use registration code 107; others, please use 108.

E2 Live Welding Demonstration
1:30 p.m. - 4:30 p.m.

Your host will be The Lincoln Electric Company, which will run some of its hottest new products. This is an off-site event with transportation provided. Hands-on opportunities and live demonstrations.

E3 Welding Nickel-Containing Alloys
2:00 p.m. - 5:00 p.m.

A. The Role of Nickel in Welding Today's Industrial Alloys
Richard E. Avery, consultant to the Nickel Development Institute, Toronto, Canada

B. Fabricating Nickel-Base Alloys Is No Harder Than Welding Carbon Steels
Greg Hohack, staff welding engineer, Haynes International, Kokomo, Indiana

C. Basics of Welding the Nickel Alloys
Donald J. Tillack, consultant to the Nickel Development Institute, Toronto, Canada

The 2000 Education Program is comprised of the Plummer Lecture, Session E1 and Sessions E2 or E3. Registration fee includes handouts, transportation if E2 is selected, and admission to The Expo. The Plummer and Sessions E1 and E3 are in McCormick Place; E2 is at The Lincoln Electric Co.'s Chicago District Office. AWS Members, $50 — use Code 31 for E1 and E3 or Code 88 for E1 and E2; others, $95 — use Code 39 for E1 and E3 or Code 89 for E1 and E2.

New for 2000

The Educators' Booth

Stop by, kick back and network with your education and training peers at the invitation of the AWS Educators' Subcommittee. Get your educator designation ribbon and wear it with pride. Meet the U.S. gold medal winner of the 1999 International Skills Competition, Ray Connolly of Belleville Area College (Illinois) — introduce him to your students. Spend some time online to see what AWS is offering educators at its Web site.

Conferences

Welding in Food Industry Applications

sponsored by the AWS D18 Committee on Welding in Sanitary Applications

Chair: Richard E. Avery, Nickel Development Institute

Co-Chair: Jerry R. Miller, International Training Institute

Wednesday, April 26

9:00 a.m. - 5:00 p.m.

Don't miss this opportunity to hear reports on how to meet high sanitary and cleanability standards when welding food processing equipment, material preparation and welding procedures, clean-in-place requirements and inspection.

1. Importance of Welding in the Food Industry

Food industry stainless steel equipment must meet high sanitary and cleanability standards. The industry has long recognized the importance and essential role of welding in producing this equipment.

Mr. Dennis Helmke, president, Flow Products, LLC, Kenosha, Wisconsin.

2. Stainless Steels: Properties for Food Industry Use

A discussion of structure and corrosion resistance of typical stainless steels used in processing and handling food products. Stainless steels are widely used in the food industry. A better understanding of them will lead to improved and intelligent applications.

Roger A. Covert, consultant to the Nickel Development Institute, Middletown, New Jersey

3. AWS Specification D18.1 — *Specification for Welding of Austenitic Stainless Steel Tube and Pipe Systems in Sanitary (Hygienic) Applications*

This discussion will address the new D18.1 specification for welding austenitic stainless steel tubing in sanitary (hygienic) applications. This discussion will also address the welding qualification and visual examination requirements of the specification. Learn how to use a new specification, application and limitations of specifications, qualifying to the specifications and meeting visual requirements of the specification.

James R. Hannahs, PE, consultant, Troy, Ohio; Chairman, AWS D18 Committee

4. The Basics of Design and Welding of Food Processing Equipment

The welding of food processing equipment should be a science, not an art. This presentation will cover basic awareness of the standards available that can be used for welding of food process equipment, what weld joints are typically encountered, what type of welding equipment and procedures are used, and what postweld treatments are beneficial to the corrosion resistance and cleanability of the welded joint.

Joseph R. McSwiggin, PE, senior project engineer, Rodem, Inc., Cincinnati, Ohio; member, AWS D18 Committee

5. Preparation for Welding and Welding Procedures

The focus will be on weld preparation of austenitic stainless steel tube welding procedures as it relates to the food industry.

M. P. (Mike) Lang, welding director, United Association, Local 501, Aurora, Illinois; member, AWS D18 Committee; and **Tim Sheenan,** E.H. Wachs Co., Wheeling, Illinois; member, AWS D18 Committee.

6. Clean-in-Place (CIP) Application in Food Processing and Pharmaceutical Industries

Discussion on the basic CIP theory for cleaning welded fabricated processing systems in food and pharmaceutical plants. Learn techniques used to clean product contact surfaces of processing equipment. Special focus would be on clean "as-welded" surfaces.

Larry Hanson, president, Sani-Matic Systems, Madison, Wisconsin; member, AWS D18 Committee.

7. Inspection of Welds for Food Service

Welds in food services have a wide range of acceptance criteria. Inspection methods and techniques depend on these criteria. Learn what inspection methods to use, typical equipment and techniques.

Richard D. Campbell, president, Welding Solutions, Inc., Broomfield, Colorado; member, AWS D18 Committee

AWS Members $295 - use registration code 80; others, $370 - use registration code 81. Registration includes refreshments, lunch and handouts. Fee also includes admission to the 2000 AWS Expo. Nonmembers receive one year's membership in AWS.

Aluminum Welding: A Two-day Seminar

sponsored by the AWS and The Aluminum Association

Thursday, April 27

8:00 a.m. - 11:45 a.m.

Session I: Fundamentals of Materials, Safety and Health

1. An Introduction to Aluminum Joining

Learn why the basic measure of aluminum joinability is the alloy's composition and melting range.

Frank G. Armao, senior application engineer, Application Engineering Department, The Lincoln Electric Company, Cleveland, Ohio

2. Safety and Health Considerations for Welding Aluminum

Although aluminum welding is a relatively safe process, the welder must be aware of potential exposure to physical and chemical agents emitted during the welding process and the effects of the alloying elements.

Seymour G. Epstein, technical director, The Aluminum Association, Washington, D.C.

3. The Aluminum Designation System and Characteristics of Aluminum Alloys

An explanation of The Aluminum Association's aluminum alloy and temper designation system. Plus, the physical and mechanical properties of aluminum and aluminum alloys.

Peter Pollak, manager, The Aluminum Association, Washington, D.C.

4. Aluminum Welding Metallurgy

The basics of aluminum alloy metallurgy and the effects of welding on alloy properties. Advice on filler alloy selection and the judicious use of preheat.

Frank G. Armao

5. Filler Alloy Selection

Get an understanding of the variables involved in the selection of filler alloys, including welded component service requirements and the characteristics of the particular base alloy being welded. These variables are essential to designing a successful welding procedure specification.

Tony Anderson, technical service manager, AlcoTec Wire Company, Traverse City, Mich.

1:00 p.m. - 5:00 p.m.

Session II: Joining Processes

6. Metal Preparation for Welding

Why metal preparation is one of the key steps toward producing good quality welded joints.

William Christy, welding technologist, Alcan International, Kingston, Ontario, Canada

7. Gas Metal Arc Welding (GMAW) of Aluminum

Learn the most suitable GMAW equipment combinations for welding aluminum. Also explained: metal transfer modes, shielding gas types, wire feed systems, and power source selection, constant voltage, constant current, pulse or variable polarity.

Tony Anderson

8. Gas Tungsten Arc Welding (GTAW) and Variable Polarity Plasma Arc Welding (VPPAW)

A presentation on welding aluminum utilizing these two processes.

William Christy

9. Fundamentals of Brazing and Soldering Aluminum

An emphasis on the wetting, spreading and the significance of contact angles, surface oxides and the importance of cleanliness; advantages and disadvantages of brazing, outlining the critical steps and manufacturing issues; the principles related to joint design, fixturing, joint clearance and thermal-expansion mismatch; cleaning, filler-alloy selection and application methods; how to protect the joint and filler during brazing using fluxes and atmospheres; heat sources; destructive and nondestructive inspection; codes and standards; and health and safety issues.

Dr. Daniel Hauser, principal research engineer, EWI, Columbus, Ohio

Friday, April 28

8:00 a.m. - 12:00 noon

Session III: Design, Quality and Performance

10. Design and Performance of Aluminum Welds

How to extract maximum performance by factoring in strength, toughness, fatigue, corrosion and other variables into the design of aluminum welds.

Donald D. Rager, planning supervisor, Reynolds Metals Company, Chester, Virginia

11. Weld Discontinuities: Causes & Cures

The discontinuities normally encountered in aluminum arc welds; how to detect the discontinuities; the possible causes of the faults; and how to avoid creating weld discontinuities.

Paul B. Dickerson, consultant, Lower Burrell, Pennsylvania.

12. Role of Grain Structures in Aluminum GTA Welds

The relationship between grain structure and solidification cracking and how the weld process parameters can affect grain structure.

Dr. Jo Ann Clarke, automotive applications engineer, Alcan Global Automotive Products, Farmington Hills, Mich.

13. Application of the AWS Structural Welding Code — Aluminum

The latest revisions to the D1.2 code. When, where and how to apply the D1.2 code to ensure quality workmanship and structural integrity.

Donald D. Rager, member, AWS D1.2 Committee

1:00 p.m. - 3:15 p.m.

Session IV: New Processes

14. High Energy Beam Welding of Aluminum

The presentation will describe how to weld aluminum alloys using laser and nonvacuum electron beam welding.

Dr. Jo Ann Clarke

15. Friction Stir Welding of Al Alloys

The presentation will describe the process used in friction stir welding Al alloys and their microstructures and mechanical properties.

Dr. Thomas J. Lienert, research engineer, EWI, Columbus, Ohio

16. Robotic Welding of Aluminum

The latest developments in arc welding power source design and wire feeding concepts used in robotic arc welding of aluminum will be presented. For those companies seeking to optimize production applications, Mr. Morehead will describe a new programmable power source output wave form for popular aluminum wire chemistries that offers additional flexibility.

Tim Morehead, marketing manager, Automation Division, The Lincoln Electric Company, Cleveland, Ohio

AWS Members, $450 - use registration code 56; others, $525 - use code 57. Registration includes all presentations, handouts, refreshments and lunch. Fee also includes the following:

AWS's D1.2: 1999 *Structural Welding Code — Aluminum*, AA's *Wrought Alloy Registration Records, Casting Alloy Registration Records, Welding Aluminum Theory* and *Practice*, and *Aluminum Standards & Data — 2000.*

In addition, Seminar-goers also receive complimentary entry to the 2000 AWS Expo. Nonmember fee includes a one-year membership in AWS.

Poster Session

Poster Session
Tuesday - Thursday, April 25 - 27
McCormick Place, Near Technical Sessions

Graphic displays of technical achievements are presented for close, first-hand examinatioo in the Poster Session. Posters present welding results and related material that are best communicated visually, as well as research results that call for close study of photomicrographs, tables, systems architecture or other illustrative materials.

The posters are presented in four categories:
(a) 2-year degree or certificate student level;
(b) 4-year degree student level;
(c) Graduate degree student level; and
(d) Commercial/Professional Division

Student Category A: 2-year or Certificate Program

SPA-1 Automated Orbital Gas Tungsten Arc Welding of Stainless Steel Canisters, by G. Loiacono and M. Dowd, Alfred State College.

SPA-2 Ultrasonic Inspection of Electron Beam Weldments, by L. Woroniecki and N. Mangino, Alfred State College.

SPA-3 Ferrite Application on Welds, by D. I. Alfaro, North Harris Community College.

SPA-4 The Annealing of Ti-6Al-4V, by S. Corone, North Harris Community College.

SPA-5 Welding Joint Porosity, by R. J. Stark, North Harris Community College.

SPA-6 Metallurgy in the Weldability of Tool Steels, by G.Vazquez, North Harris Community College.

SPA-7 Inconel 625 Overlay for API Ring Grooves, by M. Berckenhoff, North Harris Community College.

SPA-B Flame Hardening, by J. Hudson, North Harris Community College.

SPA-9 Damascus Steel, by G. Stafford, North Harris Community College.

Student Category B: Undergraduate (4-year) Degree Program

SPB-1 Some Aspects Regarding the Possibtlitites of Manufacturing the Friction Welded Joints, by F. Octavian, Technical University Gheorghe Asachi Iasi.

SPB-2 Welding Process Effects on Weldability Testing of HPS 70W High Performance Steel, by D. Thiessen, LeTourneau University.

SPB-3 Innovative Testing of High Performance Steel Welds, by D. Ryan, LeTourneau University.

SPB-4 Effects of Welding on Grain Boundary Engineered Material, by R. J. Steel, Brigham Young University.

SPB-5 Weld Force Triggering and Feedback for Resistance Spot Welding of Steel, Aluminum and Titanium, by W. Barkley, J. Wolford and B. Henderson, The Ohio State University.

SPB-6 The Effects of Weave Patterns and Welding Conditions on Weld Fusion Zone Morphology and Through-Arc Seam Tracking Performance, by T. Gray, J. Liwang and D. Pham, The Ohio State University.

SPB-7 Surface Alloying of Nickel-Base Alloys, by R. Davis, B. Galliers and M. Schoppelrei, The Ohio State University.

SPB-8 Improved Welding Through Modeling of IN 718, by R. M. Deacon, Lehigh University.

Student Category C: Graduate Degree Program

SPC-1 The Effect of Multiple Postweld Heat Treatment Cycles on the Weldability of Waspaloy, by M. Qian, The Ohio State University.

SPC-2 Optimizing Weld Design of Pressure Vessels in Thermal Cycling Service, by J. Penso, The Ohio State University.

SPC-3 Guiding Electrical Discharges with a Low-Power Carbon-Monoxide Laser, by J. R. Eastman, Edison Welding Institute.

SPC-4 Finite Element Analysis of Phase Transformation Effect on Stress Relief in Materials for Welding, by G. B. Jang, K. R. Son and S. S. Kang, R. I. S. T. Pusan National University, S. Korea.

SPC-5 Development of a Test Technique for Ductility Dip Cracking, by N. Nissley, The Ohio State University.

SPC-6 Joining of Sapphire and SUS316L Stainless Steel, by Y. Murakami, Y. Miyazawa, T. Ariga and T. Masuda, Tokai University, Japan.

SPC-7 Assembly of Structural Parts by Brazing Technology, by T. Ikegawa, T. Ariga and Y. Miyazawa, Tokai University; and T. Kuroyanagi, MEIKI. Co. Ltd., Japan.

SPC-B Brazing of Mg Alloy, by N. Masuda, T. Ariga, A. Miyazaki and Y. Miyazawa, Tokai University; and H. Matsunami, Kayoh Technical Industry Co. Ltd., Japan.

SPC-9 Laser Micro-Welding for Marginal Lap Joining of Ultra Thin Sheet Metals, by J. Du and A. Kar, University of Central Florida; W. P. Latham, Air Force Research Lab; and J. Longobardi, Metal Tech Industries.

SPC-10 Investigation of Solid-State Reactions between Simulated Slag Deposits and Fireside Boiler-Tube Weld Claddings, by N. Barbosa, A. R. Marder and J. N. DuPont, Lehigh University.

SPC-11 Validation and Application of a Multi-Component Thermodynamic Database for Solidification Modeling of Fusion Zones, by B. Newbury, Lehigh University.

SPC-12 Laser Weld Plume Dynamics, by K. R. Kim and D. Farson, The Ohio State University.

SPC-13 Trans-varestraint Testing of Aluminum Alloys, by S. Norton, The Ohio State University.

Meet the Instructors

Professional/Commercial Division

P-1 Failure Analysis and Welding Repair of A Pressure Vessel, by Z. Sun, K. W. Heng and C. P. Ang, Singapore Welding Society.

P-2 Joining Boron Carbide Reinforced Aluminum Metal Matrix Composites, by H. Zhang, Reynolds Metals Company.

P-3 Studies on the Weldability of Aluminum, Brass and Copper in Small-Scale Spot Welding, by B. Chang and Y. Zhou, University of Waterloo, Canada.

P-4 Vibrational Stress Relief of Weldment, by W. Wu, I-Shou University, Taiwan.

P-5 Project W.E.L.D. Worthy Employment Leadership Development, by R. E. Hart, Municipality of Cleveland City Schools.

P-6 Closure Welds for the High-Level Radioactive Waste Containers, by M. C. Knapp and J. A. Cogar, Framatome Cogema Fuels.

P-7 100 Percent Quality Assurance for Inertia Welding through Intelligent Data-Mining Techniques, by D. A. Hartman, M. J. Cola and V. R. Dave, Los Alamos National Laboratory.

P-8 Contact Tube Temperature during GMAW, by T. Siewert, G. Adam and T. Quinn, NIST.

P-9 Application of Backscattered Electron Diffraction to Understanding Weldability Phenomena, by J. N. DuPont, Lehigh University; and J. Michael and C. V. Robino, Sandia National Laboratories.

P-10 Measurement of Residual Stresses in Welds Using Electronic Speckle Pattern Interferometry, by V. R. Dave, P. Rangaswamy and F. Smith, Los Alamos National Laboratory; and J. Milewski, and Greg Hayman, HYTEC, Inc.

Lawrence Alexander

Understanding the Techniques of Resistance Welding

With 50 years in the industry, Lawrence Alexander's experience in resistance welding began with the design and maintenance of production welding equipment and later rising to the chair of Medar Canada, Ltd. Today, Mr. Alexander is the principal of a consulting company and a sought-after instructor and troubleshooter. He holds a master's degree in electrical engineering and has been affiliated with both TWI and EWI. He is a member of both AWS and the Welding Institute of Canada.

Steve M. Ashton

Lateral Framing Systems East of the Rockies and New Filler Metal Toughness Requirements in Static Applications

Steve Ashton is the assistant director of education for the American Institute of Steel Construction (AISC). He has been with the organization since 1998. Prior to joining AISC, he was a structural engineer for Burns & McDonnell in Kansas City, Missouri. Ashton gained hands-on fabrication experience while working for Egger Steel Company. He holds a bachelor's degree in civil engineering from South Dakota State University and a master's degree in civil engineering from the University of Kansas.

Edward M. Beck

Road Map to the D1.1 Code

With over 30 years of experience in the steel welding, testing and inspection industry, Edward Beck is a popular speaker. He is a registered professional engineer and holds a bachelor's degree from Auburn University. Currently, he is the vice president and corporate consultant at LAW Engineering and Environmental Services. His professional affiliations include AWS, AISC, ASME and ASNT, and for several years he served on the AWS D1 Structural Welding Committee.

Edward R. Bohnart

Arc Welding Power Sources: How to Extract Optimum Performance from Your Equipment Investment

Ed Bohnart is the principal of Welding and Education Consulting in Winneconne, Wisconsin. He launched his consulting practice after a successful career with Miller Electric Mfg. Co., where he directed its welding school. He is an AWS Distinguished Member and Past President. Bohnart has been active in the VICA program and instrumental in the organization of the AWS Welding Trials as an IWW USA Technical Expert. For six years Bohnart was the Chair of the AWS C5 Committee on Arc Welding and Cutting and remains an Advisor.

Richard Campbell

How to Ensure the Weldability of Stainless Steels: Part 1 — The Basics, and Part 2 — Avoiding Weld Defects

Dr. Campbell joined the AWS Precision Joining Center as a senior researcher/faculty member after an established career with EG&G Rocky Flats, Westinghouse and Rockwell International. Campbell is an expert on welding stainless steels and nickel alloys and a recognized speaker on the technical/college lecture circuits as well as a popular AWS CWI/SCWI prep instructor. Currently, he serves on both the AWS Gas Tungsten Arc Welding and Sanitary Applications subcommittees, as well as ASME's Materials Joining (bioprocessing equipment) subcommittee.

Kenneth W. Coryell

Welding Quality Assurance Management; The Why and How of Weld Procedure Specifications: The Right Way to Document Your Welding Controls to Save Time, Money and, Maybe, Your Credibility

Ken Coryell's experience includes welding quality assurance, quality control, nondestructive examination and welding engineering for the electric utility, petro-chemical, aerospace, shipbuilding and structures industries. He is an ASNT Level III certificate holder in radiography and liquid-penetrant testing, an AWS Certified Welding Inspector and a registered Professional Engineer.

For 10 years, Mr. Coryell's 12-hour video course, "Welding Inspection Technology," has been used to prepare candidates for the CWI examination. He earned both his bachelor's and master's degrees in welding engineering from The Ohio State University. His professional affiliations include AWS, ASNT, ASME, ASM International and the National Society of Professional Engineers. He is currently a welding and quality consultant based in Old Lyme, Conn., and is a frequent seminar leader and author for AWS.

Meet the Instructors

Denis E. Destefan

Process in Standardization of AC and DC Resistance Welding Current Measurements and Instrumentation

Mr. Destefan is the president of High Current Technologies, Inc. (HCT). He has 21 years' experience in welding equipment instrumentation, calibration and metrology, and automation and data acquisition systems. Mr. Destefan is a member nf the IEEE, AWS and is a member delegate for the NCSL. He is a member of the AWS C5C Committee on Gas Tungsten Arc Welding and the A10 Committee for the Measurement of Single Phase Resistance Welding Currents. He has worked for Rockwell International, EG&G Inc., and Kaiser-Hill, LLC. Mr. Destefan holds BSEE and ME degrees from the University of Colorado. Before founding HCT, he held the position of staff instructor at the AWS Precision Joining Center. He has presented workshops on Resistance Welding High Current Measurements and Calibrations at the 1995 and 1996 American Welding Society International Conventions. He has also presented papers at IEEE Measurement Conferences, NCSL and at the AWS Sheet Metal Welding Conference. Mr. Destefan holds one patent in the area of resistance welding measurements and has one patent pending for a high-current sensor.

Jesse Grantham

Business Strategies for Welding

Dr. Jesse Grantham is a welding engineer with more than 30 years of experience in the field. His consulting firm provides training and testing of welding technology. Dr. Grantham's specialized knowledge includes welding management and design of manufacturing operations; welding metallurgy; welding codes, standards and specifications; underwater welding; and nondestructive testing. He is a widely recognized expert in the fields of welding, welding management, welded steel construction and welding processes used in manufacturing.

Douglas H. Harris

Introduction to Thermal Spray: Processes, Coatings and Applications

Doug Harris, a veteran instructor and cofounder and president of APS-Materials, Inc., brings his 35 years of thermal spray process experience to the course content. While working for Monsanto Research Corp., he specialized in plasma spray technology. A holder of seven patents, awarded or pending, he has authored more than 25 articles and papers.

Charles J. Hellier

Welding Quality Assurance Management

Chuck Hellier, founder of the respected training concern Hellier and Associates, is currently vice president of Rockwood Service Corp., a multidiscipline organization offering a wide range of technical services throughout North America. Hellier has more than 40 years of experience in QA and inspection. Aside from his PE credentials, he is a board-certified forensic examiner and holds Level II certifications in five nondestructive testing methods.

Hellier has held many volunteer positions with ASNT, including president, and is an ASNT and ABFE Fellow. Today, he holds the Secretary officership for the Nondestructive Testing Management Association (NDTMA) and is also a member of AWS, ASNT, ASME, ASTM and ASM.

Eugene G. Hornberger

Design and Planning for Cost Effective Welding

Eugene G. Hornberger is a welding consultant for the Arcet Equipment Company, headquartered in Richmond, Virginia. Prior to this, Hornberger had been in charge of welder training for Newport News Shipbuilding. He has served in many positions for AWS including the Board of Directors and as Chairman, AWS Education Committee. He has written and edited several books including *Welding Processes and Practices*, coauthored with AWS Fellow (Class of 1993) August Manz. He was the editor for the new AWS publication *Design and Planning Manual for Cost-Effective Welding* and is working on several other publication projects for the society. Hornberger both teaches welding and troubleshoots for Arcet's customers, as well as leads AWS seminars on preparing for the CWI examination as a senior instructor.

Kenneth C. Jobes

Visual Inspection Workshop

Voted the Certified Welding Inspector of the Year in 1997, LeTourneau University alumnus Ken Jobes has developed and implemented inspection, maintenance, and repair programs for fossil/hydroelectric/nuclear power plants over the last twenty-seven years. Aside from his adjunct instructor duties for AWS's CWI preparatory seminars, Jobes has taught seminars in welding and welding inspection for Alabama Power, Union Carbide, Commonwealth Edison, Babcock and Wilcox, Duke Power, California Edison, Alliance Steel and many more. Mr. Jobes recently join the ranks of AWS Senior CWIs, just receiving the fourteenth certification card in this new AWS program.

Donald L. Lynn

Welding Quality Assurance Management

Don Lynn, a registered Professional Engineer for more than 20 years, is focused on the development of welding process control for clients that range from employers of hundreds of welders to operations with 5 to 10 welders. This work has led to the identification of the steps necessary for a company to achieve ISO 9000 certification in the welding operations area.

Mr. Lynn is currently a consultant to EWI on the PrimeNet TQJ assessment program and is developing the welding management training modules for the National Excellence in Materials Joining program for OSU, where Lynn obtained his degree in welding engineering.

Duane K. Miller

Road Map to the D1.1 Code

Duane Miller is a welding design engineer and manager of Engineering Services for The Lincoln Electric Company, Cleveland, Ohio. He earned a ScD degree from LeTourneau University. He serves on the SAC Project Oversight Committee and is Vice Chair of the AWS D1 Structural Welding Committee. A prolific author, Mr. Miller's articles are frequently read in the *Welding Journal*.

John Monsees

How to Weld Titanium

Mr. Monsees continues to lead the immensely popular ITA seminar "How to Weld Titanium." The International Titanium Association (ITA) is an organization that Monsees served for many years as Executive Director and now assists in a consulting capacity.

Ann L. (Anna) Petroski

Welding Quality Assurance Management

Over the past 20 years, Anna Petroski's career has ranged from work as a welder, welding inspector, hands-on and classroom instructor in welding technology, quality and quality assessment, and had directed and designed quality assurance programs. She has spent her career in welding quality assurance in machinery manufacturing, Navy nuclear and education. She has authored a number of production procedures, designed vendor surveillance programs, and successfully facilitated and maintained an ISO 9001 registration in design, build and service manufacturing firm. Ms. Petroski currently serves as Director of Certification Programs and Business Development for the American Welding Society. She previously served as a volunteer on the AWS Board of Directors and member of the Qualification and Certification Committee. Ms. Petroski is a current CWI, CQA and co-lead assessor for the International Institute of Welding's accreditation program.

John D. Ramboz

Process in Standardization of AC and DC Resistance Welding Current Measurements and Instrumentation

Mr. Ramboz has more than 40 years of experience in the field of electrical and mechanical metrology. He is a 1963 graduate of the California State Polytechnic University (Pomona) and holds a BS in Electronic Engineering. His employment background includes 3 years at General Dynamic's calibration laboratory, 8 years with the U.S. Naval Metrology Engineering Center in Pomona, California, and 25 years at the National Institute of Standards and Technology (NIST) at Gaithersburg, Maryland. Since 1993, he has been President of RAMTech Engineering, Inc. RAMTech Engineering provides engineering consulting to companies, businesses and the Government in the areas of precision measurement and metrology. He has specialized knowledge in the precise measurement of very high steady-state and transient electrical currents. He is presently collaborating with High Current Technologies, Inc., in the design, testing and manufacturing of precision high- current sensors and measurement systems. Mr. Ramboz has also jointly conducted workshops on weld current measurements at the 1995 and 1996 AWS International Conventions. He has authored numerous papers on this and related subjects.

Mr. Ramboz is currently an active member of the Institute of Electrical and Electronic Engineers (IEEE), the AWS A10 Committee for the Measurement of Single-Phase Resistance Welding Currents, several IEEE Societies and ANSI Committees and is a member delegate of the National Conference of Standards Laboratories (NCSL). He is a NIST National Voluntary Laboratory Accreditation Program (NVLAP) assessor for calibration laboratories. Mr. Ramboz has a patent pending for a novel state-of-the-art high-current sensor.

David V. Rypien

Welding Quality Assurance Management

An OSU alumnus, David Rypien is president of Hellier Technical Training, Certification and Consulting, with offices in Houston, Anaheim and Niantic, Conn. Dr. Rypien has an extensive background in materials, welding and nondestructive examination for the marine, petrochemical refinery, construction of deepwater structures, mining and railroad equipment industries. He has worked for Shell Research and Development and was corporate manager, Technical Training, for the American Bureau of Shipping.

Rypien has authored numerous publications on materials, welding, NDE and project management. He is a registered Professional Engineer in Ohio and Texas and an AWS CWI. He is a Project Management Professional and Diplomat for The American College of Forensic Engineers.

Robert E. Shaw

Road Map to the D1.1 Code

Known for his practical approach, Shaw, a registered Professional Engineer, is a popular speaker with 25 years of steel construction industry experience. He is a member of the D1 Structural Welding Committee, as well as a member of its Design and Strengthening and Repair subcommittees. He is currently updating Omer Blodgett's classic, *Design of Welding Structures*, and is president of the Steel Structures Technology Center, Inc.

Larry Smith

Welding for Tool and Die Manufacturing

President of Global Training Alliance, a company specializing in welding and its related processes, Mr. Smith has more than 30 years of experience in welding technology with highly recognized expertise in tool and die welding, maintenance welding and welding processes and procedures.

V. Vaidya

Welding Quality Assurance Management

Licensed Professional Engineer Viwek Vaidya carried out welding and quality assurance functions for Combustion Engineering prior to joining Air Liquide Canada Inc. in 1986. He has built pressure vessels, bridges, paper machines, mining equipment, hydro gates, refinery equipment and nuclear reactors in North America, Europe, China and New Zealand over the past 28 years.

Vaidya is an active member of both ISO TC 44 on Welding and the Strategic Steering Committee for Welding with CSA. Mr. Vaidya, a member of AWS, lectures at McGill University, the University of Waterloo and University of Wisconsin at Milwaukee, and holds several patents.

As a director for Air Liquide, Vaidya is keenly involved in welding technology, its development, selection and application.

Ted V. Weber

Corrosion of Welds: Causes and Cures; What Professionals New to Welding Need to Know About Its Metallurgy; Visual Inspection of Pressure Vessels and Pressure Piping

Weber has parlayed more than 28 years of experience as a materials engineer in the DuPont Company into Weber and Associates, a Hendersonville, Tennessee, based consulting practice, offering services related to corrosion, metallurgy, NDE and expert witness testimony. For 15 years, he has been an AWS CWI Instructor, and he coauthored the curriculum for the Senior Certified Welding Inspector course. He has served on the AWS Board of Directors, is an AWS Distinguished Member, and has been a NACE Corrosion Specialist and a member of NACE, ASNT and ASM. He earned a bachelor's degree in metallurgical engineering from the University of Arizona.

Continuing Education

Tuesday, April 25

Arc Welding Power Sources: How to Extract Optimum Performance from Your Equipment Investment

8:30 a.m. - 4:30 p.m.

Veteran **Ed Bohnart** has poured 30 years of hands-on experience into a much needed — and demanded — program from AWS. This isn't an advanced course inflated with theory. It's a primer directed at engineering professionals with evolving responsibilities in welding or for the ambitious senior technician.

If extracting the most from power sources has been a constant problem, if you need to know the ins and outs of setup and smooth operation, or if this facet of welding is a new job responsibility, then don't miss this opportunity. The program will benefit professionals who specify arc welding equipment and processes, such as engineers, technicians, welders, supervisors and setup and maintenance personnel. Purchasers will particularly benefit.

Topics include the following:

- Equipment operating precautions
- Equipment and process fundamentals: GTAW, SMAW, GMAW, FCAW and CAC
- Voltage, amperage and metering
- Power sources
- Controls
- Problems and troubleshooting
- Common misunderstandings

By attending, you can learn

- How to get more performance from your existing equipment.
- Why your electric power bill is the most commonly overlooked expense.
- How to use product specifications to select the power source with the right features.
- The most common arc welding power source problems and innovative solutions.

This is excellent prep before seeing The Expo, especially if you're looking to purchase arc welding power sources and miscellaneous equipment.

AWS Members, $295 - use registration code 84; others, $370 - use registration code 85. Registration includes refreshments, lunch, handouts and three AWS publications: *The Professional's Advisor on Arc Welding Power Sources, Recommended Practices for Gas Tungsten Arc Welding, and Recommended Practices for Gas Metal Arc Welding.* Nonmember fee includes one-year membership in AWS.

Progress in Standardization of AC and DC Resistance Welding Current Measurements and Instrumentation

One intensive day on new measurement capabilities for those companies working toward ISO 9000 and QS9000 compliance.

8:30 a.m. - 4:30 p.m.

Significant progress has been made in the standardization of resistance welding current measurements during the past few years. The ability to make accurate measurements that are uniform, cost effective and NIST traceable have also been made more readily achievable due to the efforts of AWS committees, government laboratories, equipment manufacturers, users and private companies.

The highly experienced seminar leaders, Denis E. Destefan and John D. Ramboz, will explore requirements for traceability and proper calibration of current meters in the context of meeting ISO and QS9000 requirements. The basis and equipment used for traceable measurements will be discussed for pulsed currents to 60 kA. State-of-the-art resistance welding current measurements will be reviewed.

A guest attorney will present the legal implications of calibrations from the standpoint of contractual, product liability and safety requirements. High-quality current sensing coils have dramatically improved the ability to accurately measure and/or control currents. Guest speakers will discuss how the calibration process has improved their efficiency and product quality. Additional information will be provided relating to the cost benefits and improved weld quality by calibrating meters and accurately measuring welding currents. The chairman of the newly formed AWS A10C Committee on Resistance Welding Current Measurements and Calibration will present an overview of the requirements set forth in this new draft standard. Progress in the development of mid-frequency DC current measurement standards will be discussed. Handouts of technical papers and other pertinent information will be made available to attendees.

AWS Members, $295 - use registration code 96; others, $370 - use registration code 97. Registration fee includes refreshments, lunch and handouts. Fee also includes admission to the 2000 AWS Expo. Nonmember fee includes a one-year membership in AWS.

Introduction to Thermal Spray: Processes, Coatings and Applications

Sponsored by AWS and the Thermal Spray Society

12:00 noon - 5:00 p.m.

Do you have new responsibilities that include improving material longevity? Then take part in this unusual opportunity to get a thorough review of this incredible process from a veteran instructor and recognized researcher. **Doug Harris** will start at — where else? — the beginning, with plasma spray, high velocity oxyfuel spray, detonation gun deposition and advanced wire arc processes.

Metallic, cermet and ceramic coating structures and properties will be reviewed, followed by facets in determining application suitability, including wear, corrosion, thermal barrier, electromagnetism and other important variables. This is excellent prep before seeing The Expo, especially if you're looking to purchase thermal spray equipment.

$75. AWS Members use registration code 66; others, please use code 67. Registration fee includes refreshments and handouts. Fee also includes admission to the 2000 AWS Expo.

How to Ensure the Weldability of Stainless Steels: Part 1 — The Basics

8:30 a.m. - 4:30 p.m.

Part 2 is on Wednesday, April 26

Although these courses are designed to stand alone, we recommend attending both Parts 1 and 2 of this comprehensive look at the weldability of stainless steel — particularly the 300 series. The instructor, **Richard Campbell**, begins with the differences between the 200, 300 and 400 series; how welding affects the metallurgy, mechanical properties and corrosion behavior; and special considerations.

Get the answers to questions like this.

- Why do some stainless steels require preheat and others prohibit it?
- What do I need to know in order to select the right filler metal?
- What are the advantages (or limitations) of gas shielded versus flux shielded?
- When should I select a particular stainless steel over another?

Part 1: AWS Members $295, — use registration code 46; others, $370 — use registration code 47. Part 1 registration fee includes refreshments and lunch, handouts and *The Professional's Advisor on Welding Stainless Steels.* Parts 1 and 2: AWS Members, $450 — use registration code 50; others, $525 — use code 51. Parts 1 and 2 registration also includes the AWS *Structural Welding Code — Stainless Steel* (D1.6-98) and a year's membership in AWS. Important: This course may be used as a refresher course by current CWIs who will accrue 7 direct hours toward their 9-year recertification requirements. CWIs attending both Part 1 (and Part 2 on Wednesday, April 26), will accrue 14 direct hours toward their 9-year recertification.

Visual Inspection of Pressure Vessels and Pressure Piping
8:30 a.m. - 4:30 p.m.

Expert **Ted V. Weber's** one-day course is designed to provide the practical aspects of visual inspection of welds during fabrication, periodic life-cycle inspections, and field weld repairs. Weber will cover the material from a quality assurance perspective, offering inspection tips that will save time and money. The course is geared for professionals responsible for new fabrication welding and in-service inspection of pressure vessels and piping, including inspectors, technicians, engineers and management who want cost-effective inspection tips for both new fabrication and in-service inspection functions.

Topics covered:

- Welding inspection management
- New fabrication
- Periodic life-cycle inspections
- Field weld repairs

AWS Members $295 — use registration code 44; others, $370 — use registration code 45. Registration fee includes refreshments, lunch, handouts and three AWS publications: 1. *The Practical Reference Guide to Visual Inspection of Pressure Vessels and Pressure Piping*, 2. *Guide for Visual Inspection of Welds* and 3. *The Everyday Pocket Handbook for Visual Inspection and Weld Discontinuity*

Note: The course consists of lecture and slide presentations only. There will be no weld replicas available for review.

Course may be used as a refresher course by current CWIs who will accrue seven (7) direct hours toward their 9-year recertification requirement.

Welding Quality Assurance Management

This fast-paced two day program will probe the basic elements controlling and, ultimately, affecting weld quality by exploring the fundamentals of a welding quality assurance program. This is an opportunity to review your existing practices or start out on the right track if you are considering creating a more robust welding QA/QC program in your organization.

Welding is considered a special process in quality management systems because quality cannot be determined solely by inspection at the end of the production process. It is the success of creating appropriate procedures and process control in the planning stages that truly ensures quality.

This two-day event will move intelligently through six selected topics and inspire your thought process as a welding QA manager, production supervisor, or construction manager. You will leave this seminar ready to implement practical strategies together with your staff on your shop floor or construction site. Expect to return home with a greater confidence in your knowledge of quality assurance, of what's on the horizon in standards, and suggestions for improving production and your control of welding quality.

Note 1: If you are considering registration to ISO 9000 or are currently maintaining registration, there is good news on the tax front. In January, the IRS ruled that the costs of maintaining, obtaining and renewing registration may be deductible.

Note 2: Attending this seminar qualifies for 12 direct contact hours for CWI 9-year recertification by continuing education.

AWS Members, $510 — use registration code 122; others, $585 — please use code 123. Registration fee includes refreshments, lunch, handouts and *AWS' Welding Quality Assurace Guideline for Fabricators* and AWS' *Design Planning Manual for Cost Effective Welding*. Fee also includes admission to the 2000 AWS Expo. The nonmember's fee includes a year's membership in AWS. See detailed description of Part I and Part II.

Welding Quality Assurance Management – Part 1, (Session 1, 2 & 3)
8:30 a.m. - 4:30 p.m
Part 2 is on Wednesday, April 26

1. Integrating Welding Quality Assurance into Your Quality System

...and, an introduction to the international welding quality assurance standard ISO 3834

Your presenter Anna Petroski begins this session with a brief review of the basics of a quality assurance system: contract review, appropriate design review, material control, personnel and procedure qualification, process control and inspection, as they relate to welding. The next important step is how to integrate these systems into your existing program.

Successful implementation of a welding quality assurance system may result in these benefits:

Increased continuity and customer satisfaction

- all subcontractors are predictably qualified; initial screening is complete
- contract review is simplified
- better or more appropriate work quality... customers get what they pay for

Use your program as a marketing tool

- demonstrate leadership in your market
- as a quality assurance tool so customers audit you less often

Your exposure to legal/financial risk is reduced

- you've got clout from using internationally recognized programs should your quality execution ever be questioned
- and, potentially, you've got proof against negligence

You will be introduced to the international standard ISO 3834 Quality Requirements for Welding, and if you are considering compliance to ISO 9000, don't miss this opportunity to get it right the first time. Even if you're already ISO 9000-certified, you may want to consider compliance or registration to this ISO system. It's sister European standard, EN 729, is already required in several European equipment directives.

2. How to Specify Welding Quality

Use the right WPS! Simply referencing a code or standard is often imprecise and vague. It is often necessary to call out optional, or exercise supplementary, requirements to ensure that welding in a specific application will be properly qualified and otherwise adequate for the intended design. Codes and standards often represent minimal required conditions and may not always be sufficient.

Use the right PQR! Unfortunately, what a "certified" welder means differs from organization to organization. How can you be sure you're using the correct qualification standard? Ken Coryell explains the pitfalls of claiming "certified" welders without bothering with the qualification process. Believe it or not, this is the approach that many companies practice. Caveat emptor!

Use the right documentation! WPSs, PQRs and performance qualification for an intended application frequently are incorrect, incomplete and, in some instances, nonexistent – despite contractor assurances to the contrary. Find out what a welding engineer looks for in the specifying organization's documentation that will help secure clear communication with the contracting organization.

3. How to Prepare Bid Specifications or Answer Requests for Proposals — While Saving Money

Your presenter, **Don Lynn,** thinks controlling cost is not a goal — it's a process. Moreover, whether you're bidding on a contract using someone else's design, or working to an in-house design, cost control begins at this phase of the process.

Ask yourself if you're working from engineering drawings that are welding-complete. Do the specifications say enough? Have you determined the cost of your bids

- Design?
- Weld size determination?
- Weld joint application?
- Manufacturing feasibility?

Continuing Education

Wednesday, April 26

Welding Quality Assurance Management – Part 2 (Sessions 4, 5 & 6)
8:30 am — 4:30 pm

4. Taking a Second Look at Process Improvement and Control for More Productivity

Consider these two situations:

1) The bulk of manufactured products use fillet welds, the design for which is taken for granted and with an execution that's practically never monitored!

2) Over the past four years, through a systematic audit process of more than 1000 welders and 60 manufacturing operations, we now know that semiautomatic welding process control has been seriously overlooked (if considered at all) with significant poor quality results and low productivity.

Process control and improvement are important elements of the ISO philosophy. Come and learn how to apply this concept to practical welding from Canadian V. Vaidya. You can simultaneously increase both productivity and quality through specific monitoring and training. An outgrowth is that this approach will re-engineer the manufacturing operation one step closer to ISO certification.

5. The NDE "Written Practice": Key Elements and Abuses

This management of nondestructive testing (NDT) systems segment is cosponsored by NDT Management Association (NDTMA)

The "Written Practice" is a procedure for the qualification and certification of NDE personnel. There are all too common misunderstandings and abuses in its preparation and application. Chuck Hellier will take you step by step into preparing an effective Written Practice. Mr. Hellier will describe the pitfalls, which will be especially helpful for those responsible for specifying NDE services. There can't be a better way to illustrate "how things can go wrong" than through the liberal use of case histories, and after 36 years in the business, Chuck Hellier has an accumulation of what-not-to-do stories.

6. How to Properly Audit an NDE System

This management of nondestructive testing systems segment is cosponsored by NDTMA.

Maintaining the quality of a NDE system requires periodic audits to identify and correct nonconformance. According to presenter David Rypien, this isn't always "bad news" since the purpose of an audit is to also determine the effectiveness of the NDE system. This presentation explains the tools for conducting an audit, and how to get the best use from the results. Knowing how an auditor will look at your present system can be the best insight into improving its effectiveness.

Corrosion of Welds: Causes and Cures
8:30 a.m. - 4:30 p.m.

During this fast-paced, one-day course, **Ted Weber** will cover what causes corrosion of metals and how to repair corroded welds. Weber uses highly relevant case histories to review the effects of alloying and heat treatment for corrosion resistance, with plenty of opportunity to ask questions and discuss the in-depth answers. The program is valuable for all professionals whose job entails repairing, identifying and fabricating pressure vessels and piping. Equipment inspectors, technicians, engineers and management can benefit from this program.

Topics covered:

- What causes the common forms of corrosion
- How to repair corroded welds
- How to avoid corrosion and minimize corrosion's effects on plant operations through alloying or heat treatment
- Case histories providing specific references to the causes and cures of welding corrosion

AWS Members, $295 — use registration code 54; others, $370 — use registration code 55. Registration fee includes refreshments, lunch, handouts and *The Practical Reference Guide to Weld Corrosion: Causes and Cures*. Fee also includes admission to the 2000 AWS Expo. Nonmember fee includes a year's membership in AWS.

Design and Planning for Cost Effective Welding
8:30 a.m. - 4:30 p.m.

Wednesday and Thursday, April 27

This course, presented by **Gene Hornberger**, covers all the aspects of accepting the job, making progress on the job, solving problems and completing the welding projects on time. It will provide the background needed by engineers, supervisors and senior technicians who carry welding management responsibilities.

Get a mumbo-jumbo-free explanation of the how and why of common pitfalls that make some welding projects difficult — or even seem impossible — to run smoothly. Find out how to avoid these negative conditions in the first place, or at very least, how to take the right corrective actions.

You should attend if you have questions like these about your fabricating project and its weldability:

- Does the fabrication perform the intended service, and will it last as long as intended?
- Is the welded fabrication on time and within budget?
- Are there any inspections or requirements associated with the weld that will prevent acceptance?
- Is there adequate weld joint access?
- Are the fabrication requirements achievable from the standpoint of accessibility, position, distortion control, weld size, inspection requirements and fabrication sequence?

Topics covered:

- Production welding cost analysis
- Welding process selection
- Fatigue consideration
- Weld joint design factors
- Defects and discontinuities
- Practical aspects of welding metallurgy
- Thermal spray fundamentals
- Welding safety
- Fitting and flame bending

AWS Members, $450 — use registration code 68; others, $525 — use registration code 69. Registration fee includes refreshments, lunch and the new AWS publication *Design and Planning Manual for Cost-Effective Welding*. Fee also includes admission to the 2000 AWS Expo. Nonmember fee includes a year's membership in AWS.

How to Ensure the Weldability of Stainless Steels: Part 2 – Avoiding Defects

8:30 a.m. - 4:30 p.m.

Part 1 is on Tuesday, April 25

Seminar leader **Richard Campbell** continues his program on the weldability of stainless steels in this stand-alone session.

If you're trying to weld stainless steels you probably need answers to these questions:

- Why you shouldn't be using certain processes, *e.g.*, oxyfuel welding or cutting
- When gas shielding can actually cause weld defects
- How to avoid cold cracking
- Why weld penetration varies — even when the same arc welding variables are used
- How to weld dissimilar metals with stainless steel filler metals

Get the information you need to do the job right.

Part 2: AWS Members, $295 — use registration code 48; others, $370 — use code 49 . Registration fee includes refreshments and lunch, handouts and *The Professional's Advisor on Welding Stainless Steels* — a new publication from AWS. Fee also includes admission to the 2000 AWS Expo. Nonmember fee includes a year's membership in AWS. **Part 1 and 2**: AWS Members, $450 — use code 50; others, $525 — use code 51.

Automated/Robotic Welding

Sponsored by AWS and the Society of Manufacturing Engineers

8:30 a.m. – 4:30 p.m.

Back by popular demand from last year's AWS Expo in St. Louis, this multi-speaker session brings together experts in automated welding technology, robotic manufacturing, fuzzy logic, welding processes, tooling, automated weld inspection and more. If you have new or expanding responsibilities in welding automation and robotics, this all-day program will introduce you to the exciting world of 21st century fabrication and manufacturing.

Topics include the following:

- Robot selection criteria
- Optimization control
- Neural networks for manufacturing process modeling
- Joint tracking
- Installation dos and don'ts
- Minimizing weld distortion
- Evaluating equipment, performance, installation and training
- Open architecture robot controls

$350. AWS Members use registration code 78; SME Members and others use code 79. Registration fee includes refreshments, lunch and handouts. Fee also includes admission to the 2000 AWS Expo.

Business Strategies for Welding

Sponsored by AWS and the Fabricators and Manufacturers Association, International

8:30 a.m. - 5:00 p.m.

This new course is specifically designed for professionals who are not proficient in welding but do have job responsibilities closely aligned to the welding process. This course will expand your knowledge of welding by providing information to enhance the efficiency of your welding operation, assist in the selection and retention of employees and provide your welders with the tools necessary to achieve extraordinary results.

The instructor, **Dr. Jesse Grantham**, will share valuable business strategies that can increase quality and productivity, improve safety and exceed your financial goals. Plus, you'll leave the workshop with a solidly researched workbook and step-by-step guidelines for implementing what you've learned.

AWS/FMA Members, $345 — use registration code 118; others, — $395 use registration code 119. Registration fee includes refreshments, lunch and workbook. Fee also includes admission to the 2000 AWS Expo.

Understanding the Techniques of Resistance Welding – Part 1

Sponsored by AWS and the Society of Manufacturing Engineers

8:30 a.m. – 4:30 p.m.

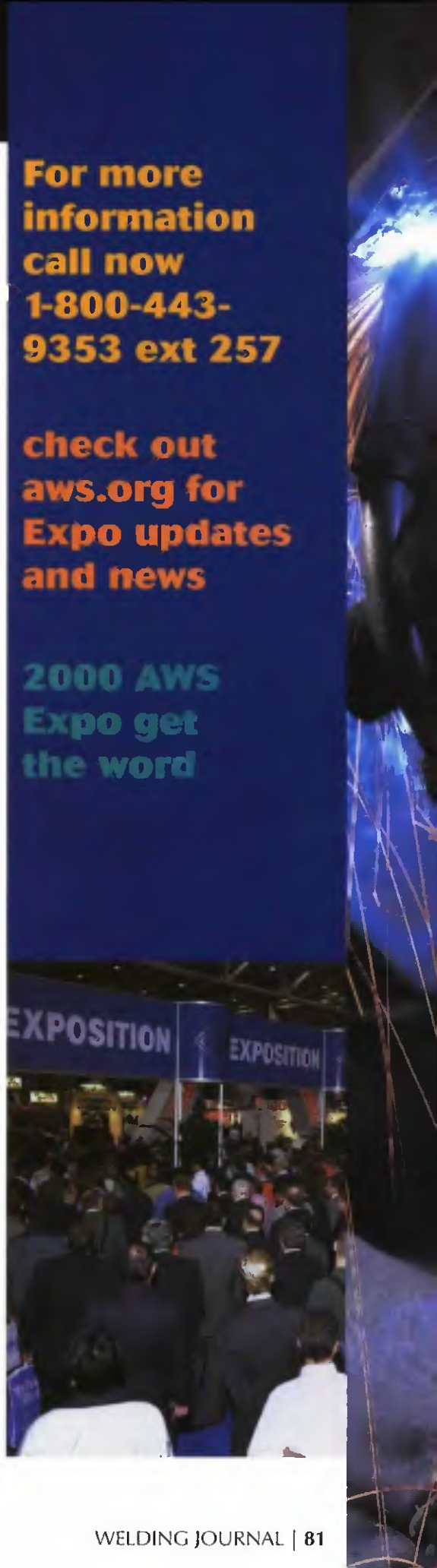
Part 2 is on Thursday, April 27

If you're a welding operator, electrician, repair expert, engineer or other professional with RW responsibilities, and you need to know the principles and equipment required to join components, fabrications and modules using RW, don't wait — sign up for this 2-day course now.

Your instructor will be **Lawrence Alexander**, whose career has spanned from literally designing resistance welding equipment to field consultant to researcher. He'll show you how to extract the most from RW with both quality and profitability in mind. Monday's Part 1 topics include the following:

- Control of variables
- Operational principles
- Nugget growth: causes of, and reducing, expulsion; development for coat material
- Control of heat development in tips, tooling and machine parts
- Tooling design

$510. AWS Members use registration code 62; SME Members and others, please use code 63. Registration fee includes refreshments, lunch each day and handouts. Fee also includes admission to the 2000 AWS Expo.



Continuing Education

Thursday, April 27

Road Map to the D1.1 Code
8:00 a.m. - 5:00 p.m.

Reprising their standing-room-only seminar from last year's AWS Convention in St. Louis, D1 Committee members **Ed Beck, Duane Miller** and **Robert Shaw** are prepared to help designers, fabricators, inspectors and engineers navigate their way through one of the most called out codes in the world — D1.1 *Structural Welding Code — Steel.*

Unlike most "maps," this seminar is going to do more than show you where to find categories of welding requirements — it's also going to explore

- What those requirements are, including prequalified joint details and inspection
- How to use D1 when designing welded connections; how to incorporate prequalified welding procedures and qualify welders
- And why the Code requires what it does.

Bring your own copy of D1.1:2000: AWS Members, $195 — use registration code 74 ; others, $270 — use code 75 . To also **get a copy of D1.1:2000 distributed in seminar**: AWS Members, $350 — use code 72; others, $420 — use code 73 . Registration fee includes refreshments and lunch. Fee also includes admission to the 2000 AWS Expo. Nonmember fees include a year's membership in AWS. **Note**: this seminar is not effective without a copy of D1.1:2000 *Structural Welding Code — Steel.*

Course may be used as a refresher course by current CWIs who will accrue seven (7) direct hours toward their 9-year recertification requirement.

What Professionals New to Welding Need to Know about Its Metallurgy
8:30 a.m. - 4:30 p.m.

You'll avoid a lot of welding problems if you have a basic understanding of welding metallurgy. So whether you're an engineer without formal welding training or an ambitious senior welder or technician, this is need-to-know information. The instructor is veteran **Ted Weber.**

Topics covered:

- Basic metallurgical aspects of welding with an emphasis on alloying effects
- Heat treatment considerations
- Welding parameters
- How to avoid welding problems and what to do when they occur
- Welding parameters
- The difference between carbon and low-alloy steels, stainless steels and several high alloys

AWS Members, $295 — use registration code 58; others, $370 — use registration code 59. Registration fee includes refreshments, lunch, handouts and *The Practical Reference Guide to Welding Metallurgy: Key Concepts of Weldability.* Fee also includes admission to the 2000 AWS Expo. Nonmembers receive a year's membership in AWS.

Bonus: attendees have an option to purchase George Linnert's *Welding Metallurgy,* AWS 4th Edition, "Fundamentals," at 50% off the regular price of $108.00. Your registration badge clears you at the AWS Bookstore for this Expo special.

The Why and How of Welding Procedure Specifications: The Right Way to Document Your Welding Controls to Save Time, Money and, Maybe, Your Credibility
8:30 a.m. - 4:30 p.m.

If you're responsible for planning a welding operation here's a question. Which of the following items is the most critical: base metal weld process, filler metal, current and range, voltage and travel speed, joint design tolerances, joint and surface preparation, tack welding, weld position, preheat and interpass temperature, or shielding gas? This course provides the answers.

The instructor, **Ken Coryell,** uses his 25 years of international and domestic experience in welding quality to shed light on the most common problems, misunderstandings and mistakes. Coryell offers insider advice, hints and tips on optimum use of the Procedure Qualification Record (PQR) and the Welding Procedure Specification (WPS).

This program will benefit owners, managers, engineers and supervisors who must qualify, write or revise their own welding procedure specifications to satisfy codes and contract documents.

Topics covered:

- Proper preparation and qualification of welding procedure specifications
- Selecting and documenting welding variables
- Documenting of standard procedure qualification testing for commonly used processes for joining ferrous plate and pipe materials

By attending you can learn:

- How to specify essential and nonessential variables commonly used in sample AWS, ASME and API code formats
- How to use standards when preparing procedures
- How to document welding variables and qualification tests
- How to avoid the pitfalls in revising previously qualified procedures
- When and how to use procedure qualification records (PQRs), and welding procedure specifications (WPSs)
- How to specifically apply a standard to manual and semiautomatic welding processes, including SMAW, GMAW, FCAW and GTAW

AWS Members $295 - use registration code 86; others, $370 - use registration code 87. Registration fee includes handouts and the B2.1-98 *Specification for Welding Procedure and Performance Qualification.* Course may be used as a refresher course for current CWIs. Current CWIs will accrue 7 direct hours toward their 9-year recertification requirement.

Welding for Tool and Die Manufacturing – Part I
Sponsored by AWS and Society of Manufacturing Engineers
8:30 a.m. - 4:30 p.m.
Part 2 is on Friday, April 28

If your goal is to learn how to build and repair tools, dies, molds and patterns, this is a can't-be-missed opportunity. A bonus for attendees is a troubleshooting/Q&A session with instructor **Larry Smith.**

Thursday's Part 1 will cover

- Four phases of tool and die welding
- Seven groups of tool steels and their elements
- Basic welding metallurgy: physical and mechanical properties
- Preheat and postheat procedures for tool steels
- Welding processes commonly used for tool and die
- Procedures for welding trim, flange and draw steels

$510. AWS Members use registration code 60; SME Members and others, please use code 61. Registration fee includes refreshments, lunch each day and handouts. Fee also includes admission to the 2000 AWS Expo.

Friday, April 28

Welding for Tool and Die Manufacturing – Part 2

Sponsored by AWS and the Society of Manufacturing Engineers

8:30 a.m. - 4:30 p.m.

Part 1 is on Thursday, April 27

Remember, if your goal is to learn how to build and repair tools, dies, molds and patterns, then don't miss this opportunity. A bonus for attendees is a troubleshooting/Q&A session with instructor **Larry Smith**.

Part 2 will cover

- Recommended filler metals for tool steels
- Distortion control
- Metals identification
- Weld quality inspection
- Welding safety
- Steps in problem solving
- Record keeping

$510. AWS Members use registration code 60; SME Members and others, please use code 61. Registration fee includes refreshments, lunch each day and handouts. Fee also includes admission to the 2000 AWS Expo.

Laser Welding Clinic

Sponsored by AWS and the Society of Manufacturing Engineers

8:30 a.m. - 4:30 p.m.

The Clinic is designed to introduce and reinforce the principles of laser welding as a production tool. You'll gain valuable insight into the selection of the laser welding process, the principles of laser processing and production.

Topics covered:

- Laser welding vs. conventional welding
- Implementing robotic laser welding
- Laser welding systems for tailored blanks
- Automotive welding applications using multi-kW ND:YAG lasers
- Laser welding as a sheet metal fabrication tool
- Laser cladding: system requirements, applications and advantages

$350. AWS Members use registration code 94; SME Members and others use registration code 95. Registration includes refreshments, lunch and handouts. Fee also includes admission to the 2000 AWS Expo.

Friction Welding Clinic

Sponsored by AWS and the Society of Manufacturing Engineers

8:30 a.m. - 4:30 p.m.

During this Clinic a panel of experts will discuss how friction welding can benefit your company. The presentation will include an introduction and overview of how friction welding works and how it improves manufacturing by producing faster, better quality welds at a lower cost. You'll also learn how to implement friction welding in your operation.

Topics covered:

- Introduction and overview of friction welding
- Friction welding of aluminum alloys and dissimilar metals
- Friction welding in the automotive industry
- New developments in friction welding

$350. AWS Members use registration code 52; SME Members and others use registration code 53. Registration includes refreshments, lunch and handouts. Fee also includes admission to the 2000 AWS Expo.

Visual Inspection Workshop

8:00 a.m. - 5:00 p.m.

Workshop Features

8 hours of expert instruction from **Ken Jobes** on

- Proper use of measuring instruments: machinist's scale, fillet weld gauges, dial caliper, micrometer, undercut gauge, magnifying glass, VWAC undercut gauge, weld reinforcement.
- Measurement and evaluation of discontinuities: porosity, undercut, overlap weld reinforcement.
- Measurement of fillet weld size.
- Measurement and evaluation of mechanical tests: guided bend test and tensile tests.
- Application of visual inspection criteria.
- Take-home material you can refer to time and again.

Who Benefits?

Quality control and quality assurance managers, engineers, inspectors, welding and shop supervisors. Those responsible for increasing productivity, cutting costs, or improving quality and reliability. Recommended for all CWI and CWE examination candidates.

By attending, you can learn

- How to use weld-measuring instruments
- Compliance to a specific code
- Dos and don'ts of documentation
- When a discontinuity is not OK
- Wheo a flaw is OK
- Why visual inspection can he the most effective NDE technique

AWS Members, $310 — use registration code 120; others, $395 — use registration code 121. Registration fee includes handouts and admission to the 2000 AWS Expo. If you are a nonmember who is not pursuing AWS certification through application and exam, the registration fee includes a year's membership in AWS.

Important: By registering for the Visual Inspection Workshop you have not automatically been cleared to take the CWI/CWE examination. Application and examination requirements and fees are independent. Call (800) 443-9353, ext. 273.

Professional Program

Tuesday, April 25

Afternoon Session: 2:00 p.m.
Session 1: Friction Stir Welding

Chair: M. Q. Richey, Lockheed Martin Energy Systems
Co-Chair: D. Nicholas, The Welding Institute

A	2:00	Residual Stresses in Friction Stir Welds of Al Alloy 6061, by Z. Feng and T. Lienert, Edison Welding Institute; and X. L. Wang, Oak Ridge National Laboratory; and J. McClure, University of Texas at El Paso.
B	2:35	Thermal and Material Flow Modeling of Friction Stirring Welding, by Z. Cao, P. Dong, J. K. Hong, and F. Lu, Battelle Memorial Institute.
C	3:10	Friction Stir Welding of Ti-6Al-4V Alloys, by T. J. Lienert, Edison Welding Institute; and W. L. Stellwag, Jr., Ferris State University.
D	3:45	Friction Stir Welding of Aluminum Metal-Matrix Composites, by T. J. Lienert, Edison Welding Institute; and W. J. Stellwag, Jr., Ferris State University.
E	4:20	A Rotating Plug Model for Friction Stir Welding, by A. C. Nunes, Jr., Marshall Space Flight Center; E. L. Bernstein, Alabama A & M University; and J. C. McClure, University of Texas at El Paso.
F	4:55	Microstructure in Friction Stir Weld of 6063 Aluminum, by Y. S. Sato, H. Kokawa, M. Enomoto, S. Jogan, and T. Hashimoto, Tohoku University, Japan.

Afternoon Session: 2:00 p.m.
Session 2 : GMA/GTA Welding

Chair: J. E. King, Oak Ridge National Laboratory
Co-Chair: R. W. Richardson, The Ohio State University

A	2:00	Development of Hollow Electrode GTAW System for Space Applications, by K. Masubuchi, Massachusetts Institute of Technology; Y. Suita, Takamatsu National College of Technology; and T. Ohji, Osaka University.
B	2:35	Variable Polarity GTAW Fusion Behavior in 5083 Aluminum, by B. M. Patchett, The University of Alberta.
C	3:10	Theoretical Modeling of Pulsed Gas Metal Arc Welding Waveform Variable Selection, by C. R. Reynolds, The Ohio State University.
D	3:45	Mechanisms and Models of Bead Formation in Gas Metal Arc Welding, by O. Yapp and C. L. Ribardo, Edison Welding Institute; and S. P. Moran, Miller Electric.
E	4:20	Development of GTAW Flux for Welding Heat Resisting Alloys, by R. G. Miller, Babcock & Wilcox of Ohio.

Afternoon Session: 2:00 p.m.
Session 3: Steel Metallurgy

Chair: O. Olson, Colorado School of Mines
Co-Chair: Y. Adonyi, LeTourneau University

A	2:00	Effect of Ferro-Alloy Additions and Depth on the Quality of Underwater Wet Welds, by M. D. Rowe and S. Liu, Colorado School of Mines; and T. J. Reynolds, Global Divers and Contractors.
B	2:35	Effect of Inclusion Size on the Nucleation of Acicular Ferrite, by H. J. Kim, T. K. Lee, and B. Y. Kang, KITECH, Korea; and S. K. Hwang, Inha University, Korea.
C	3:10	Effect of Ferrite Grain Refinement on the HAZ Tensile Properties of Ferrite-Pearlite Steel, by K. S. Bang and H. K. Jung, Pukyong National University, Korea.
D	3:45	Electronic and Magnetic Methods to Assess Weld Microstructure and Phase Stability, by O. L. Olson, V. I. Kaydanov, and D. W. Wenman, Colorado School of Mines.
E	4:20	Temperature-Time-Transfer (TTT) Diagrams for the Dissolution of Nonmetallic Inclusions during Steel Welding, by T. Bong and T. DebRoy, The Pennsylvania State University.

Afternoon Session: 2:00 p.m.
Session 4 : Resistance Welding I

Chair: P. Dong, Battelle Memorial Institute
Co-Chair: B. Bastian, Benmar Associates

A	2:00	An Empirical Model of the Effects of Pressure and Temperature on the Electrical Contact Resistance of Metals, by S. S. Babu, M. L. Santella, and B. W. Riemer, Oak Ridge National Laboratory; and Z. Feng, Edison Welding Institute.
B	2:35	Magnetic Stirring of Nugget during Resistance Spot Welding (RSW), by V. Nemchinsky, ESAB Welding & Cutting Products.
C	3:10	Nugget Formation and Dynamic Resistance in Resistance Spot Welding of Aluminum to Steel, by H. S. Chang, Myong Ji University, South Korea; and C. L. Tsai, The Ohio State University.
D	3:45	Nugget Growth and Contact Resistance in Resistance Spot Welding (RSW) Sheet Steels, by T. Liang, ANSYS, Inc; and C. L. Tsai, The Ohio State University.
E	4:20	Modeling of Resistance Spot Welds: From Process to Performance, by X. Sun and P. Dong, Battelle Memorial Institute.

Wednesday, April 26

Morning Session: 9:00 a.m.
Session 5 : Aluminum Metallurgy

Chair: C. E. Cross, Montana Tech, University of Montana
Co-Chair: G. R. Edwards, Colorado School of Mines

A	9:00	The Effect of High Temperature Eutectic Forming Impurities on Aluminum 7108 Weldablity, by C. E. Cross, Montana Tech University of Montana; M. G. Mousavi and Ø. Grong, Norwegian University of Science & Technology, Norway.
B	9:35	Fusion Boundary Microstructure Evolution in Aluminum Alloys, by A. Kostrivas, J. C. Lippold, and M. J. Mills, The Ohio State University.
C	10:10	Evaluation of Hot Crack Behavior of Aluminum Alloys by the IRC Method, by R. Aune and O. M. Akselsen, SINTEF, Norway; and C. E. Cross, Montana Tech University of Montana.
D	10:45	Grain Boundary Liquation in Aluminum Welds, by S. Kou, C. C. Huang, University of Wisconsin at Madison.
E	11:20	Thermomechanical Characterization of Hot Cracking Conditions in Welding High-Strength Aluminum Alloys and Weldability Improvement Techniques, by P. Dong, Y. Yang, and J. Zhang, Battelle Memorial Institute.

Morning Session: 9:00 a.m.
Session 6: Process Modeling

Chair: P. Dong, Batelle Memorial Institute

A	9:00	Flow Visualization of Marangoni Convection in Simulated Weld Pools, by S. Kou and C. Limmaneevichitr, University of Wisconsin at Madison.

B	9:35	Advantages of Computer-Based Weld Modeling in a Manufacturing Environment, by F. W. Brust and J. Zhang, Battelle Memorial Institute; and Y. Dong, Caterpillar, Inc.
C	10:10	Prediction of Microstructure Evolution and Harness Distribution in Repair Welds, by M. V. Li, Z. Feng, and R. Bowers, Edison Welding Institute; and D. S. Kim, Westhollow Technology Center.
D	10:45	Plasticity Modeling for Predicting Welding-Induced Distortion, by C. L. Tsai, The Ohio State University.
E	11:20	Weld Simulation Technology Development on Automotive Thin Gauge Structure, by Y. P. Yang, Z. Cao, J. Zhang, and F. Brust, Battelle Memorial Institute; and A. Fisher, R. Broman, and R. Thakkar, Tower Automotive Technical Center.

Morning Session: 9:00 a.m.
Session 7: Resistance Welding 2

Chair: S. S. Babu, Oak Ridge National Laboratory

A	9:00	Process Robustness Characteristics for Resistance Spot Welding Interstitial Free Coated Sheet, by J. Gould and D. Workman, Edison Welding Institute.
B	9:35	Effect of P and S on Hook Cracking Susceptibility of Pipes Produced Via HF ERW Process and Eliminated in ERW Joint of Pipes, by C. M. Kim, Pohang Iron & Steel Co., Ltd., Korea; and Y. S. Kim, Hong-Ik University, Korea.
C	10:10	Primary Dynamic Resistance Monitoring in Timer during Resistance Spot Welding, by S. Rhee and Y. Cho, Hanyang University, Korea.
D	10:45	Application of Conductive Heat Resistance Seam Welding for a Range of Aluminum Applications, by J. E. Gould, D. Workman, and L. R. Lehman, Edison Welding Institute.
E	11:20	Investigation of Mash Seam Blank Welding High Strength Steels, by H. Shao and J. Gould, Edison Welding Institute; and C. Albright, The Ohio State University.

Morning Session: 9:00 a.m.
Session 8: Stainless Joining 1

Chair: S. A. David, Oak Ridge National Laboratory
Co-Chair: B. M. Patchett, University of Alberta

A	9:00	HAZ Secondary Austenite Formation in Duplex Stainless Steels during Multipass Welding, by A. J. Ramirez and J. C. Lippold, The Ohio State University; and S. D. Brandi, Universidade de São Paulo, Brazil.
B	9:35	Weld Metal Properties in GTA Welding of Supermartensitic 13% Cr Stainless Steel, by T. Håbrekke and O. M. Akselsen, SINTEF, Norway; and G. Rørvik and P. E. Kvaale, Statoil, Norway.
C	10:10	HAZ Cracking in Type 347 with Design Matrix of C, N and Nb, by L. Li and R. W. Messler, Jr., Rensselaer Polytechnic Institute.
D	10:45	Standardization of Varestraint Test Procedure, by T. L. Finton and J. C. Lippold, The Ohio State University; and R. J. Bowers, Edison Welding Institute.
E	11:20	Chromium Depletion and Grain Boundary Structure in Sensitized Alloy 600, by H. Kokawa, T. Masuda, Y. S. Sato, C. Fukuoka, and M. Akashi, Tohoku University, Japan.

Afternoon Session: 2:00 p.m.
Session 9: Stainless Joining 2

Chair: W. Lin, Pratt & Whitney
Co-Chair: R. W. Messler, Rensselaer Polytechnic Institute

A	2:00	A Martensite Boundary on the WRC-1992 Diagram — Part III: Effect of Mo, C, N, by D. J. Kotecki, The Lincoln Electric Co.
B	2:35	Direct Dissimilar Welding of Carbon Steel to Stainless Steel Using Narrow Groove SAW, by B. Green and D. Harwig, Edison Welding Institute; and R. Donaldson, Westinghouse, EMD.
C	3:10	Weldability of Heat Resistant Austenitic Stainless Steels, by J. Lee and M. Y. Lee, Research Institute of Industrial Science and Technology (RIST), Korea.
D	3:45	Design of Externally Applied Magnetic Fields for Eliminating the Hard Zone in Carbon Steel/Stainless Steel Dissimilar Joints, by K. H. Hou, H. T. Kuo, S. A. Szu, and F. R. Hsu, Chang Gung University, Taiwan.
E	4:20	Microstructural Characterization and Residual Stress Measurement of Dissimilar Metal Welds, by C. S. Kusko, J. N. DuPont and A. R. Marder, Lehigh University.

Afternoon Session: 2:00 p.m.
Session 10: Sensing and Control

Chair: R. Richardson, The Ohio State University
Co-Chair: Y. M. Zhang, University of Kentucky

A	2:00	Assessment of a Top Face Penetration Control System for GTA Welding, by R. Jones and G. Melton, The Welding Institute.
B	2:35	Analysis of Arc Light Mechanism for Sensing of GTAW Process, by P. J. Li and Z. M. Zhang, University of Kentucky.
C	3:10	Droplet Transfer Control in GMAW of Titanium Alloy, by P. J. Li and Z. M. Zhang, University of Kentucky.
D	3:45	Estimation of Weld Bead Size in CO_2 Laser Welding by Multiple Regression and Neural Network, by S. Rhee, H. Park and Y. W. Park, Hanyang University, Korea.
E	4:20	Arc Stability Estimation and Fuzzy Control for Good Arc Condition in Short Circuit Transfer Mode of CO_2 Arc Welding, by M. J. Kang, K. C. Kim and Y. K. Kweon, Research Institute of Industrial Science and Technology (RIST), Korea; and S. Rhee, Hanyang University, Korea.

Afternoon Session: 2:00 p.m.
Session 11: Advanced Materials

Chair: G. R. Edwards, Colorado School of Mines
Co-Chair: T. Lienert, Edison Welding Institute

A	2:00	Mechanical Behavior Evaluation of a Nickel Aluminide Weldment, by M. L. Santella, V. K. Sikka, R. W. Windeman and R. J. Barkman, Oak Ridge National Laboratory.
B	2:35	Reactive Synthesis of Iron Aluminide - Titanium Carbide Composites through Electron Beam Welding of Green Bodies, by V. R. Davé, Los Alamos National Laboratory; and T. W. Eagar, Massachusetts Institute of Technology.
C	3:10	Effects of the Laser Beam Parameters on the AZ91 D Weld Microstructure, by M. P. Marya and G. R. Edwards, Colorado School of Mines.
D	3:45	Investigation of Fe-Al Claddings in High-Temperature Sulfidizing Environments, by S. W. Banovic, J. R. Regina, J. N. DuPont and A. R. Marder, Lehigh University.
E	4:20	Grain Growth in the HAZ of GTA Welded Titanium Weldments, by Z. Yang, S. Sista, and T. DebRoy, The Pennsylvania State University; and J. W. Elmer, Lawrence Livermore National Laboratory.

Professional Program

Thursday, April 27

Morning Session: 9:00 a.m.
Session 12: Laser Welding

Chair: J. O. Milewski, Los Alamos National Laboratory
Co-Chair: T. Lienert, Edison Welding Institute

A	9:00	Weld Metal Composition Change during Laser Welding of 5182 Aluminum Alloy, by H. Zhao and T. DebRoy, The Pennsylvania State University.
B	9:35	Combined Weld-Pool-Shape and HAZ Thermal Model for Aluminum Alloy Laser Arc Welds, by J. M. Vitek, S. S. Babu and S. A. David, Oak Ridge National Laboratory.
C	10:10	Study on Laser Forming of Different Materials (Report 1), by M. Kutsuna, Nagoya University, Japan; and T. Nakamura, Nakamura Technical Institute, Japan; and K. Masubuchi, Massachusetts Institute of Technology.
D	10:45	Factors Affecting Defects and Profiles of Laser Lap Welds, by J. Xie, Edison Welding Institute; and X. Chen, Visteon Automotive Systems.
E	11:20	Guiding Electrical Discharges with a Low-Power Carbon-Monoxide Laser Beam, by J. Eastman, Edison Welding Institute; and C. E. Albright, W. R. Lempert and S. T. Merriman, The Ohio State University.

Morning Session: 9:00 a.m.
Session 13: Ni-Based Alloys

Chair: M. L. Santella, Oak Ridge National Laboratories
Co-Chair: J. C. Lippold, The Ohio State University

A	9:00	A Methodology for Quantifying Postweld Heat Treatment Cracking Susceptibility, by W. Lin, Pratt & Whitney.
B	9:35	Preferential Corrosion of Dendritic Microstructures in NiCrMo Type Welds, by K. Luer, J. N. DuPont, and A. R. Marder, Lehigh University.
C	10:10	Ductility-Dip Cracking Evaluation of Inconel 82 Filler Metal, by R. Bowers, Edison Welding Institute; and J. Kikel, BWX Technologies, Inc., NED.
D	10:45	Microstructure Development in Nickel Base Superalloys during Weld Thermal Cycle, by S. S. Babu and S. A. David, Oak Ridge National Laboratories.
E	11:20	Microstructural Characterization of Laser and GTA Welds in Ni Base Alloys, by B. D. Newbury and J. N. DuPont, Lehigh University; and C. V. Robino and G. A. Knorovsky, Sandia National Laboratories.

Morning Session: 9:00 a.m.
Session 14: Steel Weldability

Chair: Y. Adonyi, LeTourneau University
Co-Chair: T. Siewert, NIST

A	9:00	Significant Factors Influencing HAZ Hardness of 9% Nickel Steel, by A. H. Price, Texas A & M University.
B	9:35	Modeling of Nitrogen Dissolution during GTA Welding of Iron, by T. A. Palmer and T. DebRoy, The Pennsylvania State University.
C	10:10	Effects of Steelmaking and Plate Processing on Weldability, by Y. Adonyi, LeTourneau University.
D	10:45	Postweld Heat Treatment Response of the Course-Grained, Heat-Affected Zone in a Modified Cr-Mo Steel, by J. G. Nawrocki, J. N. DuPont and A. R. Marder, Lehigh University.
E	11:20	The Relationship between Retained Austenite and Hydrogen Cracking Susceptibility in Weld Joint with Different Restraint Stress Severity, by Y. Park, I. Maroef and D. L. Olson, Colorado School of Mines; and A. Landau, Ben-Gurion University of the Negev, Israel.

Afternoon Session 2:00 p.m.
Session 15: Weld Design

Chair: N. C. Cole, NCC Engineering, Inc.
Co-Chair: P. Dong, Battelle Memorial Institute

A	2:00	Strength of Three Dimensional Weld Groups, by O. Blodgett, Lincoln Electric Co.
B	2:35	Effect of Joint Misalignment on Buckling Behavior of Welded Plate Girders, by M. L. Liaw, CASE-DMI; and C. L. Tsai, The Ohio State University.
C	3:10	Thermal Tensioning for Control of Buckling Distortion, by R. Duli and J. Russell, Edison Welding Institute.
D	3:45	The Importance of Material Fabrication History on Weld Durability and Fracture Response of Structures, by E. W. Brust, Battelle Memorial Institute.
E	4:20	A New Structural Element Test for Evaluating HSLA-65 Steel Weldments, by J. B. Sickles, P. J. McMullen, P. J. Konkol and N. R. Martin, Concurrent Technologies Corporation.

Afternoon Session: 2:00 p.m.
Session 16: EB & Laser Beam Welding

Chair: T. M. Mustaleski, Lockheed Martin Energy Systems
Co-Chair: D. Farson, The Ohio State University

A	2:00	Evaluation of Platings in Small Scale Laser Welding of Thin Sheets, by E. J. Biro, Y. Zhou and D. C. Weckman, University of Waterloo, Canada; and K. J. Ely, Edison Welding Institute.
B	2:35	Spectral Analysis for Laser Weld Quality Monitoring, by A. Ali and D. Farson, The Ohio State University.
C	3:10	Design of Compact Nd:YAG Laser Focus Heads, by Y. Guo and D. Farson, The Ohio State University.
D	3:45	Optical, Acoustic and Plasma Charge Signals in Laser Welding, by O. Farson, The Ohio State University.
E	4:20	High Energy Electron Beam Brazing of Carbon-Carbon Composites, by V. R. Davé, Los Alamos National Laboratory; D. L. Goodman, Science Research Laboratory, Inc.; and T. W. Eagar, Massachusetts Institute of Technology.

Afternoon Session: 2:00 p.m.
Session 17: Special Processing

Chair: R. R. Kapoor, Saint-Gobain Ind. Ceramics

A	2:00	Efflux Plasma Charge Sensor for Keyhole Plasma Arc Welding, by S. B. Zhang and Y. M. Zhang, University of Kentucky.
B	2:35	Flexible Forming of Sheet Metal Using Plasma Arc, by A. T. Male, P. J. Li, Y. W. Chen, Y. M. Zhang, University of Kentucky.
C	3:10	Heat Generation Mechanisms in Induction Tube Welding and Implications on Process Parameter Selections, by Y. P. Yang and P. Dong, Battelle Memorial Institute.
D	3:45	Bonding Mechanisms in Ultrasonic Solid State Welds, by K. J. Ely, Edison Welding Institute.

Industrial Technology Sessions

Wednesday, April 26

Afternoon Session: 2:00 p.m.
Session IT1: Fabrication & Applications

Chair: D. E. Powers, PTR-Precision Technologies, Inc.
Co-Chair: John E. Hinrichs, The Welding Link

A	2:00	Bending Distortion of Steel Plate after Flame Cutting with FEA, by M. C. Song, S. C. Park and J. G. Youn, Hyundai Heavy Industries Co., Ltd., Republic of Korea.
B	2:35	Comparison of Laser and Electron Beam Weld Tensile Properties, by D. D. Kautz, R. L. Page, and P. A. Stevens, Los Alamos National Laboratory.
C	3:10	Laser Brazing of the Space Shuttle Main Engine Nozzle, by Y. P. Gao, R. E. Seaman, T. J. McQuidan, and R. P. Martiens, Rocketdyne Propulsion and Power, the Boeing Company.
D	3:45	Knowledge Based Ultrasonic Inspection of Welds, by T. Trapp, and H. Castner, Edison Welding Institute; L. Udpa, Iowa State University; and R. P. Kok, Kok and Associates, Inc.; and M. Novak, The Naval Surface Warfare Center.
E	4:20	Fume Reduction in Shipyard Cutting Operations, by I. O. Harris, Edison Welding Institute.

Thursday, April 27

Morning Session: 9:00 a.m.
Session IT2: GMAW/FCAW

Chair: I. D. Harris, Edison Welding Institute
Co-Chair: S. Ferree, ESAB Welding & Cutting Products

A	9:00	Insuring 200 Max. Brinell Weld Deposit Hardness when Using E71T-XX Flux Cored Electrodes for Sour Gas Service, by S. Luke, Oresser-Rand.
B	9:35	Effect of Welding Procedure on AWS A5.20-95 E71T1 Flux Cored Wire Deposits, by E. S. Surian and N. M. R. Rissone, DEYTEMA, Argentina; I. S. Bott, Catholic University of Rio de Janeiro, Brazil; and L. A. deVedia, Universidad Nacional de San Martín.
C	10:10	Tandem Wire GMAW Performance on Oxidized Steel Plate, by O. L. Ketron and S. Grown, Edison Welding Institute; and R. E. Longenecker, Consultant.
D	10:45	Effect of Shielding Gas and Consumable Selection on GMAW Galvanized Steels, by B. Green and M. Boring, Edison Welding Institute.
E	11:20	Effects of Silicon and Sulfur Content of Welding Wire on Spatter Generation in GMA Welding, by Y. H. An and J. B. Lee, POSCO Technical Research Laboratories, Korea; and D. S. Um, PUSAN National University, Korea.

Afternoon Session: 2:00 p.m.
Session IT3: Special Applications

Chair: D. D. Harwig, Edison Welding Institute
Co-Chair: V. A. McCray, Exxon Mobil Research & Engineering

A	2:00	Welding of Ferritic Stainless Converter to Cast Iron Manifold, by J. Kotnik, D. Pope, and M. Behling, Arvin Industries; and S. Kiser, Special Metals.
B	2:35	Improved Corrosion Resistant Coatings by HVDF Spraying, by D. Harvey, The Welding Institute, United Kingdom; and O. Lunder, Sintef Materials Technology, Norway.
C	3:10	Optimizing Weld Design of Pressure Vessels in Thermal Cycling Service, by J. A. Penso, W. O. Soboyejo, D. G. Howden and C. L. Tsai, The Ohio State University.
D	3:45	Heat Sink Welding for Preventing Hot Cracking in Alloy 2195 Intersection Welds: A Feasibility Study, by Y. P. Yang and P. Dong, Battelle Memorial Institute; and P. R. Roger, NASA, Marshall Space Flight Center.
E	4:20	Advances on Electron Beam Drilling, by U. Schwab, Messer igm Robotersysteme AG Steigerwald, Strahltechnik, Germany.

Sponsored Sessions

Wednesday April 26

Morning Session: 9:00 a.m.
Session SP1: Welding/Weldability of Difficult and/or Unusual Materials

Sponsored by the U.S. Department of Energy (DOE)
Interagency Manufacturing Operations Group (IMOG)

A	9:00	Weldment Creep in Tantalum Alloy T-111, by C. V. Robino, B. D. Hansche, J. J. Stephens, M. T. Valley, and J. R. Michael Sandia National Laboratories.
B	9:35	Plasma Arc and Gas Tungsten Arc Welding of Copper, by P. W. Fuerschbach, C. T. Morgan and G. R. Eisler, Sandia National Laboratories.
C	10:10	Weldability and Properties of Free Machining Stainless Steel, by J. Brooks, S. Goods, T. Headley, G. Knorovsky, C. Robino, and N. Yang, Sandia National Laboratories.
D	10:45	AEM Study of the Joint Interface between Stainless Steel and Niobium, M. J. Cola, D. F. Teter, R. M. Dickerson, Los Alamos National Laboratory.
E	11:20	Grain Boundary Character Distribution in Alloy 690 and Its Influence on Weldability, by M. J. Cola, V. R. Davé and G. N. A. Hussen, Los Alamos National Laboratory; and M. Kumar, Lawrence Livermore National Laboratory.

Afternoon Session: 2:00 p.m.
Session SP2: Modern Diagnostic Techniques

Sponsored by the U.S. Department Of Energy (DOE)
Interagency Manufacturing Operations Group (IMOG)

Chair: J. Milewski, Los Alamos National Laboratory
Co-Chair: C. V. Robino, Sandia National Laboratories

A	2:00	Advances and Limitations in High Resolution Gleeble® Dilatometry, by J. D. Puskar, C. V. Robino, M. Reece, and G. A. Knorovsky, Sandia National Laboratory.
B	2:35	Beam Characteristics of High Power Fiber Delivered Nd:YAG Lasers, by D. O. MacCallum and P. W. Fuerschbach, Sandia National Laboratories; and J. Milewski and M. Piltch, Los Alamos National Laboratories.
C	3:10	Calculated vs. Experimental Heat Inputs in Laser Spot Welding, by G. A. Knorovsky, Sandia National Laboratories.
D	3:45	Plasma Temperatures in Hyperbaric GTAW Arcs, by P. Burgardt, Los Alamos National Laboratory.
E	4:20	Further Validation of a Modified Faraday Cup for the Determination of the Power Distribution in High Power Electron Beams, by T. M. Mustaleski, Lockheed Martin Energy Systems; J. W. Elmer, and A. Teruya, Lawrence Livermore National Laboratories.

Afternoon Session: 2:00 p.m.
Session SP3: Global Benchmarking through Participation in the IIW

Sponsored by the American Council of the IIW

Chair: P. W. Ramsey, Ramsey & Associates
Co-Chair: R. E. Long , Welding Specialists, Inc.

A	2:00	An Overview of the IIW, by B. Braithwaite, The Welding Institute, United Kingdom.
B	2:35	An Overview of the American Council, by T. Siewert, NIST.
C	3:10	The Activities of a Typical Commission - Commission II, by D. Kotecki, Lincoln Electric Co.
D	3:45	IIW Personnel Qualification and Training Activities, by R. J. Teuscher, Airgas; and D. G. Howden, The Ohio State University.

Examinations

SCWI/CWI/CWE Examination

Saturday, April 29, 8:00 a.m. - 5:00 p.m.

This examination is offered to applicants interested in obtaining the Certified Welding Inspector (CWI), Certified Welding Educator (CWE) or Senior Certified Welding Inspector (SCWI) certification.

Certified Welding Inspectors help ensure the quality of welding work and industrial products. Meeting the Society's rigorous CWI criteria has become the standard for recognizing the achievement in the welding business.

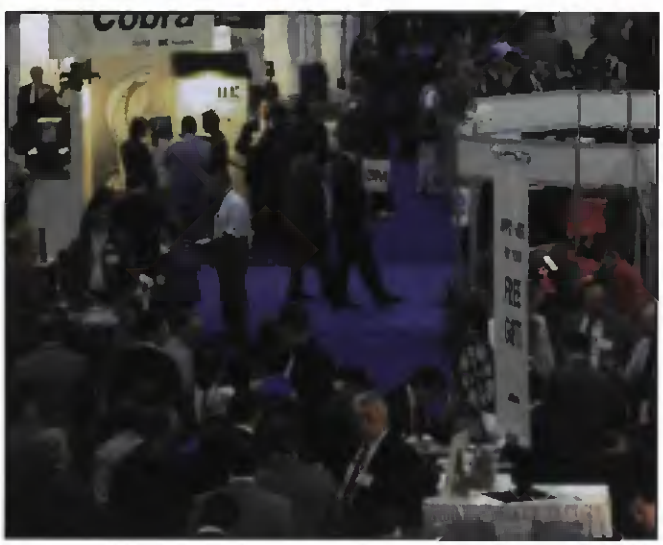
The American Welding Society also has responded to the needs of welding educators to have their skill and knowledge verified to the nationally recognized QC-5 Certified Welding Educator Standard. Federal and state education budget cutbacks make this a particularly valuable designation.

The Senior Certified Welding Inspector Program (SCWI) is intended for seasoned inspection managers who have been CWIs for at least 6 years, and who have no fewer than 15 years of experience in an occupational functinn that has a direct relationship to welded assemblies. This certification should prove to be the benchmark for the career welding inspection professional.

Exam applications must be completed and submitted to the AWS Certification Department six weeks before the scheduled examination. Request an information package and an examination application from the Certification Department by mail or by telephone at (800) or (305) 443-9353 ext 273. The status of a completed and submitted application will be confirmed by mail, where it will be stated whether the applicant meets qualifications to sit for the examination.

SCWI/CWI Examination: AWS Members $410, Nonmembers $595;
CWE Examination: AWS Members $305, Nonmembers $495

Nonmember price includes three-year membership.



ACD Sessions

Wednesday April 26

Morning Session: 9:00 a.m. - Noon
ACD 1: Submerged Arc Welding Today

Chair: J. F. Saenger, Jr., Edison Welding Institute CWI

Manufacturers of submerged arc equipment, wire and fluxes will describe today's products and their advantages. There will be eight presentations, with opportunities for listeners to question the presenters at the end of the session.

A.	9:00	Welding Automation Equipment for the Submerged Arc Prncess, by Kevin Corgan, Pandjiris, Inc.
B.	9:20	Development of Portable Submerged Arc Equipment, by Bisham Malkani, Gullco International.
C.	9:40	Microprocessor-based Submerged Arc Controls and Power; Consumables for High Toughness Applications, by Jerry Uttrachi, ESAB.
D.	10:00	State-of-the-Art Submerged Arc and Electroslag Strip Cladding, by Russel Fuchs, Bohler-Thyssen Welding USA.
E.	10:20	Submerged Arc Materials for 300 Series and Duplex Stainless Steels, Nickel Alloys, by Frank Babish, Sandvik Steel Co.
F.	10:40	Low Hydrogen Consumables, by Matthew James, The Lincoln Electric Co.
G.	11:00	Summit Arc AC/DC CC/CV Power Source Used as a Trail Arc in a Tandem Arc Application, by Kevan Kokkonen, Miller Electric Mfg. Co.
H.	11:20	Today's Flux-Recovery Systems, by Mark Lauber, Invincible AirFlow Systems
I.	11:40	Question and Answer Session

Afternoon Session: 2:00 p.m. - 5:00 p.m.
ACD2: Today's Flux-Cored Technology — New Products, New Applications

Chair: Susan Fiore, ESAB Welding & Cutting Products

A.	2:00	New Family of Vanadium & Tungsten Carbide Hardfacing Alloys, by Bill Mosier, Polymet Corporation.
B.	2:20	Capabilities and Limitations of Modern Flux Cored Wires for the Weldiog of Duplex Stainless Steels, by Russel Fuchs, Bohler Thyssen Welding. USA.
C.	2:40	All-Position Gas-Shielded Flux Cored Wires for Nickel-Based Alloys (the past year has seen a significant increase in the usage level), by Dr. Ravi Menon, Stoody Company.

ACD Sessions

D.	3:00	Two or Three Out-of-Position Flux Cored Electrodes, by William Alonso, The Lincoln Electric Co.
E.	3:20	A Series of Metal Cored Wires for Welding Austenitic, Ferritic and Martensitic Stainless Steels, by Stan Ferree, ESAB Welding & Cutting Products.
F.	3:40	1/16-in. Coreshield 8 (E71T-8) Shielded Flux-Cored Wire for Welding in All-Positions. Designed for more stringent weld metal impact properties in seismic areas, by Stan Ferree, ESAB Welding & Cutting Products.
G.	4:00	Unique Seamless E70T-1 Flux Cored Wire: Moisture Absorption, Copper Coating, Electrical Conductivity, by Terry D. Byrd, Thermal Arc/Stoody Company.
H.	4:20	Nickel-Based Cored Wires, by John Beyer, Cor-Met, Inc.

Afternoon Session: 2:00 p.m. — 5:00 p.m.
ACD 3: Brazing and Soldering of Dissimilar Metals

Presented by the Brazing and Soldering Manufacturers' Committee
To be announced

Thursday, April 27, 2000

Morning Session: 9:00 a.m. - 12 Noon
ACD 4: Protecting Your Welder and CoWorkers from Fumes, Radiation and Noise

To be announced

Afternoon Session: 2:00 p.m. - 5:00 p.m.
ACD 5: New GMAW Equipment — What Can All This Sophisticated Hardware Do for Me?

Chair: David Meyer, ESAB Welding & Cutting Products

A.	2:00	Microprucessor Controlled Orbital GMAW, by Ken Brazzell, Liburdi Dimetrics.
B.	2:35	Aristo 2000: Man-Machine Interface for the Millennium, by Joe Devito, ESAB Welding and Cuting Products.
C.	3:10	HMII Series Dip Pulse, Inverter Power Supply, by Tim Nacey, Panasonic Factory Automation.
D.	3:45	Pulsed Arc GMAW Equipment for Tandem Wire Welding, by Joseph Veilla, Clous Robotic Welding, Inc.
E.	4:20	Turbo Pulse DF — User Benefits of Fuzzy Logic Control; AC GMAW, by William Guest, Daihen.
F.	4:55	New GMAW Equipment, by Joe Fink, Miller Electric Co.

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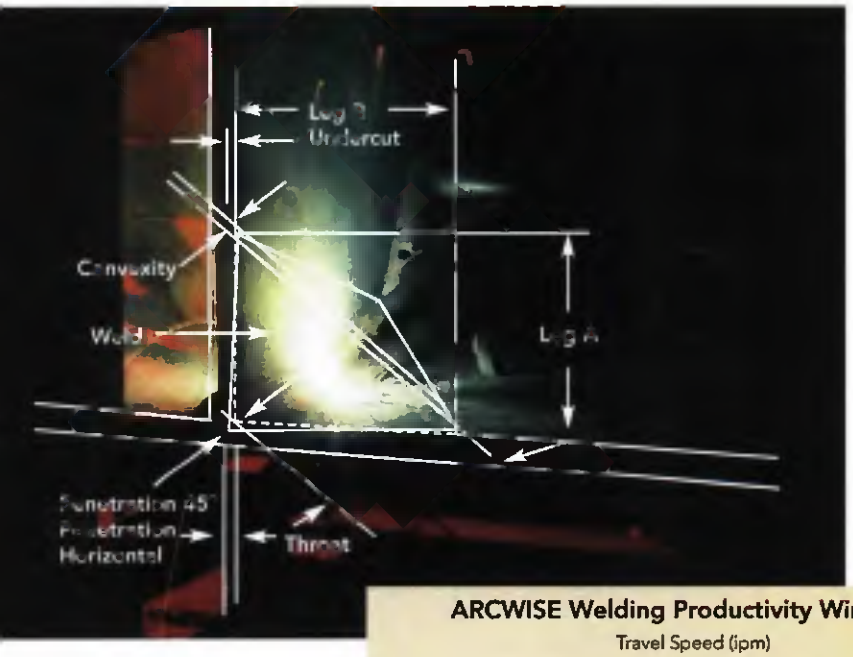

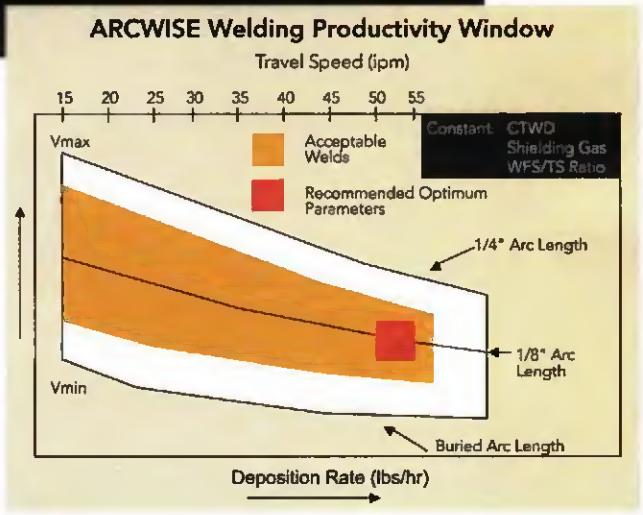

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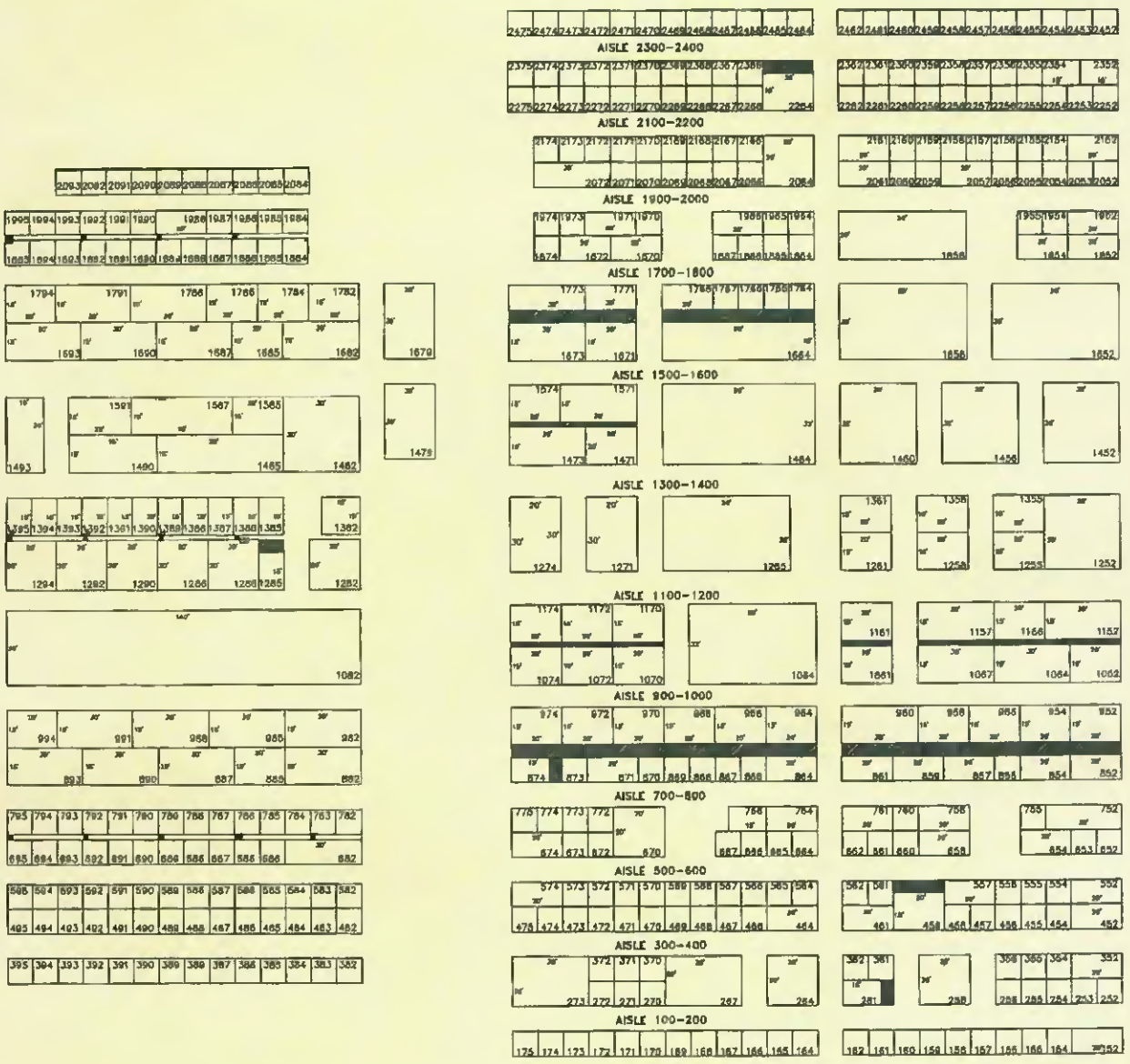

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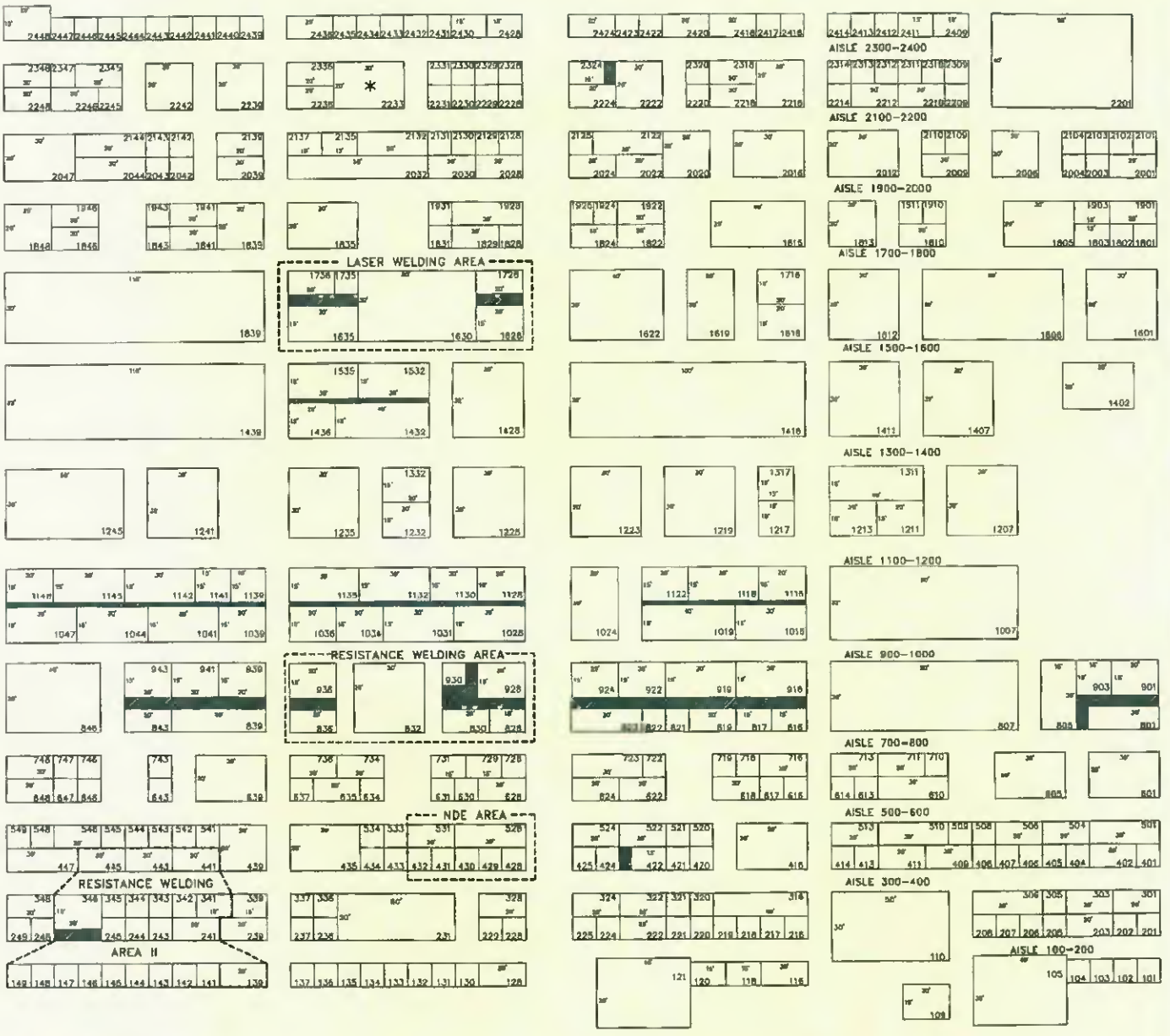

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Issue 4

aluminations

Is spray transfer too hot? Short circuit too cold? Then consider pulsed MIG for aluminum. It can combat warpage, burn through, lack of puddle control, lack of fusion, spatter and poor appearance. This aluminations explains the pulsed process and introduces a simple, affordable machine with built-in pulsing controls.

Shedding light on aluminum welding issues

questions ANSWERS

Q: Can pulsed MIG boost productivity?

A. *For certain applications, absolutely. Compared to short circuit or spray transfer, pulsed MIG often permits using a larger diameter wire and/or faster wire feed speeds without adding excess heat. This increases travel speed and/or deposition rates. For example, one fabricator welding lap joints on thin gauge aluminum increased travel speed from 105 to 144 in./min. after switching to pulsed MIG.*

Q: Does pulsed MIG create cleaner looking welds than spray transfer?

A. *Yes, in aluminum with high magnesium content, such as the 5000 series. The higher current and arc temperatures of spray transfer vaporize the magnesium, causing a gray film to form on the weld surface, especially at the toes. Pulsed MIG, with its lower average current, reduces the amount of vaporization. As a secondary benefit, it also reduces fume generation.*

Q: Why switch to pulsed MIG for aluminum?

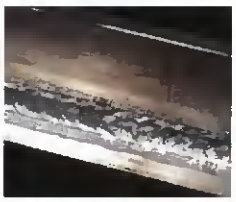
A. *Many shops switch for greater control and to obtain a highly uniform bead. With pulsed MIG, the weld puddle cools between pulses and freezes faster. This provides operators with better directional control over the weld bead. Also, the puddle is less likely to sag or look excessively convex when welding out-of-position. In fact, bead appearance can approach that of TIG (see photo). Shops TIG welding aluminum thicker than 1/8 in. might consider pulsed MIG as a way to increase output while satisfying appearance and quality control demands. Also, pulse welding avoids lack of fusion which can occur with the colder short circuiting transfer.*

David Almy
Welding Engineer
Miller Electric Mfg. Co.

In pulsed MIG welding, technically a modified spray transfer process, the machine switches between a high peak current and a low background current (see Fig. 1). The peak current pinches off a spray transfer droplet and propels it toward the weldment. The background current maintains the arc, but is too low for metal transfer to occur.

Pulsing can lower heat input to levels associated with short circuit transfer, yet it provides benefits associated with spray transfer. For example, pulsed welding a 1/8 in. thick section of aluminum with a 3/64 in. diameter wire requires an average of 140 amps. In this program, a 90 amp background current eliminates worries about burn through or warping, while a 350 amp pulse of peak current provides good penetration and wet out. As with spray transfer, pulsing produces little to no spatter or porosity; like short circuit transfer, it works well in thinner gauge and out-of-position applications.

As a financial incentive, consider that non-pulsed welding 1/8 in. aluminum typically calls for .035 in. wire, which lists for $5.16/lb. Now compare this to the 3/64 in. wire in the pulsed example above; it lists for $4.85/lb. Standardizing on larger diameter wire, and using that single wire for a wide variety of thicknesses, is a common benefit of the pulsed process.



Unretouched photo of pulsed MIG weld bead

Equipment for Pulsing

Unfortunately, many aluminum fabricators hesitate to adopt pulsed MIG. Concerns about equipment complexity, operator comfort and purchase price typically hold them back. Miller's new Invision™ 354 MP and Invision 456 MP, however, overcome such concerns.

These power sources feature built-in programs for 4000 and 5000 series aluminum wire. To begin welding, select the program that matches your wire size and type. After that, they set up like a conventional MIG system: pick a wire feed speed and turn the trim control to find the correct arc length. You never have to modify pulsing parameters to maintain good welding conditions for different wire speeds or trim settings. Using this system, operators feel very comfortable switching to pulsed MIG because it's "familiar."

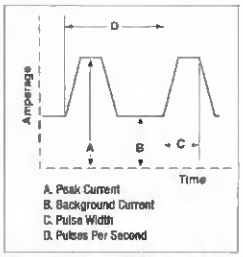


Fig. 1 Pulsed MIG wave form

The Invision 354 and 456 MP provide optimized performance with Miller's standard wire feed systems for MIG welding aluminum, such as the XR™ feeder and XR-Edge™ with gooseneck gun. You do not need a programmable feeder or pulsing pendant. For more information and a free technical article on Pulsed MIG, call 1-800-4-A-MILLER (1-800-426-4553) or visit our website at www.MillerWelds.com

2000 AWS International Welding and Fabricating Exposition

BUYERS' GUIDE

McCormick Place
2301 S. Lakeshore Dr.
Chicago, IL 60616
April 26–28, 2000

This guide lists exhibitors according to major product types on display. Exhibit Highlights on pages 147–201 provide a more detailed listing for each exhibitor. Use the floor plan on pages 92–93 to locate booths.

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MICRO GTAW

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ORBITAL WELDING

Foremost Machinery Corp. 1765

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Flaw Detectors for Testing Weld Integrity

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ROBOTIC PERIPHERALS

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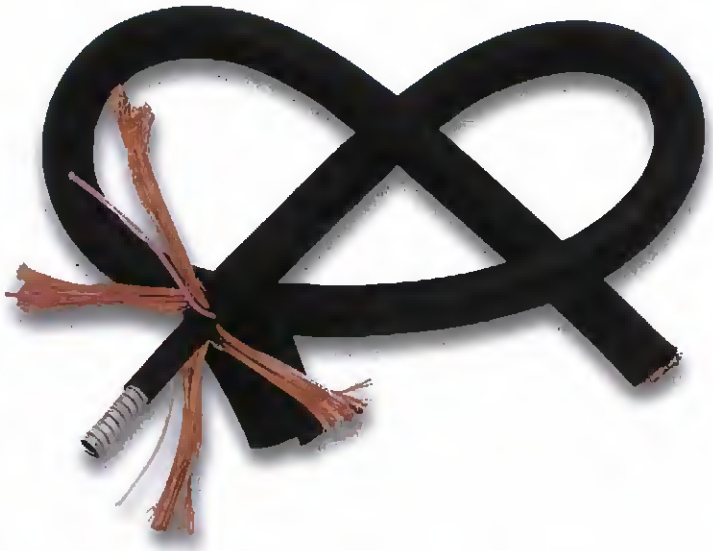

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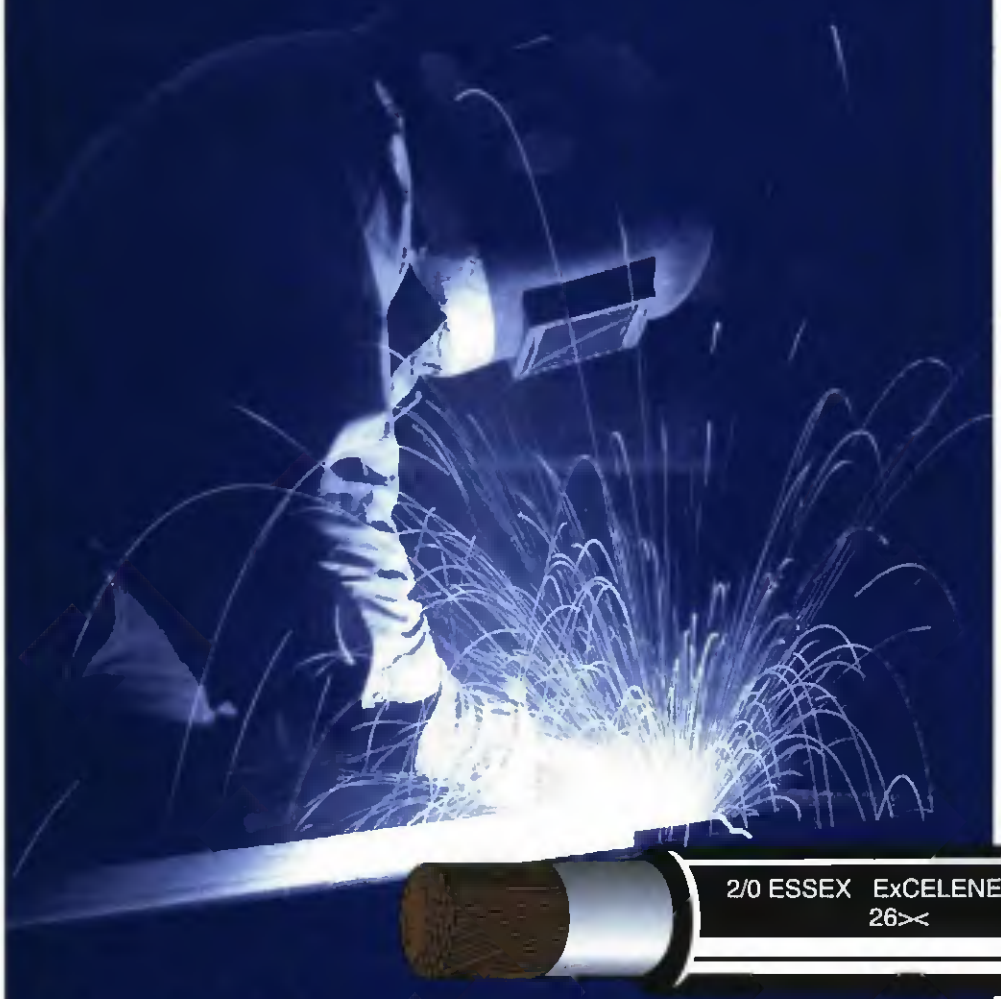

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NATURAL GAS

ORBITAL SAWS

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Erico Inc. 1943

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Beijing Metals & Minerals Import & Export Corp. 2362

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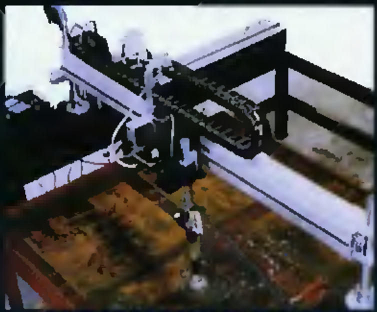

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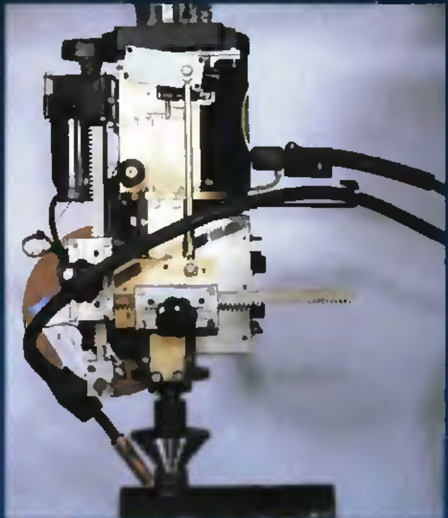

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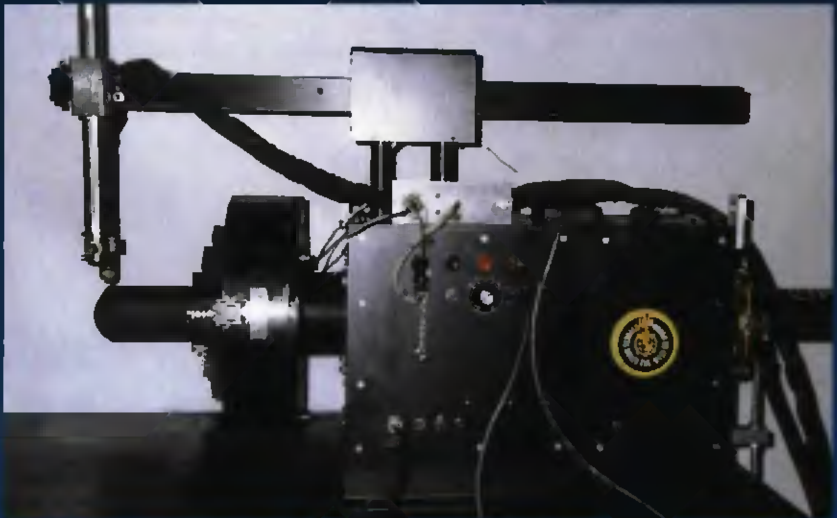

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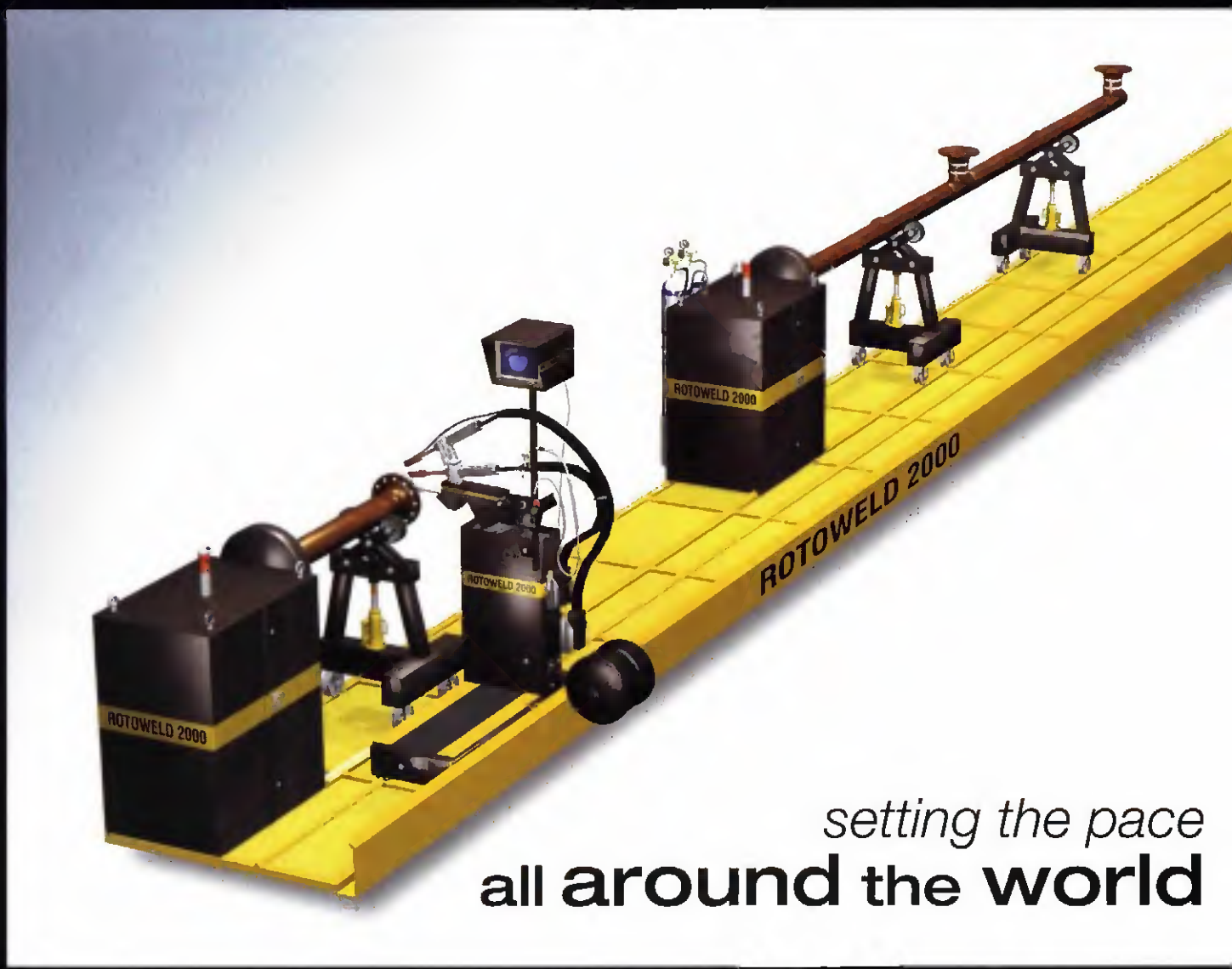

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METAL CORED WIRES

Air Products & Chemicals, Inc. 1619
Atlas Welding Accessories, Inc. 734
Atlas-Raisen L.L.C. 868
Aufhauser Corp. 2229
BMS, Inc. 601
Bohler Thyssen Welding USA Inc. 2006
Corex 1805
Cor-Met, Inc. 1054
Devasco Int'l, Inc. 458
ESAB Welding & Cutting Products 807
Harris Welco Div. of J.W. Harris Co. 1332
Hobart Brothers Co. 1805
Hyundai Welding Products, Inc. 882
Inweld Corp. 1841
Koballoy Co. 601
Lincoln Electric Co., The 1439
Machine Tools.com 1361
McKay Welding Products 1805
National Standard Co. 1460
Natweld-Hi Alloy Corp. 1841
Polymet Corp. 1870
Praxair, Inc. 1245
Rankin Industries, Inc. 1355
Robinson Technical Products Midwest 434
STEiN-USA 361
Techniweld Alloys & Welding Supplies 2173
Thermadyne Holdings 1416
Trimark 1805
Unibraze Corp. 1965
Uniweld Products, Inc. 1024
Washington Alloy Co. 861
Weartech Int'l, Inc. 643
Weld Mold Co. 2436
Weldrite Welding Products, Inc. 520

MILD STEEL WIRE

Chosun Steel Wire Co. 964

NICKEL

Air Products & Chemicals, Inc. 1619
American Filler Metals Co. 970
Arctech Welding Electrodes & Wires Ind. Inc. 2210
Aufhauser Corp. 2229
Avesta Welding Products, Inc. 1057
Beijing Metals & Minerals Import & Export Corp. 2362
Bohler Thyssen Welding USA Inc. 2006
Chosun Steel Wire Co. 964
Cor-Met, Inc. 1054
ESAB Welding & Cutting Products 807
Forges De Saint-Hippolyte S.A. (Selectarc) 252
Gedik Welding Inc. 201
Harris Welco Div. of J.W. Harris Co. 1332
Hobart Brothers Co. 1805
Inco Alloys Int., IAI Welding Products, A Special Metals Co. 723
Inweld Corp. 1841
Lincoln Electric Co., The 1439
Machine Tools.com 1361
McKay Welding Products 1805
MG Welding Products 1954
Midalloy, Inc. (Formerly Midwest Alloys & Technology) 1829
Natweld-Hi Alloy Corp. 1841
Oerlikon Welding Ltd. 2222
Polymet Corp. 1870
Praxair, Inc. 1245
Robinson Technical Products Midwest 434
Sandvik Steel Co. 1824
Selectrode Industries, Inc. 722
Techniweld Alloys & Welding Supplies 2173
TUV America 2313
Unibraze Corp. 1965
Uniweld Products, Inc. 1024
Washington Alloy Co. 861
Weartech Int'l, Inc. 643
Weld Mold Co. 2436
Weldmark 2253
Weldrite Welding Products, Inc. 520

OTHER FILLER METALS/ ELECTRODES

Atlas-Raisen L.L.C. 868
Beijing Metals & Minerals Import & Export Corp. 2362
Bohler Thyssen Welding USA Inc. 2006
Erico Inc. 1943
Intercon Enterprises, Inc. 1070
Titanium Wire Corp. 660
TUV America 2313
Unibraze Corp. 1965
Uniweld Products, Inc. 1024
Weldrite Welding Products, Inc. 520

QUALIFICATION OF FILLER METALS

Beijing Metals & Minerals Import & Export Corp. 2362
TUV America 2313

SOLID WIRE

Cor-Met, Inc. 1054

STAINLESS STEEL

Air Products & Chemicals, Inc. 1619
American Engineering & Welding 775
American Filler Metals Co. 970
Arctech Welding Electrodes & Wires Ind. Inc. 2210
Atlas Welding Accessories, Inc. 734
Aufhauser Corp. 2229
Avesta Welding Products, Inc. 1057
BMS, Inc. 601
Bohler Thyssen Welding USA Inc. 2006
C.H. Symington & Co., Inc. 549

TESTING EQUIPMENT

CUSTOMIZED

DESTRUCTIVE TESTING EQUIPMENT

Robotic Accessories Div., Process Equipment Co. 1941
Techniweld Alloys & Welding Supplies 2173

GAS ANALYZERS

GOW-MAC Instrument Co. 859

HARDNESS TESTING

Equotip Associates 141

HYDROSTATIC

Expansion Seal Technologies 249

METALS TESTING LABORATORY

Stork-Herron Testing Laboratories Inc. 2125

NDE SERVICES

Conam Inspection Inc. 528
EWI (Edison Welding Institute) 1456
FIBA Technologies, Inc. 542
IRT-Scanmaster Systems, Inc. 828
NonDestructive Testing Group 431
Robotic Accessories Div., Process Equipment Co. 1941
TN Technologies 631
Weldship Corp. 428

NDE EQUIPMENT

American Engineering & Welding 775
Atlas Welding Accessories, Inc. 734
British Federal-North America 273
Controls Corp. of America 1928
Dynaflux, Inc. 823
Equotip Associates 141
ESAB Welding & Cutting Products 807
Exel Design Co. 408
Expansion Seal Technologies 249
FIBA Technologies, Inc. 542
Impact Engineering, Inc. 1955
Intercon Enterprises, Inc. 1070
IRT-Scanmaster Systems, Inc. 828
Kistler Instrument Corp. 2066
Krautkramer Branson 2001
Magnaflux 2102
Metorex Inc. 432
Nasco Inc. 2222
Niton Corp. 534
Olympus America Inc. 710
Panametrics, Inc. 328
Robotic Accessories Div., Process Equipment Co. 1941
Sherwin, Inc. 533
Spectronics Corp. 429
Staveley NDT/Conam Inspection 528
StressTel 221
TN Technologies 631
Weldship Corp. 428

OTHER TESTING EQUIPMENT

AccuData, Inc. 2032
Equotip Associates 141
MIM Industries, Inc., A Brother Co. 1822
Navy Joining Center (NJC) 1456
Stork-Herron Testing Laboratories Inc. 2125
TN Technologies 631

REMOTE VISUAL INSPECTION EQUIPMENT

Olympus America Inc. 710

WELD MONITORS

AccuData, Inc. 2032

RELATED PRODUCTS & SERVICES

ALLOY ANALYZER

TN Technologies 631

AIR FILTRATION PRODUCTS

TDC Filter Mfg., Inc. 2143

AIR & LIQUID COOLED DIESEL ENGINES

Briggs and Stratton Corp. 758

AIR&LIQUID COOLED GAS ENGINES

Briggs and Stratton Corp. 758

ALIGNMENT TOOLS

Walhonde Tools Inc. 2320

ALLOY IDENTIFICATION

Metorex Inc. 432

ALUMINUM EXOTHERMIC WELDING

Erico Inc. 1943

BULK WIRE PACKAGING

Carris Reels, Inc. 2246
Spanco, Inc. 222

CAD/CAM

Burny/Cleveland Motion

FURNACES

GAUGING STDP SYSTEMS

GMAW-GTAW REPAIR SERVICE

GMAW WIRE DEREELERS

HAND TOOLS & POWER TOOL ACCESSORIES

HARDBOARD REELS

HEAT TREATING/STRESS RELIEVING

HVAC

INDUCTION BRAZING EQUIPMENT

INDUSTRY RELATED PUBLICATION

ISO 9000 CERTIFICATION

LADDERS & SCAFFOLDING

LASER JOB SHOP

METAL & ALLOY POWDER

METAL ARTWORK

METALWORKING EQUIPMENT

MODULAR FIXTURING FOR WELDING

MOLDING KITS

NAILED WOOD REELS

NAMEPLATES AND LABELS

NUMERICALLY CONTROLLED EQUIPMENT

OTHER PRODUCTS AND SERVICES

PIPE END PREPARATION

PIPE NOTCHING

PLASTIC REELS

PLYWOOD REELS

PRECIOUS METAL REFINING

PROCESS MONITORING

PRODUCTION ENGINEERING TOOLS

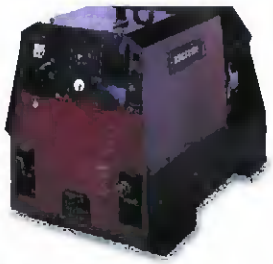
PROTECTIVE COATINGS

NEW FROM

THERMADYNE

Innovative Solutions For Today's Welding Needs

THERMAL ARC



New Exciter™ Power Source is Turning Heads

Thermal Arc's all new Exciter™ welding power supply features a 15HP Kohler® gas engine and is designed for both 12V and 24V battery charging. Exciter is the perfect solution for CC Stick (SMAW) welding with a 210 amp/100% duty cycle capability. Auxiliary power generation is 115VAC at 5.5k VA. The new Exciter is just one of several new additions to the Thermal Arc line of precision power supply products.

Thermal Arc, Inc. www.thermalarc.com

GENUINE VICTOR EQUIPMENT

Don't Leave Safety To Chance

Victor is committed to operator safety. That's why we put "built-in" flashback arrestors and check valves into every torch we make. Victor's patented VanGuard™ safety system gives operators optimum protection every time they light up their torch. See the new line of "FC" series cutting torches and torch handles today. Why settle for less... and leave safety to chance.

Victor Equipment Company www.victorequip.com

THERMAL DYNAMICS

Plasma Arc Cutting at It's Finest!

High output amperage, overload protection, auto-pilot restart, trigger latch, and a new ergonomic torch design lead the list of impressive features that put the new PakMaster™ XL Plus in a class by itself. XL Plus systems are available for cutting 1/2" to 1" material with speed and efficiency previously unheard of. Thermal Dynamics is your clear "first choice in plasma".

Thermal Dynamics Corporation www.thermal-dynamics.com

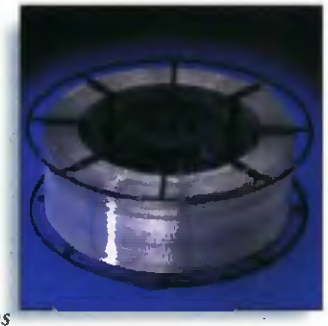
Tweco

New SprayMaster™ Air Cooled Mig Gun

Now there's a better solution for spray and pulse welding applications. Tweco's new SprayMaster™ series MIG Guns come with heavy duty contact tips and diffusers for optimum performance and the results you want in high heat welding applications. Our new 250, 350, and 450 amp SprayMaster™ guns feature simplified direct rear connections for easy installation and are rated 80% duty cycle with Argon/ CO_2 gases.

Tweco Products Company www.tweco.com

STOODY

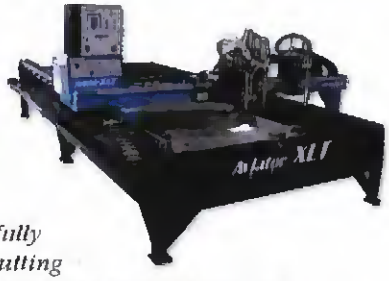


New High Performance Stainless Steel Wire

Stoody's new line of flux-cored Stainless Steel Wire is available in two formulations for true all-position welding and flat & horizontal welding needs. Features include high deposition rates and efficiencies, smooth arc characteristics, low spatter levels, easy peeling slag, and state-of-the-art vacuum packaging.

Stoody Company www.stoody.com

C&G SYSTEMS™



New Aviator XLT™ is Designed Right - Priced Right

Our new Aviator XLT is a fully unitized plasma/oxy-fuel cutting system complete with Thermal Dynamics PakMaster™ 150XL plasma power supply for under $40,000! A 6' x 12' downdraft table, Burny® 1250 CNC controller, 500 IPM PWM drive package and FastCam® nesting software make the Aviator XLT perfect for the job shop or manufacturer... at a price you can live with. See the new Aviator XLT and C&G Systems' other fine cutting machine options today.

C&G Systems, Inc. www.cgsystems.com

Thermadyne Industries, Inc. • 101 S. Hanley Rd. • St. Louis, Mo 63105 • Phone (314) 721-5573 • Fax (314) 746-2324 • www.thermadyne.com

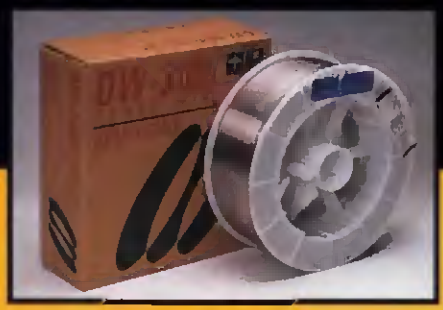
VISIT US IN BOOTH 1416 AT THE AWS WELDING SHOW

Circle No. 132 on Reader Info-Card

KOBELCO FLUX CORED WIRE

THE SPOOL OF EXCELLENCE®

The wire that takes you to the top in flux cored welding



DW Stainless Series
AWS: A5.22–95

Frontiarc-711
AWS: E71T-1, 1M, 12, 12M

DWA-55ESR
AWS: E71T-12MJ

SEE US AT AWS SHOW BOOTH 605 **Circle No. 82 on Reader Info-Card**

KOBELCO WELDING OF AMERICA INC. 7478 Harwin Dr., Houston, Texas 77036
713.974.5774 Fax: 713.974.6543 kobelcowelding.com

WELDABLE STAMPING LUBRICANTS

Metal Mates, Inc. 237

WELDING CONSULTATION

Stork-Herron Testing Laboratories Inc. 2125

WELDING PUBLICATIONS

American Welding Society, The 0
British Federal-North America 273
Fabricating Equipment News 219
Gases & Welding Distributor 522
Industrial Machinery Digest 219
Kromer Cap Co., Inc. 1831
Lincoln Electric Co., The 1439
Machine Tools.com 1361
MAN - Modern Applications News 1952
Metal Forming Magazine 856
Photonics Spectra 1735
Practical Welding Today/ The FABRICATOR 618
Punch Press-The Metalworkers Market Place 556
TWI 2061
Welding Design & Fabrication 522
Welding Journal, The 2

WIRE BASKET REELS

Carris Reels, Inc. 2246

WORK CELLS

Jesco Industries Inc. 510

WORKERS' COMPENSATION INS.

Amerisafe, Inc. 2275

METAL WORKING EQUIPMENT

ANGLE BENDING

Comac USA Inc. 871
ITA, Inc. 871

ANGLE ROLLS

Eagle Bending Machines, Inc. 2047
Heller's Son, Inc., E.G. 1252

BANDSAWS

Hyd-Mech Saws 435

BEAM CAMBERING/ STRAIGHTENING

Heller's Son, Inc., E.G. 1252

BENDING

World Machinery & Saws System Co. 2110

BENDING & SHEARING

Advanced Fabricating Machinery 748
Centerline (Windsor) Ltd. 936
CML USA, Inc. 2072
Comac USA Inc. 871
COMEQ, Inc. 1019
Eagle Bending Machines, Inc. 2047
Edwards Mfg. Co. 956
Foremost Machinery Corp. 1765
Formdrill-Div. of Foremost Machinery 1866
HACO-Atlantic, Inc. 839
Heller's Son, Inc., E.G. 1252
ITA, Inc. 871
Machine Tools.com 1361
Mega Mfg./Piranha-Allsteel 1028
Peddinghaus Corp. Tool Div. 2139
Punch Press-The Metalworkers Market Place 556
Scotchman Industries 639
Simplex Div. Templeton, Kenly & Co., Inc. 402
Uni-Hydro, Inc. 475
United ProArc Corp. 1671
Unittool Punch & Die Co. 130

BLAST CLEANING

Jet Wheelblast Equipment 2328
Pangborn Corp. 267
Wheelabrator - 8CP 1217

COIL STRIP DEREELERS

Accra-Wire Controls, Inc. 2032

CUSTOMIZED AUTOMATION

MIM Industries, Inc., A Brother Co. 1822

DEBURRING

H & B Distributors 1130

DRILLING

Hougen Mfg., Inc. 1041

END PREPARING TOOLS

Walhonde Tools Inc. 2320

IMPORTER

Atlas-Raisen L.L.C. 868

IRONWORKERS EQUIPMENT

Armstrong-Blum Mfg. Co. 974
Edwards Mfg. Co. 956
Heller's Son, Inc., E.G. 1252

MAGNET-BASE DRILL/ANNULAR CUTTERING

Hougen Mfg., Inc. 1041
Universal Drilling & Cutting Equipment, Ltd. 322

OTHER METALWORKING EQUIPMENT

Accra-Wire Controls, Inc. 2032
ADF Systems, Ltd. 2161
Advanced Measuring Systems 1803
ArcOne 846
Atlas-Raisen L.L.C. 868
Comac USA Inc. 871

Scorcher Welders from MQ Power

Your dream machines are now a reality.

Diesel powered

Gas powered

Scorcher Welders. 225 to 500 amps. Gas or diesel. Only from MQ Power.

The portable welders you've dreamed about are now a reality. Scorcher Welders have every feature and convenience you could ask for.

Weld anything, anywhere. Very stable DC arc performance for both DC constant current and DC constant voltage — even with wire sizes down to .030. Extremely clean AC power — the best in the industry.

Ultra quiet. Scorcher Welders are welcomed in residential areas, hospital zones, and on the construction site.

Reliable. With no brushes to worry about, these machines are virtually maintenance-free.

Lowest operating cost. Fuel efficient engines for maximum efficiency.

Available in sizes from 225 to 500 amps, in gas and diesel configurations, your dream machines are here. From MQ Power. Call, fax, e-mail or write for information.

MQ POWER

MQ POWER CORP.
A DIVISION OF MULTIQUIP INC.
POST OFFICE BOX 6254 • CARSON, CA 90749
310-537-3700 • 800-883-2551 • FAX: 310-632-2656
E-MAIL: mq@multiquip.com • WWW: multiquip.com

Manufactured by Denyo Ltd. SCORCH™ the Dragon is a registered trademark of Ronn Lucas / "LEMME OUT!" Productions Inc.

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SEE US AT AWS SHOW BOOTH 1682

Save Money

On TIG Welding Products From China

❑ Tungsten Electrodes for TIG Welding

Ground finish tungsten electrodes for TIG and PLASMA welding or cutting according to AWS A5.12 or ISO 6848

AWS A5.12	EWTh-2 (Red)	EWP (Green)	EWCe-2 (Orange)	EWLa-1 (Black)	EWZr-1 (Brown)

1% Ytteriated tungsten electrodes are also available.

❑ Alumina Nozzles and Insulators for TIG and PLASMA Welding or Cutting

10N44-50, 13N08-13, 14N57-61, A53N24-27, 54N14-19, 53N58-61, 57N74-75, 53N87-89, 10N47L-49L, 54N15L-17L, 14N68-72, 796F71-79, 23040079-23040083, TGNxxxxx, etc. Special drawings are also acceptable.

❑ Tungsten, Molybdenum Powders or Wire for Spraying

❑ Flux-Cored Wire for Welding

E71T-1 according to AWS A5.20 or YFW-24 according to JIS Z3313, which has received the approval of Lloyd's Register of Shipping, ABS (American Bureau of Shipping), DNV (Det Norske Veritas) and GL (Germanischer Lloyd), etc.

❑ Titanium and Magnesium Wire for Welding

ERTi-1, -2 (pure titanium) or ERTi-5 (Ti6A14V) according to AWS A5.16. ER AZ61A according to AWS A5.19, etc.

❑ Fused Fluxes for Submerged-Arc Welding

FS-FG2 and FS-FG3 according to JIS Z3352, which has received the approval of Lloyd's, ABS and DNV, etc.

Beijing Metals & Minerals Import Export Corp.
No.5 Fangzhuang Lu, Zuoanmenwai, Beijing, 100078, P.R. China
E-mail: bjmetals@public.bta.net.cn

Tel: (011-86-10) 6764-9947
Fax: (011-86-10) 6762-0568

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SEE US AT AWS SHOW BOOTH 2362

EXHIBIT HIGHLIGHTS

McCormick Place
2301 S. Lake Shore Dr.
Chicago, Ill.

April 26–28, 2000

This alphabetical listing of exhibitors in the 2000 AWS International Welding Exposition offers a preview of what will be displayed in each booth. The booth numbers listed can be used in conjunction with the show floor plan on pages 92–93 to pinpoint the location of a particular exhibit. WEMCO and AWS Sustaining Member Companies are highlighted in color.

AACCO 2068
5220 N. 125th, Butler, WI 53007
(262) 781-7160; FAX (262) 781-3558
www.aaccobraze.com

AACCO will exhibit its complete line of brazing and soldering fluxes, which is composed of the Kwikflux and Xcel Flux product lines, along with various brazing alloys in many forms such as wire, strip, paste, powder and preformed shapes. Samples, showing porosity-free welds, will be displayed that were coated with its weld-through, preconstruction primer Deoxaluminite. Also on display will be sample parts brazed using the company's flux and alloys.

ABB Flexible Automation Welding Systems Div. 2012
4600 Innovation Dr.
Fort Collins, CO 80525
(970) 225-7600; FAX (970) 225-7700
www.abb.com/usa

ABB will introduce a new FlexArc® compact arc welding cell featuring the new IRB 140 robot with a new S4Cplus controller. The robot can be mounted on the floor, wall or inverted, and has a 29-in.-radius work envelope. Another new FlexArc featuring a manual indexing work table will also be displayed. In addition, the BullsEye® automated robot calibration system and RobotStudio™ digital plant technology software will be demonstrated.

ABICOR Binzel 1064
650 Research Dr., Ste. 110
Frederick, MO 21703
(301) 846-4196; FAX (301) 846-4497

ABICOR Binzel will show its extensive line of semiautomatic, automatic and robotic GMA welding guns and GTA welding torches, plus robotic peripherals in action on a working robot. Products on display will include the new ALPHA Series of air-cooled GMAW guns and VTS (variable torch system) modular robotic guns. Technical personnel will be on hand to answer questions and to recommend products for specific applications.

Abmast Abrasives Corp. 348
4025 Welcome All Rd., Ste 110
Atlanta, GA 30349
(404) 629-2160; FAX (404) 629-0245

Abmast will highlights its line of bonded abrasives, cut-off and and grinding wheels, diamond blades, wire brushes, fiber discs and floor maintenance products.

Accra-Wire Controls, Inc. 2032
10891 Northland Dr. NE
Rockford, MI 49341
(616) 866-3434; FAX (616) 866-9468
www.acrainc.com

AccuData, Inc. 2032
9700 Myers Rd., Clarklake, MI 49234
(517) 529-4995; FAX (517) 529-4996

Ace Industrial Products 424
5043 Ferlin Ave., St. Louis, MO 63115
(800) 949-1472; FAX (314) 385-3254
www.associatedequip.com

Acme Cryogenics, Inc. 2430
2801 Mitchell Ave.
Allentown, PA 18103
(610) 966-4488; FAX (610) 791-2837
www.acmecryo.com

Acme Retining Scrap Iron & Metal Co. 2155
3357 S. Justine, Chicago, IL 60608
(773) 523-4500; FAX (773) 523-7283

ADF Systems, Ltd. 2161
1302 19th St. N., P.O. Box 278
Humboldt, IA 50548
(800) 959-1191; FAX (800) 798-5100
www.adfaya.com

ADF will display its family of aqueous parts washing equipment. The line includes rotary baskets, top- and front-load models; manual tank-type models; pass-through, tumbler style, glovebox and agitation dip tanks; and drawer-type, auger-style, spray booth and conveyor washers. Also on display will be equipment suited for cleaning operations before or after welding or machining, assembly, fabrication or other requirements. Factory personnel will be available to answer questions.

Advanced Fabricating Machinery 748
No. 65 Route 125, Kingston, NH 03848
(603) 642-4906; FAX (603) 642-4813
www.advancedfab.com

Advanced Fabricating Machinery will showcase its latest tube/pipe bending technology. On display will be empty benders, mandrel benders, end formers, portable benders, horizontal press benders, ram benders, high-speed benders and multiprocess transfer lines. Personnel will answer questions regarding your bending application.

Advanced Kiffer Systems Inc. 1274
15666 Snow Rd.
Cleveland, OH 44142-2351
(216) 267-8181; FAX (216) 267-8182
www.aks-inc.com

Advanced Measuring Systems 1803
1202 N. Wooster Ave.
Dover, OH 44622
(330) 602-1203; FAX (330) 343-7050

Aervoe-Pacific Co., Inc. 2022
1198 Mark Circle
Gardnerville, NV 89410
(775) 782-0100; FAX (775) 782-4027

Aervoe-Pacific will exhibit its line of paints, coatings, lubricants and chemicals. Highlighted will be the company's Anti-Spatter, which was specifically developed for the welding industry. It is a nonflammable, temporary film that keeps welding tips and nozzles clean and leaves a transparent yellow, tacky film that visually confirms proper coverage. It cleans up quickly with a brush.

Affinity Industries Inc. 2428
775 Rt. 16, P.O. Box 1000
Ossipee, NH 03864
(603) 539-3600; FAX (603) 539-8484
www.AffinityChillers.com

Air Products & Chemicals, Inc. 1619
7201 Hamilton Blvd.
Allentown, PA 18195
(800) 654-4567; FAX (800) 880-5204
www.airproducts.com

Air Products and Chemicals will introduce a new family of welding gases — Ferromaxx™ and Alumaxx™ for aluminum and Inomaxx™ for stainless steel — designed to increase weld speed, enhance weld quality and improve productivity. Also, a new Integra™ cylinder that is lighter, smaller, more stable and able to hold more gas than traditional cylinders will be introduced as a portable, optimized flow alternative for shielding gas delivery.

Airflow Systems, Inc. 264
11370 Pagemill Rd., Dallas, TX 75243
(214) 503-8008; FAX (214) 503-9596
www.airflowsystems.com

Airflow Systems will offer information on how to solve the many air and dust problems from welding manufacturing processes. Highlighted will be compact portable units, complete environmental control booths, total ambient air cleaning systems, central dust collection systems, downdraft tables, low-pressure source pickup hoods and high-pressure vacuum systems. Personnel will also provide hands-on application demonstrations.

Airgas 1118
259 Radnor-Chester Rd.
Radnor, PA 19087
(610) 902-6271; FAX (610) 225-7263
www.airgas.com

Alcotec Wire Corp. 916
2750 Aero Park Dr.
Traverse City, MI 49686
(616) 941-4111; FAX (616) 941-9154
www.alcotec.com

AlcoTec Wire will showcase its line of premium-quality aluminum welding, brazing and thermal spraying wire. The company produces all registered filler alloys for welding, in many sizes and packages. The company maintains rigorous statistical control over the entire manufacturing process with product traceability from the mine to individual spools. It will showcase its production methods, including a mechanical shaving process for aluminum wire that produces a high-quality surface free of surface oxides and abnormalities and the latest diemond wire drawing technology. The company's wire feedability process for welding wire ensures uniform, uninterrupted feeding of the filler metal through the welding equipment.

Allied Flux Reclaiming, Ltd./Harbert's Products Inc. 1471
501 S. Cedar Lane
Greencastle, PA 17225
(800) 377-3103; FAX (717) 597-1717
www.recycleflux.com

Allied Flux Reclaiming will exhibit its custom, closed-loop SAW flux/slag recycling equipment. Personnel will explain how the equipment returns the slag generated as recycled flux, which is environmentally friendly, performs with less dust and helps the user save money. Third-party testing is available for AWS, ASME and CWB welding applications.

Alphatex Co. 2059
No. 829, Chung Wha Rd.
Sec.1, Chung Li, Tao-Yuan Halen
Taiwan, R.O.C
886 3 4610505; FAX 886 3 4612504
www.alphatex.com.tw

America Fortune, Co. 2003
10107 Duchamp Dr.
Houston, TX 77038
(713) 774-5606; FAX (713) 774-1763

America Fortune will display gas cylinders manufactured by Beijing Tianhai Industry Co., the largest gas cylinder manufacturer in China, for which it is the exclusive agent. The company has imported DOT and TC gas cylinders for industrial and medical use since 1995, and it provides customers with DOT or

TC test report and product liability insurance for each gas cylinder. Engineers from the manufacturer will be on hand to answer questions.

American Cap Co., Inc. 2101
15 Church St., Wheatland, PA 16161
(724) 981-4461; FAX (724) 981-4495

American Engineering & Welding 775
8030 E. 47th St.
Indianapolis, IN 46226
(317) 541-8343; FAX (317) 545-8129
www.am-eng-welding.com

American Filler Metals Co. 970
6060 Donoho St., Houston, TX 77033
(713) 649-8785; FAX (713) 644-9628
www.amfiller.com

American Laser Spares 2157
24730 Crestview Ct.
Farmington Hills, MI 48335
(248) 474-5216; FAX: (248) 474-9277
www.americanlaser-spares.com

American Saw & Mfg., Co./Lenox 854
301 Chestnut St.
East Longmeadow, MA 01028
(800) 628-3030; FAX (413) 525-8867
www.lenoxsaw.com

American Society for Nondestructive Testing, Inc. (ASNT), The 534
1711 Arlingate Lane
Columbus, OH 43228-0518
(614) 274-6003; FAX: (614) 274-6899
www.asnt.org

American Tool Companies, Inc. 305
701 Woodlands Pkwy.
Vernon Hills, IL 60061
(800) 866-5740; FAX (937) 382-8199
www.americantool.com

American Tool will highlight its Record® forged, plated screw welding clamps and Vise-Grip® 9DR and 9SP locking C clamps. The Record clamps feature a copper-plated pad and acme thread screw that resists spatter buildup. The Vise-Grip clamps offer an extra throat width and depth of 3½ and 4¾ in., respectively; their greater reach and flex allow a range of sizes to be clamped without changing the adjusting screw.

American Torch Tip Co. 439
6212 29th St. E.
Bradenton, FL 34203
(941) 753-7557; FAX (941) 753-6917
www.americantorchtip.com

American Welder Repair 2432
9026 Kautzman Rd. No. 30
Billings, MT 59101-6102
(406) 656-7913; FAX (406) 652-0215
www.amwr.com

American Welder, The 0007
550 N.W. LeJeune Rd.
Miami, FL 33126
(305) 443-9353; FAX (305) 443-7559

American Welding Society 0001-0009
550 N.W. LeJeune Rd.
Miami, FL 33126
(800) 443-9353; FAX (305) 443-7559
www.aws.org

Certification. Visit the Certification Department booth and learn about the many certification programs now available from AWS. Details and application information will be available for the Senior Certified Welding Inspector, Certified Welding Inspector, Certified Welding Educator, Certified Welder, Accredited Test Facility and AWS NDE Inspector certification programs.

Conferences. AWS conference proceedings are available for purchase. Pick up the schedule of future AWS conferences and the latest conference brochures.

Education Get Educated! Visit the Education booth and receive information on seminars designed to prepare the welder for Certification. Learn all about the highly publicized S.E.N.S.E. program and ways to become a participating organization. Do you want to study at home? Now you can! Get answers about the Home Study Program intended for individuals who want to study at their own pace and in the comfort of their own home. Does your company

need to certify welders on site? Through the In-House Program we can certify welders right in your own facility. Experience the ambiance of a smaller class and the instruction of an expert in the field. This In-House program is customized to fit your needs. While at the booth, don't forget to ask about the new programs being developed to further advance your career. Free samples of Education literature will be available.

Foundation. The AWS Foundation booth will feature information about its mission and programs. District and National scholarship applications will be available, as well as applications for the Praxair International Scholarship and the Student Loan Program. Engineering Your Future instructor guides and Section Hole-in-One contest information can also be obtained. The Foundation's successful year will be described in the booth display along with recognition of our donors. Representatives will be on hand to answer questions and discuss such grassroots fund-raising programs as Section Investment Agreements, corporate gift interests and individual gift planning. Look for some special activities including an adventurous and memorable ride in a flight simulator. A repeat from last year will be the "Relaxation Station," where a staff of trained massage therapists will soothe showgoers' sore muscles.

Membership. Win valuable prizes by renewing your AWS membership at the Show! When you join or renew, your name is entered into our drawing. Drawings will be held throughout the week, increasing your chances of winning. New members will get 20% off when they join. Plus, knowledgeable staff will be on hand to answer all of your questions.

Publications. Browse the latest AWS technical books, audiovisuals and standards at the Publications Booth. Sample copies are available and staff will be on hand to take your order.

Welding Journal is AWS's official monthly magazine, specifically serving the welding and joining processes industry. It includes practical articles, welding product news, industry developments, AWS news, research papers, advertisements and much more. Winner of nine editorial awards in 1999, including Best-Written Magazine and Best In-Depth Reporting. Also featured will be *The American Welder*, the *Welding Journal's* new stand-alone supplement written specially for the hands-on welder.

Inspection Trends — The Magazine for Materials Inspection and Testing Personnel will also be featured. Launched in 1998, this AWS magazine serves the entire nondestructive examination industry, including all AWS Certified Welding Inspectors. Pick up a copy of all three magazines and meet editorial and advertising staff members in Booth 0009.

American Weldquip, Inc. 1258
P.O. Box 397
Sharon Center, OH 44274-0397
(330) 239-0317; FAX (330) 239-0031
www.weldquip.com

American Weldquip will exhibit its complete line of air- and water-cooled, hand-held, automatic and robotic GMA welding guns. New product developments include robotic torch conversion packages that feature rigid mounting brackets with integral tool-center-point maintenance features and a complete line of water-cooled automatic and robotic guns redesigned to significantly reduce the maintenance typically associated with water-cooled GMAW guns. The exhibit will also include demonstrations of the Tig-Point longitudinal tungsten electrode grinder.

AmeriSafe, Inc. 2275
2301 Highway 190 W.
DeRidder, LA 70634
(800) 897-9719; FAX (800) 450-1081

Ameritherm Inc. 2043
39 Main St., Scottsville, NY 14546-0801
(716) 889-9000; FAX (716) 889-4030
www.ameritherm.com

Ameritherm, a specialist in solid-state RF induction heating, will exhibit the new Atmospheric Brazing System (ABS). ABS cleanly brazes individual silver, copper and brass alloy parts in an inert atmosphere without oxidation, carbon buildup, flux or acid cleaning baths. The system, designed for in-line operation, brazes up to 48 parts/min at 1450–2200°F. A convenient touch screen interface provides automatic operation with complete manual override.

AMET Inc. 952
35 N. 1st East., Rexburg, ID 83440
(208) 356-7274; FAX (208) 356-8932
www.ametinc.com

AMET will display ArcSense, its latest weld monitoring system. This high-speed monitoring system performs real-time quality assessments with outstanding graphical displays. The system can be networked and will monitor multiple arcs. The latest ADVENT welding process control system will also be displayed. The company's turnkey welding systems provide complete programmed control of welding parameters and multi-axis coordinated motion. Graphical program creation, integrated real-time video display, high-speed data acquisition and sophisticated data analysis are available.

Ampco Metal Inc. 1828
P.O. Box 2004, Milwaukee, WI 53201
(414) 645-3750; FAX (414) 645-6466
www.ampcometal.com

Ampco Metal will exhibit copper alloy arc welding electrodes, filler metal and spooled wire for joining and surfacing applications involving wear, impact and corrosion. Products to be featured are available in aluminum bronze, nickel-aluminum bronze, manganese-nickel-aluminum bronze and deoxidized copper conforming to AWS, AMSE, MIL and federal specifications. The alloys are recommended for use with the shielded metal arc, gas metal arc and gas tungsten arc processes involving a wide range of similar and dissimilar metals.

Anderson Inc. 634
P.O. Box 977
Plymouth, IN 46563
(219) 935-0920; FAX (219) 935-0924

Anderson Products 728
1040 Southbridge St.
Worcester, MA 01610
(508) 755-6100; FAX (508) 755-4694

Anglo American Enterprises Corp. 1924
403 Kennedy Blvd.
Somerdale, NJ 08083
(856) 784-8600; FAX (856) 784-0085
www.saetools.com

Anval, Inc. 1768
301 Route 17, Ste. 800
Rutherford, NJ 07070
(201) 939-1065; FAX (201) 939-1608
www.anval.com

AOQC Moody International, Inc. 202
650 N. Sam Houston Parkway E.
Ste. 228
Houston, TX 77060
(281) 591-7882; FAX (281) 448-5602
www.aoqcmoody.com

Applied Robotics Inc. 843
648 Saratoga Rd.
Glenville, NY 12302
(518) 384-1000; FAX (518) 384-1200
www.arobotics.com

Applied Robotics will display its line of automation accessories, including QuickSTOP collision sensors, Smartscan safety light curtains, compliancy devices, PIAB vacuum products, XChange tool change systems, single-axis force sensors, PHD grippers and QuickConnect systems. The company's high-quality, reliable products are used widely in manufacturing, welding, assembly and material handling throughout the world.

Arc Machines, Inc. 416
10500 Orbital Way, Pacoima, CA 91331
(818) 896-9556; FAX (818) 890-3724
www.arcmachines.com

ARC Specialties 1767
P.O. Box 35539
Houston, TX 77016
(713) 631-7575; FAX (713) 631-2555
www.arcspecialties.com

Arc-Zone.com 2245
1181 Avenida Esteban #9
Encinitas, CA 92024-7106
(800) 944-2243; FAX (760) 634-8155
www.arc-zone.com

Arc-Zone will exhibit its line of proprietary, brand name and OEM replacement parts and accessories for GMAW, GTAW and plasma arc, including hand-held, mechanized and robotic torches. Also on display will be productivity-enhancing, high-performance torches, replacement parts, tungsten electrodes, quick-change GTAW adapters, state-of-the-art coolant additives, water coolers and robotic peripherals. Personnel will also be on hand to answer questions regarding welding, cutting and allied applications.

Arcon Welding L.L.C 452
2020 Northwood Dr.
Salisbury, MO 21801
(410) 860-0300; FAX (410) 860-0302

ArcOne 846
85 Independence Dr.
Taunton, MA 02780
(508) 884-9600; FAX (508) 884-9666

Arcone will display its line of welding and safety products. The company will present new singles and new shades of auto-darkening welding filters. It will display five welding helmet designs that are available in variable and passive shade selections. The company will introduce the Compact air series of powered air purifying respirators and supplied air respirators for welding, industrial, automotive and agricultural applications. Also on display will be its line of welding machines and accessories engineered to provide high-quality, reliable performance.

Arcsmith 1612
2601 Lockheed Ave.
Watertown, SD 57201
(800) 843-7912; FAX (605) 882-2100
www.arcsmith.com

Arctech Welding Electrodes & Wires Ind. Inc. 2210
Okcumusa Cad. Tezgul Ishani #2/6
Sishane, Istanbul 80020
Turkey
90 2122530501; FAX 90 2122530588
www.arctech.com.tr

Arctech, which began operations in 1993, will display its line of wires, electrodes, fluxes and equipment. The company's facilities have been checked and approved by international supervisory institutions such as ABS, BV, DNV, LRS, GL, TÜV and DB.

Armstrong-Blum Mfg. Co. 974
1441 Business Center Dr.
Mount Prospect, IL 60056
(847) 803-4000; FAX (847) 803-4019

ATI Industrial Automation 2137
503-D Highway 70 E.
Garner, NC 27529
(919) 772-0115; FAX (919) 772-8259
www.ati-ia.com

ATI Industrial Automation will exhibit its line of robotic end-effectors, including robotic tool changers for resistance welding applications. Also on display will be robotic tool changers featuring the company's patented No Touch Locking™ technology and the Protector line of robotic crash protection devices that feature automatic reset capability.

Atlantic China Welding Consumables, Inc. 2230
No. 2 Machongkou, Zigong
Sichuan 643010, China
868135101672; FAX 868135101200

Atlas Welding Accessories, Inc. 734
501 Stephenson Hwy.
P.O. Box 969, Troy, MI 48099
(248) 588-4666; FAX (248) 588-2706

Atlas will introduce its new line of in-plant protective enclosures and a new 500-lb welding positioner. It will also show a complete display of its lifetime guaranteed weld cleaning hammers and other products, such as specialty wrenches, C clamps, hose reels, pipe rollers and support stands, for the welding fabrication field.

Atlas-Raisen L.L.C. 868
9419 Wildwood Lake Dr.
Whitmore Lake, MI 48189
(734) 449-5254; FAX (734) 449-4690
www.atlasraisen.com

Auburn Mfg. Inc. 414
P.O. Box 220
Mechanic Falls, ME 04256
(800) 264-6689; FAX (207) 345-3380
www.auburnmfg.com

Auburn will display its line of high-temperature-resistant fabrics used for welding protection. The fabrics are available in forms for a variety of applications, from drop cloth to stress relief. The company manufactures more than 30 different fabrics to cover temperatures from 600° to 3000°F for industrial uses that include shipbuilding, power generation and petrochemical processing.

Aufhauser Corp. 2229
39 W. Mall, Plainview, NY 11803
(516) 694-8696; FAX (516) 694-8690

Avesta Welding Products, Inc. 1057
425 N. Martingale Rd., Ste. 2000
Schaumburg, IL 60102
(847) 413-4216; FAX (847) 517-4108

Avesta Welding Products will showcase its line of stainless steel welding consumables. On display will be a wide range of high-quality electrodes, flux cored wire, solid wire, welding strip, pickling pastes and fluxes. Personnel will be on hand to explain the company's technical assistance capabilities and its extensive network of distributors.

AWS Certification Dept. 0004
550 N.W. LeJeune Rd.
Miami, FL 33126
(800) 443-9353; FAX (305) 443-7559

AWS Cyber Cafe 0009
550 N.W. LeJeune Rd.
Miami, FL 33126
(800) 443-9353; FAX (305) 443-7559

AWS Education Dept. 0005
550 N.W. LeJeune Rd.
Miami, FL 33126
(800) 443-9353; FAX (305) 443-7559

AWS Foundation 0001
550 N.W. LeJeune Rd.
Miami, FL 33126
(800) 443-9353; FAX (305) 443-7559

AWS Inspection Trends Magazine 0007
550 N.W. LeJeune Rd.
Miami, FL 33126
(800) 443-9353; FAX (305) 443-7559

AWS Membership Dept. 0008
550 N.W. LeJeune Rd.
Miami, FL 33126
(800) 443-9353; FAX (305) 443-7559

AWS Technical Publications 0008
550 N.W. LeJeune Rd.
Miami, FL 33126
(800) 443-9353; FAX (305) 443-7559

Bear Paw Magnetic Tools Inc. 1801
4613 Aircenter Circle
Reno, NV 89502-5949
(775) 829-1810; FAX (775) 829-1819

Bear Paw Magnetic Tools will showcase its magnetic tools for metalworking lifting needs and offer demonstrations of the products. Highlighted will be inside, outside and adjustable angles for welding; sheet lifters and separators; crane assemblies; magnetic bars; base blocks; drill jigs; gun chucks and fishing tools.

Beijing Advanced Metal Materials Co., Ltd. 2154
Room 309, No. 30 Beiwalu
Beijing 100089, P.R. China
86 10 68410484; FAX 86 10 68410470
www.bam.com.cn

Beijing Advanced Metal Materials will exhibit its line of tungsten electrodes. Also showcased will be tungsten carbide-cobalt pellets and molybdenum powder for surfacing applications; hafnium and zirconium filler metals; titanium wire (ERTi-2, 3, 4 and ERTi-5); contact tips with triangular-shaped openings for welding wire; welding filter plates; and gouging electrodes.

Beijing Metals & Minerals Import & Export Corp. 2362
No. 5 Fangzhuang Lu, Zuoanmenwai
Beijing 100078, China
86 10 67649947; FAX 86 10 67620568

Beijing Metals and Minerals will exhibit its line of welding wires and electrodes for welding aluminum, nickel and copper.

Belchfire Corp. 2214
4916 N. 125th St., Butler, WI 53007
(414) 783-1500; FAX (414) 783-1700

Belchfire will highlights its line of torches, which are used by welding fabricators, cast iron and steel users and marine repair service shops, where welding codes and alloy content prescribe higher temperatures for welding. Foundries also use the torches to preheat, maintain interpass temperature, postheat in casting repairs and reduce moisture content, as well as prevent thermal shock in molds and ladle liner materials.

Belleville Area College 2088
2500 Carlyle Rd., Belleville, IL 62221
(618) 235-2700; FAX (618) 235-2874
www.becnet.edu

Bernard, Div. of DovaTech, LTD. 1428
449 W. Corning Rd.
Beecher, IL 60401
(708) 946-2281; FAX (708) 946-6726

Bernard will highlight its line of gas metal arc welding guns, including air-cooled and water-cooled, semiautomatic, fully automatic and robotic products, plus accessory and replacement items. The company's CustomSelect program enables end users and distributors to tailor product specifications to their individual needs, including cable length and torch configurations.

OBO Bettermann 1052
409 Parkway View Dr.
Pittsburgh, PA 15205
(412) 787-5970; FAX (412) 788-6627

Bluco Corp. 1170
509 Weston Ridge Dr.
Naperville, IL 60563
(800) 535-0135; FAX (630) 837-1847

Bluco will showcase its Demmeler modular fixturing system, which features a five-sided, high-strength steel table with an accurate grid pattern of bores on all sides. A patented positioning and clamping bolt locates and locks fixturing components with 3 tons of force. Tables up to 3000 X 1500 mm in size can be joined together for fixturing of larger parts. A compensating swing clamp fits into any bore to hold parts without distortion. Complex fixtures can be ready in a few hours; simple ones in a few minutes. On-site training, CAD database and training videos will be offered.

BMS, Inc. 601
4344 S. Main, Pearland, TX 77581
(281) 482-7007; FAX (281) 482-9216

BMS will provide information regarding the use of propylene as a fuel gas for the metalworking industry. Propylene, which is marketed under the HPG® name, is an economical and safe fuel gas for various metal working applications, including oxyfuel cutting, brazing, heating and thermal spraying. HPG is available in cylinders or in bulk storage of 1000 or more gallons. Also on exhibit will be a line of cutting, brazing and heating equipment for most OEM torches.

Bohler Thyssen Welding USA Inc. 2006
P.O. Box 721678, Houston, TX 77272
(800) 527-0791; FAX (281) 499-4347
www.btwusa.com

Bohler Thyssen Welding will feature its new stainless flux cored wires for all-position pipe welding; a full line of submerged arc, gas tungsten arc and gas metal arc consumables for high-temperature chromium P91 steels; and a Soudokay small-ID strip cladding head. Also highlighted will be a full line of high-quality electrodes, wires and fluxes from Bohler, Thyssen, Soudokay and UTP.

Bonal Technologies, Inc. 622
21178 Bridge St.
Southfield MI 48034
(248) 353-2041; FAX (248) 353-2028
www.bonal.com

Bonal Technologies will display its state-of-the-art, patented, nonthermal stress relief and weld conditioning technology. Highlighted will be the Meta-Lax 2600 microprocessor graphic certification system, the Meta-Lax 1700 graphic/manual certification system and the Meta-Lax Model 700 manual certification system. Information will be provided on how you can "certify" stress relief, virtually eliminate heat treat stress relief costs without sacrificing quality, improve fatigue life and reduce weld cracking and distortion.

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one supplier...
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Circle No. 75 on Reeder Info-Cerd

Please see us at the AWS Show, Booth 1407

Jackson Products, Inc. 2000

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SEE US AT AWS SHOW BOOTH 345

Circle No. 14 on Reader Info-Card

Bore Repair Systems Inc. 2135
Cheshire Tpk., Alstead, NH 03602
(603) 835-2409; FAX (603) 835-2609
www.borerepair.com

Bosch Automation Technology 1679
40 Darling Dr., Avon, CT 06001
(860) 409-7070; FAX (860) 409-7080

Bradford Derustit Corp. 617
P.O. Box 151, Clifton Park, NY 12065
(877) 899-5315; FAX (518) 899-6848
www.derustit.com

Bradford Derustit will feature its Derustit SS-3 stainless steel cleaner, which removes heat and flame coatings, scale, slag and other inclusions from stainless steel quickly and efficiently. Also on display will be B-P No.1 Brightener, a metal cleaner that provides a quick, economical method of removing heat stains, rust, discoloration and tarnish from the surface of many types of steel, copper, brass and other metals; and B-P Rust/Oxide Remover, which works effectively with no acid-handling problems. The chemical rust and oxide remover attacks rust, scales and oxides from ferrous and nonferrous metals.

Briggs and Stratton Corp. 758
P.O. Box 702,
Milwaukee, WI 53201-0702
(414) 259-5333; FAX (414) 259-5313
www.briggsandstratton.com

Briggs & Stratton will display various engines from its Standard, I/C, Intek and Vanguard lines of air-cooled gasoline engines in the 3 to 25 hp range, as well as Vanguard liquid-cooled gasoline and diesel engines from 18 to 31 hp.

British Federal-North America 273
1100 N. Opdyke, Ste. 100
Auburn Hills, MI 48326
(248) 371-0202; FAX (248) 371-0290

Broco, Inc. 624
8690 Red Oak St.
Rancho Cucamonga, CA 91730
(909) 483-3222; FAX (909) 483-3233
www.brocoinc.com

BTU Contracts, Inc. 954
6432 N. Ridgeway Ave.
Lincolnwood, IL 60645
(847) 673-7790; FAX (847) 673-7794
www.btucontracts.com

BTU Contracts, a supplier of major bulk industrial gases, will provide information on its products, including propylene. Propylene is a safe, economical, high-performance fuel for metalworking and is recommended for use in many HVOF thermal spray processes. Personnel will be on hand to discuss a variety of bulk and cylinder delivery systems.

Bug-O Systems Equipment 1139
3001 W. Carson St.
Pittsburgh, PA 15204
(800) 245-3186; FAX (412) 331-0383
www.bugo.com

Bug-O Systems will demonstrate its new MDS cladding system. This system was designed for use on large areas, such as pulp digesters and boiler tubes. Also shown will be its modular drive system, which can run on three different rail systems, and the company's standard straight-line cutting and welding systems.

Burny/Cleveland Motion Controls Inc. 1142
7550 Hub Pkwy., Cleveland, OH 44125
(800) 321-8072; FAX (216) 642-2199
www.burney.com

Cleveland Motion Controls will exhibit its family of BURNY® controls for new or older oxygen cutting machines, including BURNY shape-cutting controls, Servopak® drive systems for x-y axis control, Replicator® tracing systems for template following, Levitator® systems for torch height control and fully integrated control systems. Featured will be the new BURNY10®, an open architecture PC-based control using Windows NT®-based software, and the new Replicetor CCD pattern tracing system with advanced video-imege-capture technology, which maximizes quality, speed and reliability.

Burr King Mfg., Co. Inc. 1782
3 Tamara Lane, Warsaw, MO 65355
(660) 438-8998; FAX (660) 438-8991

C & G Systems, a Thermadyne Co. 1416/1228
1401 Glenlake Ave., Itasca, IL 60143
(630) 467-0600; FAX (630) 467-0606
www.cgsystems.com

C. K. Worldwide Inc. 1616
3501 C St. N.E., Auburn, WA 98002
(253) 854-5820; FAX (253) 939-1746
www.ckworldwide.com

C. K. Worldwide will introduce new ways for GTA welding users to save up to 40% on their argon costs without sacrificing weld quality, speed or appearance. C. K. will also show inexpensive, portable, semiautomatic equipment that will increase GTA welding productivity up to three times that of manual welding operations. Also on display will be a portable, inflatable purge welding chamber, new large-diameter gas lens (1.125-in. ID) with a clear nozzle designed for use in welding reactive metals. The company will also display its line of patented GTA welding torches, parts and accessories.

C-Spec 2062
2291 Heritage Hills Dr.
Pleasant Hill, CA 94523
(925) 943-1120; FAX (925) 930-8223
www.capec.com

C-Spec will showcase its software for code-intelligent and code-aware management of welding procedures, welder qualifications and NDE reports in accordance with ASME, AWS and EN requirements. The software allows users to automatically create or review WPSs, PQRs and WPQs for code compliance. The company offers complete production weld management systems for plants, fabrication shops and construction projects.

C. H. Symington & Co., Inc. 549
77 E. Wilson Bridge Rd., Ste. 104
Worthington, OH 43085
(614) 848-4821; FAX (614) 848-4861

C. H. Symington will display a line of Symex gouging torches, parts, electrodes, ground clamps, cable connectors and related accessories. The company will also feature its new Symex Star-Trac II automatic gouging torch, the Star-Trac I semiautomatic gouging torch and the S-66 torch with the patented 360-deg swivel cable.

Caldwell Group, The 544
5055 26th Ave., Rockford, IL 61109
(800) 628-4253; FAX (815) 229-5686

Canadian Welding Bureau, a Div. of the CWB Group 653
7250 W Credit Ave.
Mississauga, Ontario L5N 5N1, Canada
(905) 542-1312; Fax (905) 542-1318
www.cwbgroup.com

CWB personnel will be on hand to provide information on CWB Group-Industry Services, a nonprofit, independent organization that provides specific services through its three divisions. The Canadian Welding Bureau provides certification of welding operations for steel, aluminum, reinforcing bars, resistance welding, welding consumables, welding inspection organizations, welding and metal product inspectors and manufacturers of steel building systems. Quasar provides ISO 9000 and QS 9000 certification/registration and auditor training. Gooderham Centre for Industrial Learning provides WELD_IT software, modular learning systems and in-plant training.

Carborundum Abrasives North America 513
1 New Bond St., P.O. Box 15008
Worcester, MA 01615-0008
(800) 286-2849; FAX (508) 795-5489
www.carborundumabrasivee.com

Carborundum Abrasives will features its full line of stock products for welding applications. Grinding wheel products displayed will include Premier Red depressed center and cutoff wheels and portable snagging cones and plugs. Coated abrasive products shown will include backstand grinding belts, sanding sheets, conventional and flap discs for portable grinding, and surface finishing products including belts, rolls, sheets and unified wheels.

Carris Reels, Inc. 2246
439 West St., Rutland, VT 05701
(802) 773-9111; FAX (802) 770-3581
www.carris.com

Carris Reels will showcase a complete line of reels for the welding wire industry. The company offers nailed wood, plywood, masonite, light-duty steel spoke and stamped metal spools, as well as a complete selection of plastic spools and wire baskets. The company's packages handle all bulk requirements from 30–1000 lb. It will also provide information on its reel management and recycling services.

Cebora S.p.A. 941
Via Andrea Costa 24
Cadriano Di Granarolo (Bologna)
40057, Italy
39 51 765000; FAX 39 51 765222
www.cebora.it

Cebora will feature a full line of welding machines for a variety of processes, including SMAW, AC and DC GTAW and GMAW. It will also display plasma arc cutting machines. Featured will be its new line of sinusoidal absorption, single-phase, inverter-based power sources that allow for a savings of approximately 30% of absorbed power, for the same or greater power delivery for welding or cutting.

Centerline (Windsor) Limited 936
P.O. Box 7068
Windsor, Ontario N9C 3Y6, Canada
(519) 734-8464; FAX (519) 734-1369
www.cntrline.com

Ceodeux, Inc. 658
221 Westec Dr.
Mount Pleasant, PA 15666
(724) 696-4340; FAX (724) 696-4364

Cerbaco Ltd. 2122
2899 Nostrand Ave.
Brooklyn, NY 11229
(718) 252-9200; Fax (718) 252-9201

Cerbaco will provide samples from its line of more than 500 configurations of nonmetallic weld backings that permit finished-quality, full-penetration welds from one side. Where one-sided welding is undesirable, the backings eliminate the need for arc gouging or heavy grinding prior to second-side welding. The company specializes in furnishing custom configurations and formulations. Technical assistance and demonstrations of free custom-design services will be offered.

CGW Abrasive Mfg., USA 2336
7530 N. Caldwell Ave., Niles, IL 60714
(800) 447-4248; FAX (800) 447-3731

Champion Laboratories, Inc. 1571
200 S. Fourth St., Albion, IL 62806
(618) 445-5413; FAX (618) 445-5496

Champion Laboratories will feature Eurofilter USA dust control cartridge filters, designed for use in all major brands of pulse-jet collectors, and the Vantage V+ cartridge collector for dust and fume control. With the V+ design, cartridges are secured at top and bottom for increased durability and longer service life, and are easily accessed from the outside to minimize exposure and downtime for change-out.

Chemclean Corp. 203
130-45 180th St.
Springfield Gardens, NY 11434
(718) 525-4500; FAX (718) 481-6470
www.chemclean.com

Chicago Protective Apparel 409
8140 N. Ridgeway
Skokie, IL 60076
(847) 674-7900; FAX (847) 674-7906
www.chicagoprotective.com

China National Wujin Mahang Welding & Cutting Plant 647
No. 145#, Hedong St. Mahang, Wujin
Jiangsu, Province 213162, P. R. China
86 05 46706120; FAX 86 05 46701045

Chosun Steel Wire Co. 964
253 N. Santa Fe Ave., P.O. Box 45
Salina, KS 67401
(888) 424-6786; FAX (785) 827-5604

Clausing/Metal Muncher 939
1819 N. Pitcher St.
Kalamazoo, MI 49007
(616) 345-7155; FAX: (616) 345-5945
www.clausing-industrial.com

Cleveland Convention & Visitors Bureau 747
50 Public Square, Cleveland, OH 44113

Cloos Robotic Welding, Inc. 231
911 Albion Ave.
Schaumburg, IL 60193
(847) 923-9988; FAX (847) 923-9989

CML USA, Inc. 2072
10227 General Dr., Orlando, FL 32824
(407) 857-1122; FAX (407) 851-3009
www.bcity.com/ercolina

CMS Gilbreth-Dissolvo 356
3001 State Rd., Croydon, PA 19021
(215) 785-3350; FAX (215) 785-4017
www.dissolvo.com

CMW Inc. 139
70 S. Grey St., Indianapolis, IN 46201
(317) 634-8884; FAX (317) 638-2706
www.cmwinc.com

CNI-Ceramic Nozzles, Inc. 1925
23L Commerce Rd., Fairfield, NJ 07004
(973) 276-1535; FAX (973) 276-1537

Codeware 746
11221 Richmond Ave., Ste C-103
Houston, TX 77082
(281) 497-5705; FAX (281) 497-5839
www.codeware.com

Colorado School of Mines 1986
Center for Welding, Joining and Coatings Research, Golden, CO 80401
(303) 273-3797; FAX (303) 384-2189

Comac USA Inc. 871
532 Route 15, Sparta, NJ 07871
(973) 579-3400; FAX (973) 579-3222
www.ita.cc

COMEQ, Inc. 1019
P.O. Box 207
White Marsh, MD 21162-0207
(410) 933-8500; FAX (410) 933-1600
www.comeq.com

Computer Eng., Inc. 2324
509 N.W. 5th St.
Blue Springs, MO 64014
(816) 228-2976; FAX (816) 228-0680
www.computereng.com

Computer Engineering will demonstrate the all-new Welding Pro-Write for Windows™ and AWS Welding. Both software programs have PQRs, WPSs, WPQs, welder management and built-in code checking features.

Computer Weld Technology, Inc. 1358
4544 S. Pinemont, Ste. 200
Houston, TX 77041
(713) 462-2118; FAX (713) 462-2503
www.cweldtech.com

Computer Weld Technology will offer information on its solutions for automating, controlling and monitoring the welding process. Products on display will include the Thru-Arc™ tracking system, which is designed to track a weld joint through the arc with no physical contact to the workpiece; the ADM IV™ arc data monitor; and the WDL II™ weld data logger, which is used in quality control/quality assurance applications and documentation for ISO 9000 and QS 9000 requirements.

Computers Unlimited 2044
2407 Montana Ave., Billings, MT 59101
(406) 255-9500; FAX (406) 255-9595
www.cu.net

Computers Unlimited will display its TIMS (total information management system) software, which it has been providing to gases and welding distributors for 21 years. The software provides a complete package for order entry, inventory management and cylinder control.

Conam Inspection Inc. 528
192 Internationale Blvd.
Glendale Heights, IL 60139
(800) 982-6626; FAX (630) 681-0009
www.conaminsp.com

Conam Inspection will showcase its comprehensive nondestructive inspection services, metallurgical and chemical analysis and mechanical testing services for a broad range of industries. The company has more than 750 professionals on staff and maintains a network of nationwide facilities to serve its customers.

Continental Abrasives 2414
16871 Noyes Ave.
Irvine, CA 92606
(949) 474-1101; FAX (949) 863-3078

Contour, Div. of Jackson Products 1407/1411
2997 Clarkson Rd.
Chesterfield, MO 63017
(636) 207-2750; FAX (636) 207-2810
www.jackprod.com

Contour Products, a division of Jackson Products, will display its precision layout and measur-

ing tools that are long lasting and easy to use. The tools help bring precision to any layout task. Laterials, ellipses or oblong circles can be made on any irregular flat or round surface. The tools require no complicated formulas and no more cut and try for needless material waste.

Contract Fusion Inc. 228
977 Waterman Ave.
East Providence, RI 02914
(800) 562-9270; FAX (401) 431-0237
www.cfistudwelding.com

Contract Fusion will show its new 550XL industrial miniature stud welding machine, which offers a fast, reliable end cost-effective way to instantly attach studs and other small weldable parts to most similar and dissimilar metals. Small studs from 0.018 to 0.107 in. in diameter can be welded instantly without annealing, distortion or discoloration. Typical applications include short production runs, R&D and prototyping. The machine will fit on any benchtop and is easy to set up and operate. The company will also provide information on its in-house fusion welding services.

Controls Corp. of America 1928
1501 Harpers Rd.
Virginia Beach, VA 23454
(800) 225-0473; FAX (757) 422-3125
www.concoa.com

CONCOA will present gas distribution systems necessary for Industrial CO_2 lasers, including products used in the delivery of the resonator, purge and assist gases. The Laser Edge Solution Software for distributors will be on line during the show. In addition, pressure and flow control equipment and distribution systems for all industrial gas applications will be featured. A complete line of gas epparatus for oxyfuel cutting, welding and heating will also be on display.

Convergent Energy 2152
1 Picker Rd., Sturbridge, MA 01566
(508) 347-2681; FAX (508) 347-5134
www.convergent-energy.com

Convergent Energy will highlight its full line of products, which includes lasers and laser systems. The company offers CO_2 lasers ranging from 225 W to 45 kW and Nd:YAG lasers up to 500 W average power. The company designs and integrates standard and custom turnkey laser systems for a wide variety of welding and metal processing applications.

Cooper Power Tools 635
P.O. Box 1410, Lexington, SC 29071
(803) 359-1200; FAX (803) 359-2013

COOPTIM Ltd. 866
Petofi S.u. 21, Oload H-2049, Hungary
36 23 382409-109; FAX 36 23 382321
www.cooptim.hu

Cor-Met, Inc. 1054
12500 E. Grand River
Brighton, MI 48116
(800) 848-2719; FAX (810) 227-9268

Cor-Met will feature its nickel-, cobalt- and iron-based specialty cored wire and coated electrodes for joining, cladding and hardfacing. Highlighted will be its large-diameter electrodes,in sizes up to 20 mm.

Corex 1805
400 Trade Square East
Troy, OH 45373
(937) 332-4000; FAX (937) 332-5224
www.hobartbrothers.com

Corex will exhibit a complete line of high-quality tubular and metal cored wires, which includes self-shielded, gas-shielded and low-alloy flux cored wires and metal cored wires. The wires are available in a wide variety of package sizes. Company engineers and sales staff will be available to answer all of your filler metal questions and make product recommendations.

Crouse-Hinds Molded Products 362
4758 Washington St.
LaGrange, NC 28551
(919) 566-3014; FAX (919) 566-9537

Cryogas International 822
5 Militia Dr., Lexington, MA 02421
(781) 862-0624; FAX (781) 863-9411
www.cryogas.com

Cryogenic Industries/ ACD 972
25720 Jefferson Ave.
Murrieta, CA 92562
(909) 696-7840; FAX (909) 698-7484
www.cryoind.com

Cryostar U.S.A. 236
2670 Lehigh St., Whitehall, PA 18052
(610) 231-0210; FAX (610) 231-1522
www.cryostar.fr

Cryostar USA will feature its line of cryogenic equipment, including cryogenic pumps and turbomachinery for industrial gas, petrochemical and natural gas applications. The compeny offers centrifugal and reciprocating pump units from process and transfer to HP pumps for LOX, LIN, Lar and CO_2 ser-

vices, as well as high-efficiency expansion turbines for air separation and liquefier plants complete with the controls and subsystems. A compressor, oil brake, generator or combination alternatively can drive the company's turbines.

CTR, Inc. 116
298 Porter Rd., Rock Hill, SC 29730
(803) 324-8101; FAX (803) 324-8187
www.ctrinc.com

CVI 1802
2288 Westbrooke Dr.
Columbus, OH 43228
(614) 529-5431; FAX (614) 876-5648
www.chart-ind.com/CVI

CVI, a Chart Industries company, will showcase its line of high-quality cryogenic equipment. The company manufactures a wide range of products, from cryogenic pumps, valves and vacuum-insulated pipe to high-pressure filling plants. Featured will be the PD series of high-pressure cryogenic pumps that feature a low-maintenance design, easy serviceability and a strong performance warranty. These pumps are designed for industrial companies, chemical processing plants, cylinder filling distributors, medical oxygen suppliers and other critical applications.

Cypress Welding Equipment Inc. 1141
P.O. Box 690168, Houston, TX 77269
(281) 469-0746; FAX (281) 469-9354

D. L. Ricci Corp. 258
P.O. Box 527
Red Wing, MN 55068
(651) 388-8661; FAX (651) 388-0002
www.dlricci.com

DAIHEN, Inc. 2201
761 Crossroads Ct.
Vandalia, OH 45377
(937) 454-9660; FAX (937) 454-9661
www.daihen-usa.com

DAIHEN, a leading manufacturer of welding power supplies, plasma cutters and robots, will exhibit the Turbo Pulse DF, capable of GMA and aluminum welding, plusGTA welding systems, spool guns and plasma cutters ranging from portable to 120 amps. The company's robotic products vary from a portable robotic welding system to a material handling system with 255-lb payload. The product line also includes a variety of "weld ready" standard robotic cells.

Dake 152
724 Robbins Rd.
Grand Haven, MI 49417
(616) 842-7110; FAX (616) 842-0859
www.dake-div-jsjcorp.com

DALEX-WERKE Niepenberg GmbH & Co. KG 832
P.O. Box 1162/1163
Wissen, Federal Republic of Germany
49 2742 77346; FAX 49 2742 77125
www.dalex.de

DALEX will exhibit its entire range of products including gas shielded arc welding machines, welding rectifiers and transformers, plasma cutting machines, resistance welding machines (AC/DC), portable spot welding guns and medium frequency resistance welding machines, memorized program welding control units and CNC program control units and water recooling units.

Dalloz Safety (Willson/ Bilsom) 421
P.O. Box 622
Reading, PA 19603-0622
(610) 371-6161; FAX (610) 371-7874
www.cdalloz.com

Dalloz Safety, formerly Willson Safety, will exhibit its complete line of eye and face, respiratory and hearing personal protection equipment for welding applications. The company's products include disposable, reusable and supplied air respirators and welding-specific filters and cartridges; safety spectacles with shade lenses; clear and shaded visors; and hearing protectors including earmuffs, earplugs and canal caps.

Darco Southern, Inc. 407
P.O. Box 454, 254 Darco Dr.
Independence, VA 24348
(540) 773-2711; FAX (800) 327-2610
www.darcosouthern.com

Darco Southern manufactures high-temperature textiles for applications to 3000°F. All products are asbestos-free and ceramic-free. Products showcased will include cloth, tape, rope, sleeving, batting, welding curtains/blankets, aprons, mittens, boots and kneeling pads.

Dataweld, Inc. 1155
1909 Citizens Bank Dr.
Bossier City, LA 71111
(318) 746-6111; FAX (318) 746-0323
www.dataweld.com

DCE, Inc. 654
11301 Electron Dr.
Louisville, KY 40299
(502) 267-0707; FAX (502) 267-3074

De-Sta-Co Industries 1532
2121 Cole St.
Birmingham, MI 48009
(248) 594-5650; FAX (248) 644-3929
www.destaco.com

Del Littgates, Inc. 1493
190 Lewis St.
P.O. Box 6126
Buffalo, NY 14240-6126
(716) 853-7994; FAX (716) 854-5424
www.liftgate.com

Deneb Robotics, Inc. 816
5500 New King St.
Troy, MI 48098
(248) 267-9696; FAX (248) 267-8458
www.deneb.com

Deneb Robotics will showcase its UltraArc™ interactive 3-D graphics-based engineering tool specifically for designing, programming and optimizing robotic arc welding applications through simulation and analysis. UltraArc enables the user to thoroughly analyze workcell performance, optimize cell configuration and debug the process plan before any tooling is purchased or fabricated. From the simulated model, UltraArc can automatically generate and download robot motion and process programs to achieve a highly efficient robot arc welding system.

Dengensha America Corp. 2132
7647 First Place Dr.
Bedford, OH 44146
(440) 439-8081; FAX (440) 439-8217

Dengensha America will exhibit a fully operational resistance spot welding machine equipped with an automatic weld nut feeder as well as a servo-operated spot weld gun. Also on display will be a portable welding transformer with an integrated weld timer/contactor and a resistance weld monitor featuring a waveform and/or numeric printer with an 800-weld memory.

Deutz Corp. 2028
3883 Steve Reynolds Blvd.
Norcross, GA 30093
(770) 564-7100; FAX (770) 564-7222
www.deutz.da

DEUTZ is a worldwide manufacturer of diesel and gas engines covering a comprehensive power range from 6 to 10,000 hp. The company now can be reached toll-free, 24 hours for emergency parts and service information at (800) 241-9886.

Devasco Int'l, Inc. 458
9618 W. Tinwall
Houston, TX 77041
(713) 690-8977; FAX (713) 690-7354

Direct Wire & Cable, Inc. 220
P.O. Box 57
Denver, PA 17517
(717) 336-2842; FAX (717) 336-0505

Divers Academy of the Eastern Seaboard, Inc. 2087
2500 S. Broadway
Camden, NJ 08104
(609) 966-1871; FAX (609) 541-4355
www.diversacademy.com

DO ALL 1282
254 N. Laurel Ave.
Des Plaines, IL 60016
(847) 803-7250; FAX (847) 803-7269

DO-Ceram Engineered Ceramics Co. Ltd. 343
Hessiingsweg 65-67
Dortmund-Brackel
NRW D-44309, Germany
49 23192502520;
FAX 49 23192502570
www.yarngulde.net/doceram

DO-Ceram Engineered Ceramics manufacturers advanced ceramic components and is a leading producer of centering pins for resistance welding. The company will feature its DO-Ceram Cerazur, which helps users meet today's stingent requirements such as high heat-resistance, mechanical toughness, electrical insulation and surface anti-sticking characteristics. When using DO-Ceram Cerazur, optimum process safety, long life and high precision are the results.

Doringer Cold Saws 229
13400 Estrella Ave.
Gardena, CA 90248
(310) 366-7766; FAX (310) 366-7573
www.doringer.com

DovaTech, Ltd. 1428
449 W. Corning Rd.
Beecher, IL 60401
(708) 946-2281; FAX (708) 946-6726

DovaTech is the business entity having domestic and international manufacturing, marketing, engineering, sales and distribution responsibilities for the Bernard, Weldcraft, PlazCraft and K&K brand welding and cutting products. It operates manufacturing plants in Beecher, Ill., Lake Zurich, Ill., Burbank, Calif., and at D-Tech, its subsidiary in Kranenburg, Germany. In addition to the complete lines of K&K, Weldcraft and PlazCraft torches and accessories, DovaTech will showcase a working robotic work cell with the new integrated Bernard robotic torch package.

Drillco Cutting Tools 2452
12649 S. Choctaw Dr.
Baton Rouge, LA 70815
(334) 626-5171; FAX (334) 621-0017

Dynabrade, Inc. 716
8969 Sheridan Dr.
Clarence, NY 14031
(800) 828-7333; FAX (716) 631-2073
www.dynabrade.com

Dynaflux, Inc. 823
241 Brown Farm Rd.
Cartersville, GA 30120
(800) 334-4420; FAX (770) 382-9034

Eagle Bending Machines, Inc. 2047
P.O. Box 189
Bay Minette, AL 36507
(334) 937-0947; FAX (334) 937-4742
www.eaglebendingmachines.com

Eastern Etching & Mfg. Co. 652
Foot of Grape St.
Chicopee, MA 01003
(413) 594-6601; FAX (413) 594-6600
www.eastern-etching.com

Edwards Mfg Co. 956
P.O. Box 166, Albert Lea, MN 56007
(507) 373-8206; FAX (507) 373-9433
www.edwardsironworkers.com

Elderfield & Hall, Inc. 303
775 W. Jackson Blvd., 5th Floor
Chicago, IL 60661-5408
(800) 747-9353; FAX (312) 930-9499
www.kooltools.com

In addition to its SynchroTig 4 GTAW Wire Feeder, Elderfield & Hall will exhibit and demonstrate two new GTAW power supplies: a 200-A AC/DC power supply with single phase power input and a 320-A AC/DC power supply with an integrated water cooler, featuring 100% duty cycle at 300-A output. Both machines feature very precise, soft arcs. Also introduced will be the new 300-A, single phase, GMAW power supply, which features 180-A output at 100% duty cycle.

Electro-Max Mfg. Co. 930
6522 Diplomat Dr.
Sterling Heights, MI 48314
(810) 997-9751; FAX (810) 997-9726

Electrode Dressers, Inc. 443
4506 Roger B. Chaffee S.E.
Grand Rapids, MI 49506
(616) 538-6224; FAX (616) 538-6777
www.electrodedressers.com

Electron Beam Technologies, Inc. 1122
1275 Harvard Dr.
Kankakee, IL 60901
(815) 935-2211; FAX (815) 935-8605
www.electronbeam.com

Electron Beam Technologies will display samples of POLY-XL® jacketed GMAW welding and plasma cutting composite/coaxial power cable. This cable is available to original GMAW/plasma torch manufacturers. The new Fast 'n Easy®, wire feeder and Straight 'n Easy® wire straightener will be demonstrated along with the QCC and ERC conduits. The company's GMAW welding conduit systems are designed to provide a flexible, insulated wire guide from a remote wire package up to the wire feeder. All equipment is designed for long life to reduce welding costs. Applications engineers will be available to discuss your cable and conduit requirements.

Elocab Tailor-Made Cables 216
258 McBrine Dr.
Kitchener, Ont. N2R 1H8, Canada
(519) 893-1155; FAX (519) 893-2766
www.elocab.com

Elocab Tailor-Made Cables has no one-size-fits-all products. Each cable is designed and manufactured to precise customer needs, resulting in higher reliability and better cost efficiency. Tailor-made cables come in quantities as small as 300 ft. with 3–6 weeks delivery. Applications include automation, robotics, inspection, controls, etc. In Europe, the company wires 80% of all spot welding robots operated by the automobile industry. The company's bestselling power and control cables sporting UL-approved halogen-free PUR jacketing will be highlighted.

Emhart Fastening Teknologies 121
49201 Grallot
Chesterfield, MI 48051
(810) 949-0440; FAX (810) 949-0443
www.emhart.com

Encompass Engineering LLC 205
461 Park Ave., STE 100
Lake Villa, IL 60046
(847) 265-2940; FAX: (847) 265-2944

Engelhard Corp. 2231
235 Klivert Rd., Warwick, RI 02886
(401) 739-9550; FAX (401) 739-9555

Engelhard will showcase its complete line of brazing alloys, brazing fluxes, lead free solders and soldering flux. State-of-the-art facilities enable the production of consistently high-quality products. Its Silvaloy Brazing Alloys are available in a wide variety of forms: wire, rods, sheet, plymetal, rings, washers and other specialty preforms; and the company's automatic brazing systems feature leading edge technology, reliability and value.

Entron Controls, Inc. 445
465 E. Randy Rd.
Carol Stream, IL 60188
(630) 682-9600; FAX (630) 682-3374

Environmental Air Solutions 509
1482 High Country Rd.
Coralville, IA 52241-1110
(319) 358-7794; FAX (319) 358-7794
www.neu-air.com

Environmental Air Solutions will feature its system that can ven-

Guaranteed For Life!

For over 60 years, Atlas has manufactured the best weld cleaning hammers available. We have always stood behind our hammer quality and durability, and now we're making it official.

Atlas hammers are
GUARANTEED FOR LIFE!

When cleaning slag, we guarantee our head-to-handle connection against coming apart, and our hammer heads against chipping, cracking, or breaking. If any of these events occur, we will repair or replace the hammer free of charge.

Some knock-offs are trying to pass themselves off as original Atlas tools, but they miss the point when it comes to quality. Rigorous impact testing proves that Atlas outlasts the look-a-likes 10 to 1.

What makes Atlas hammers the best?

- ☐ The original head-to-shaft cross pin design provides the strongest joint...heads won't fly off the handle.
- ☐ Forging grade steel with mill certification analyses substantiates uniformity.
- ☐ Heads are induction heat treated providing hardness and maximum toughness.
- ☐ Hammers meet or exceed Federal Specifications for performance and safety.
- ☐ Black Oxide finish is rust resistant, and will not peel, chip, or flake...unlike paint.

Circle No. 16

You just can't beat quality at a fair price
Found only where quality welding products are sold.

ATLAS WELDING ACCESSORIES, INC.
P.O. Box 969 ◆ Troy, MI 48099
248-588-4666 ◆ Fax 248-588-3720

Always Guaranteed Quality with ATLAS

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

ATLAS Pipe Supports
Four head styles:

- ◆ V-head
- ◆ Ball caster transfer
- ◆ Bar stock roller
- ◆ Dual wheel roller

Circle No. 166

ATLAS Roller Stands
Three head styles:

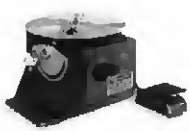
- ◆ Dual wheel roller (steel or stainless)
- ◆ Dual wheel (rubber)
- ◆ Ball caster transfer

Circle No. 165

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. 164



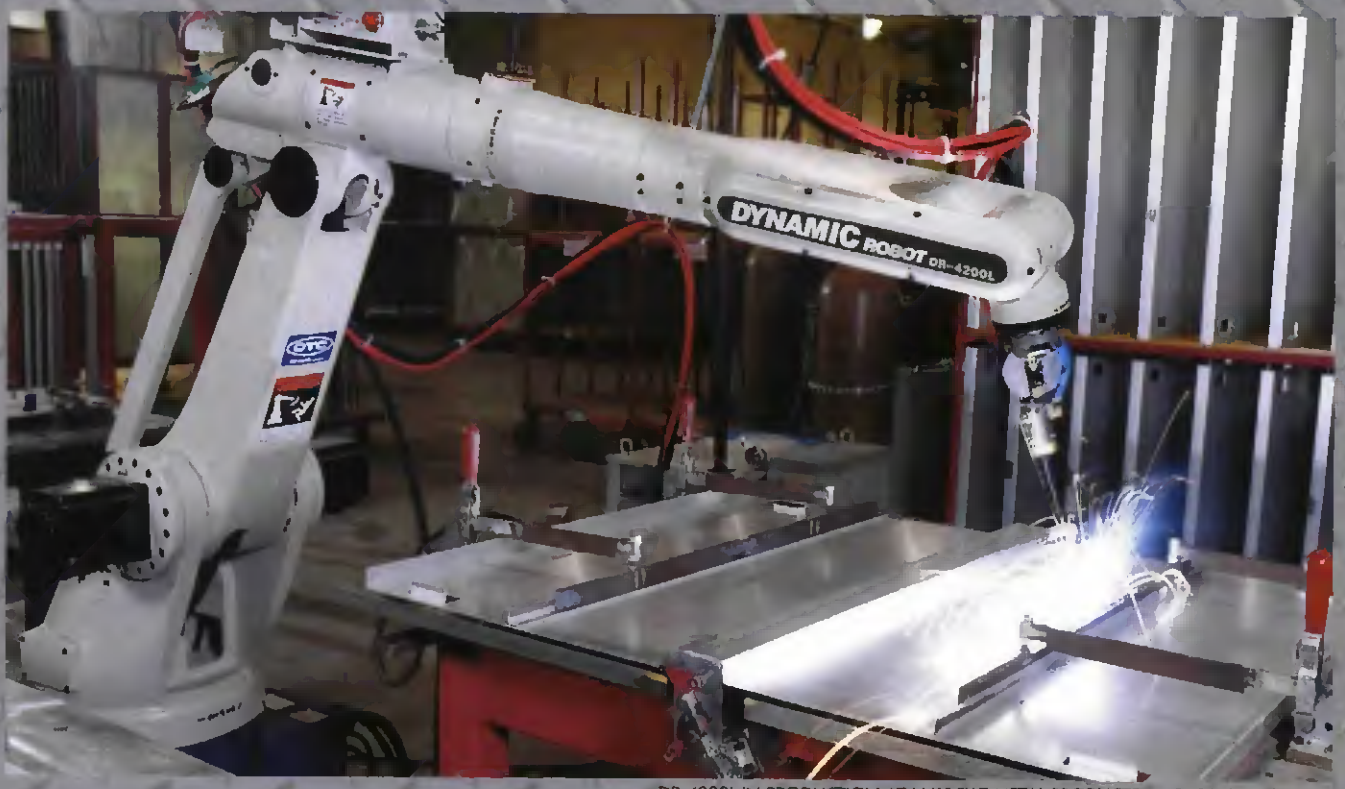
ATLAS Rotary Table Positioners

- ◆ 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

Circle No. 44

AWS Show Booth #734

WHO SAYS WELDING ALUMINUM IS TOUGH?



DR-4200L IN PRODUCTION AT MAYVILLE METAL PRODUCTS — CASA GRANDE, AZ

DAIHEN Makes It Simple!

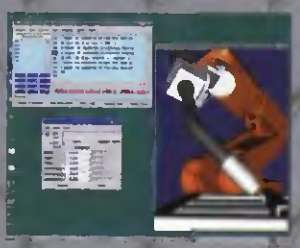
FLEXIBLE AUTOMATION OR MANUAL WELDING

Whether you're welding large aluminum automobile components or small aluminum parts, DAIHEN can provide a single source welding system that's right for you.

Our cutting edge welding equipment and robot technology offer high speed, dependable productivity, and superior aluminum welds every time.

WELDING ROBOTS

The easy teach method of our robots gets you up and running quickly with no particular operator skill required. Specially designed wire feeders and torches work in conjunction with power source features that enable smooth wire feeding with perfect arc starts and arc ends.



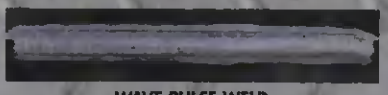
OTC-95 OFFLINE PROGRAMMING

Economical and user-friendly offline programming is available. This allows production-ready part programming while the robot is in operation on other jobs, saving you valuable production time.

Stand-alone systems, in addition to complete plug and play robot cells with pre-engineered safety features, are available for immediate installation and operation.

WELDING POWER SOURCES

DAIHEN pulse MIG systems offer patented fuzzy logic control features that automatically control arc voltage — greatly simplifying weld parameter settings and ensuring ideal arc conditions. The wave pulse option provides a TIG bead appearance with the higher speed of MIG welding, while minimizing the risk of blow holes and crack susceptibility.



WAVE PULSE WELD

By combining AC with DC output, our TIG power sources offer flexible arc control for a very focused arc. This delivers narrow beads with deep penetration.

TURBO PULSE 350 / 500 DF

ACCUTIG 300P

No matter what your aluminum welding needs are, give us a call. We'll be glad to show you just how simple it can be.

Total Technology, Single Source

www.daihen-usa.com

SEE US AT AWS SHOW BOOTH 2201

OTC DAIHEN Inc.

DAIHEN Inc.

761 Crossroads Ct.
Vandalia, OH 45377
937-454-9660

5311 W.T. Harris Blvd. W.
Charlotte, NC 28269
704-597-8240

Circle No. 107 on Reader Info-Card

tilate without the loss of heat. The "old," hot air is taken from the ceiling and blown outside As the air is being blown outside, it is being used to heat the fresh air being brought in from the outside. Environmental Air Solutions removes welding fumes, carbon monoxide, diesel smoke, blue smoke from CNC machines and anything else that goes in the air. References in your industry are available upon request.

EquoTip Associates 141
140 Industry Dr., RIDC Park W.
Pittsburgh, PA 15275-1028
(412) 788-8976; FAX (412) 788-8984

EquoTip Associates will highlight its portable metal hardness tester and all of its accessories, including impact devices for specific problems such as between gear teeth and large castings, as well as the new Equostat for thin materials, which is totally portable with high accuracy, resolution and repeatability. It is usable in any direction; convertible to HR B & C, Brinell, Shore and Vickers; stores up to 5000 values for later transfer to computer; and conforms to the EquoTip Standard ASTM A956-97.

Erico Inc. 1943
34600 Solon Rd., Solon, OH 44139
(440) 248-0100; FAX (440) 248-0723
www.erico.com

Incorporated in 1903 as the Electric Railway Improvement Company, today ERICO is a diversified global corporation made up of three business groups: the Industries Business Group, containing concrete reinforcement products, industrial products, panelboard products and rail electrical products divisions; the Fixing and Fastening Business Group with electrical and mechanical divisions; and the Facility Electrical Protection Business Group with grounding and lightning/surge divisions. Its well-known product brands include CADDY® fasteners, CADWELD® connections, ERITECH® ground rods and accessories, LENTON® mechanical rebar splices and FLEXIBAR® conductor products.

ESAB Welding & Cutting Products 807/1007
P.O. Box 100545
Florence, SC 29501
(843) 664-4393; FAX (843) 664-5575
www.esab.com

ESAB Welding & Cutting Products, the world's largest manufacturer of welding and cutting equipment and filler metals, will hold demonstrations of new multiprocess welding and plasma cutting equipment, new flux cored wires, SAW equipment and fluxes, GMAW equipment and filler metals, GTAW/SMAW equipment and electrodes, oxyfuel equipment, and All-State maintenance products. The company will display a full line of filler metals and equipment for applications in SAW, GMAW, GTAW and SMAW. Plasma and oxyfuel equipment will also be displayed. The ESAB Demonstration Trailer will be featured, and ESAB's e-commerce opportunities will be highlighted.

Esco Tool 2024
50 Perk St., Medfield, MA 02052
(508) 359-4311; FAX (508) 359-4145
www.escotool.com

Esco Tool will display its latest line of Esco Millhog end prep tools featuring the new "Dictator." Featuring a unique attachment, this machine easily performs multi-angular end preps and flange face preparations on all schedules of pipe to 18 in. Highlighted will be the new electric-powered Millhog with capabilities of end prepping all schedules of tube and pipe to 3½ in.

eSprocket 2311
388 Fore St., Portland, ME 04101
(207) 775-9119; FAX: (207) 772-0108
www.esprocket.com

Essen Trade Shows c/o GACC 857
40 W. 57th St., 31st Floor
New York, NY 10019
(212) 974-8457; FAX (212) 262-5085
www.essentradeshows.com

Schweissen & Schneiden, the largest international trade fair for welding, joining, cutting and surfacing, will be taking place September 12–18, 2001, in Essen, Germany. In 1997, more than 900 exhibitors showed their products to almost 100,000 trade buyers from 94 countries. An additional 200,000 sq ft of exhibition space will be available for 2001. Essen Trade Shows, together with AWS, will be organizing a U.S. Pavilion for this event.

Essex 321
1601 Wall St., Fort Wayne, IN 46802
(219) 461-4000; FAX (219) 461-4887
www.superioressex.com

Essex will exhibit ExCelene Welding Cable, Super ExCelene Welding Cable and Flexible Portable Cord for power supplies, which are only a few of the products the company manufactures for the welding in-

dustry. The company is a division of Superior Telecom, North America's largest wire and cable manufacturer.

Euro-Tool 103
Tranaasvej 14, Saeby DK 9300
Denmark
45 98401555; FAX 45 98401585

Eurofilter USA 1571
200 S. 4th St., Albion, IL 62806
(618) 445-5413; FAX (618 445-5496
www.champlabs.com

Eurosider SAS 2144
Piazza Dante 17
Grosseto 58100, Italy
39 564524117; FAX 39 564416833
www.eurosider.com

Everest VIT, Inc. 870
199 Hwy 206, Flanders, NJ 07836
(973) 448-0077; FAX (973) 448-9147
www.everestvit.com

EWI (Edison Welding Institute) 1456
1250 Arthur E. Adams Dr.
Columbus, OH 43221-3585
(614) 688-5000; FAX (614) 688-5001
www.ewi.org

Exel Design Co. 408
1448 19th St.
Santa Monica, CA 90404
(310) 449-0054; FAX (310) 449-1154

Expansion Seal Technologies 249
334 Godshall Dr.
Harleysville, PA 19438
(800) 355-7044; FAX (215) 513-4333
www.expansionseal.com

Expert Components Inc. 239
794 Riverside Dr.
Asheville, NC 28801
(828) 251-9316; FAX (828) 251-9853
www.expert-components.com

Fabricating Equipment News 219
One Chase Corporate Dr., Ste. 300
Birmingham, AL 35244
(800) 366-0676; FAX (205) 987-3237
www.fabequipnews.com

Fabricating Equipment News is distributed monthly to the nation's top engineers, operation managers, purchasing agents and purchasing professionals. Each edition provides readers with trustworthy and comprehensive information on the fabricating industry. Every issue features articles on innovations, problem-solving tips and techniques, industry news and the latest fabricating trends.

Factory Cat 682
1509 Rapids Dr.
Racine, WI 53404
(262) 632-1143; FAX (262) 632-3335
www.factorycat.com

Factory Cat will exhibit its line of industrial and commercial cleaning equipment, walk-behind and rider sweepers and scrubbers.

Falcon Abrasive Mfg., Inc. 337
P.O. Box 713
Walnut, CA 91789
(800) 322-8812; FAX (909) 594-4721

FANUC Robotics North America, Inc. 1639
3900 W. Hamlin Rd.
Rochester Hills, MI 48309
(800) 477-6268; FAX (248) 276-4133
www.fanucrobotics.com

FEMI S.R.L 1854
Viale Dell' Industria 6
Legnaro (PO) 35020, Italy
49 8830300; FAX 49 8830333

Ferris State University 2085
College of Technology
109 Swan Building
Big Rapids, MI 49307
(616) 592-2952; FAX (616) 592-2407
www.ferris.edu

FHP Elmotor AB 943
Ankarsrum S-59090, Sweden
46 49053300; FAX 46 49050990
www.fhp-elmotor.se

FIBA Technologies, Inc 542
97 Turnpike Rd.
Westboro, MA 01581
(508) 366-8381; FAX (508) 336-1915)
www.fibatech.com

Since 1958 FIBA Technologies has served the compressed gas industry Today, it provides high-quality equipment to the compressed gas, cryogenic and chemical industries. Products and services include tube trailers; ABS/ISO skid containers; ASME & DOT tube & gas compressor systems; carbon dioxide, chemical and cryogenic storage and transport equipment; vaporizers; and hydrostatic, ultrasonic and acoustic emission testing of pressure vessels. The company has DOT- and/or ASME-registered facilities in Massachusetts, Kentucky, Louisiana and Pennsylvania

Flame Technologies, Inc. 2052
P.O. Box 1776
Cedar Park, TX 78613
(512) 219-8481; FAX (512) 219-8477

Flame Technologies will display its complete line of advanced gas apparatus equipment. Products to be shown include cutting tips for all OEM torches, heating equipment and rosebuds. One main feature will be state-of-the-art brazing equipment for fuel gases. The Steel Industry Products (SIP) division will feature continuous casting torches and tips using the advanced post mixing designs.

Flange Wizard Tools 2252
2140 S. Santa Fe St.
Santa Ana, CA 92705
(714) 437-4931; FAX (714) 434-9615
www.flangewizard.com

Flange Wizard® Tools will exhibit its quality hand tools for welders and fitters in all phases of the industry. Staff will be on hand to answer any questions on the products. Special show offers will be available at the booth.

Flexovit USA, Inc. 761
1305 Edan-Evans Center Rd.
Angola, NY 14006
(716) 549-5100; FAX (716) 549-7932
www.flexovitusa.com

Flowdrill Inc. 420
2031 S. Big Bend Blvd.
St. Louis, MO 63117
(314) 781-3933; FAX (314) 781-3610

The company will showcase the Flowdrill System®, a unique innovative process developed to form a bushed hole in a variety of metals by thermal and chipless forming with the Flowdrill® tool. The system is being used successfully with a high degree of accuracy and repeatability in stainless and mild steel, copper, brass and aluminum of thicknesses from 1/16 in. to 1/2 in. The range of applications includes tubular metal furniture; wheelchairs; bicycles; radiators; air conditioning components; manifolds for the gas and water industries; and the manufacture of automobiles, trucks and utility vehicles.

Foremost Machinery Corp. 1765
425 Huehl Rd.
Northbrook, IL 60062
(847) 272-7880; FAX (847) 272-7948
www.foremostmachinery.com

Fork-Levator Inc. 1872
Box 547, Walmore Rd., Gate 8, Bldg. 4
Niagara Falls, NY 14302
(716) 285-0685; FAX (716) 694-6903
www.oselator.com

Fork-Levator will feature Osalator, a popular robot indexing table used in robotic work cells throughout North America. Available in 2-, 3-, 4- or 5-station versions, it offers capacities up to 10,000 lb. Features include fast cycling, natural self-locking, a patented orbital-lok drive and precise position repeatability. In addition, customized tooling is frequently incorporated into applications ranging from welding to laser jet cutting and small parts material handling.

Formdrill-Div. of Foremost Machinery 1866
425 Huehl Rd.
Northbrook, IL 60062
(847) 272-7880; FAX (847) 272-7948
www.foremostmachinery.com

Frimar SAS 1764
Corso Italia 2
Verdellino (BG) 24049 Italy
39 035885272; FAX 39 035870465
www.vtcenter.net-frimar

Frommelt Machine Guarding Products 241
4343 Chavenelle Dr.
Dubuque, IA 52002-2654
(800) 553-5560

Frommelt Safety Products 924
4343 Chavenelle Dr.
Dubuque, IA 52002-2654
(414) 362-6366; FAX: (319) 589-2754
www.frommeltsafety.com

Fusion Inc. 958
4658 E. 355th St.
Willoughby, OH 44094
(800) 626-9501; FAX (440) 942-9083
www.fusion-inc.com

Fusion will showcase its brazing and soldering process that automates volume applications on automatic machines. Also displayed will be its paste filler metals that are applied as single step. The company's machines operate with single operator at rates between 100 and 800 p/h.

Galt Technical Services 819
409 Broad St., Ste. 201
Sewickley, PA 15143
(412) 749-0100; FAX (412) 749-6075

Galt Technical service specializes in engineering, manufacturing and servicing support equipment for the flame cutting industry. Its products include standard water tables, water jet cutting tables, dry exhaust tables, automated laser cutting tables and complete automated handling systems. In addition, it also offers filtration units for both wet and dry cutting applications. The company's resources, personnel and proven experience enables it to produce a variety of specialized products to meet any plate support requirement.

Gander Brands Inc. 464
14556-121A Ave.
Edmonton AB T5L 4L2, Canada
(800) 661-6564; FAX (780) 447-4454
www.gandarbrand.com

Gander Brands, a manufacturer of quality welding products since 1949, will exhibit its diverse line that includes protec-

tive garments for GTA, GMA and SMA welding and high-heat products made from quality materials with superior craftsmanship.

Garryson, Inc. 968
11805 Westline Industrial Dr.
St. Louis, MO 63146
(800) 404-5364; FAX (800) 404-5374

Garryson will introduce and demonstrate Flexidisc, the first "flexible" flap disc of its kind. The company is a manufacturer of flap discs, flap wheels and quick-change abrasive products, which are produced in an ISO9002 environment. Free samples will be available at the company's booth.

Gas Technology Energy Concepts, LLC 225
401 William L. Gelter Pkwy., Ste. 4
Buffalo, NY 14215
(716) 831-9695; FAX (716) 831-0878
www.gas-tec.com

G-TEC will highlight its patented natural gas compressors for torch cutting, brazing, heating and other oxyfuel applications. Its systems elevate low-pressure utility gas service up to 50 lb/in.^{2}. Users can fill their own adsorbed gas low-pressure storage cylinders for on-site jobs. Also exhibited will be its natural gas cutting and brazing torch tips. Key industries for the company include manufacturing, fabrication, refrigeration, scrap metal, boiler repair, plumbing/HVAC, general contracting, maintenance/repair and steel service centers.

Gases & Welding Distributor 522
1100 Superior Ave.
Cleveland, OH 44114
(216) 696-7000; FAX (216) 931-9524

Gasflux Co. 2224
32 Hawthorne St., P.O. Box 1170
Elyria, OH 44036-1170
(440) 365-1941; FAX (440) 365-3495
www.gasfluxusa.com

Gasflux will demonstrate its specialed process of introducing a flux automatically into the flame for torch brazing. For more than 60 years, the company has promoted this process, which is successfully used with many applications when copper/zinc, copper phosphorus and silver brazing alloys are used as a filler metal. The process can be easily adapted to work with most manual and automatic brazing systems. It also manufactures paste fluxes for low-, medium- and high-temperature silver brazing and supplies quality brazing alloys.

GasTech Products, Inc. 867
7547 Kellogg Rd.
Concord, OH 44077
(440) 358-9966; FAX (440) 358-9966
www.gastechproducts.com

GBC-America 406
2519 E. Southmore
Pasadena, TX 77502
(713) 472-8122; FAX (713) 472-6804
www.gbcindustrialtools.com

GBC-America will exhibit and demonstrating portable pipe/tube pneumatic and electric beveling, cutting and other accessory pipe/tube working products. Unique design and benefit features make it possible to cover a broader diameter of sizes with fewer machines, ranging in diameter from ½ to 60 in. in either I.D. or O.D. mount options.

Gedik Welding Inc. 201
Ankara Cad. No. 28
81520 Seyhli-Pendik
Istanbul, Turkey
90 2163785000; FAX 90 2163787936
www.gedik.com.tr

Gedik Welding will showcase its numerous types of welding electrodes, GMA welding wires, GTAW rods and submerged arc welding wires.

General Cylinders Corp. 760
1685 Shermer Rd.
Northbrook, IL 60062
(847) 272-7500; FAX (847) 272-9161
www.gencyl.com

General Cylinders will highlight its complete line of high pressure cylinders from Medical B through 400 cu ft.

Generico 674
4525 Edison Ave.
Chino, CA 91710
(909) 606-2726; FAX (909) 606-6485
www.generico.com

Generico will exhibit its line of gas welding, heating and cutting equipment. The company plans to introduce hundreds of new products this year. Some of the new items on display will be torches, regulators and the GenAir line of air/gas welding apparatus. Also on display will be a full line of point-of-purchase packaged items, as well as its most popular welding and cutting outfits.

Genesis Systems Group 1658
8900 Harrison St.
Davenport, IA 52806
(319) 445-5600; FAX (319) 445-5699
www.genesis-systems.com

GenusTech 2262
340 N. Main, Ste. 318
Plymouth, MI 48170
(734) 459-3100; FAX (734) 459-1219
www.genustech.com

GenusTech will highlight its new series of electronic-controlled, DC motor-actuated power ramp clamps used in automotive welding systems, robotic gripper applications and in fixtures on automated guided vehicles. These electric clamps dramatically reduce fixture complexity and lower total costs. In addition, the company will exhibit the pneumatic series of power ramp clamps, pin locators, and rotary clamps used in body in white applications.

Genweld 674
4525 Edison Ave.
Chino, CA 91710
(909) 606-2726; FAX (909) 606-6485

Genweld will exhibit its line of gas welding, heating and cutting equipment. Several new products, including torches, regulators and accessory items, will be introduced. Also on display will be a full line of point-of-purchase packaged items, as well as the company's most popular welding and cutting outfits.

Georg Fischer Pipe Tools 1145
407 Hadley St., Holly, MI 48442
(248) 634-8251; FAX (248) 634-0574
www.gfdisausa.com

Georg Fischer will exhibit tools to simultaneously cut and bevel tubes and pipes made of high alloy steel/stainless steel, IOW and unalloyed steel and casting material. This unique titanium-coated tool can be used in a combination format with the company's RA2, 4, 6, 8, 12 or RA21, 41 cut-off machines to save time and money.

German Welding Society 857
Aachener Strasse 172
Dusseldorf 40223, Germany
4902111591302; FAX: 49 02111591300
www.valtrainc.com

Good Hand, Inc. 413
720 S. Vail Ave.
Montebello, CA 90640
(323) 722-5244; FAX (323) 725-7226
www.valtrainc.com

Good Hand will display its Strong Hand sliding arm clamps (f-clamp style) with fully replaceable components. It will also feature toggle clamps for use in a wide variety of hold down and OEM applications. Toggle clamp models include horizontal, vertical, push/pull, latch, pliers, heavy duty and pneumatic. Also on display will be a full line of operating accessories including handles, handwheels, knobs, levers, cranks, work holding tools and specialty fasteners.

Goss Inc. 1716
1511 Rt. 8, Glenshaw, PA 15116
(412) 486-6100; FAX (412) 486-6844

Goss will feature a new line of reduced-size welding handles and tips. Its Stubby line is designed for welding in areas of limited access or where improved tip control is required and includes specialty tips such as the twin, flex and "G" design.

GOW-MAC Instrument Co. 859
277 Brodhead Rd.
Bethlehem, PA 18017
(610) 954-9000; FAX (610) 954-0599
www.gow-mac.com

GOW-MAC Instrument Co. manufactures gas analyzer packages and systems for user-specified applications. Systems are based on its complete line of GCs, point-of-use gas analyzers and data reduction systems. Analyses include industrial, welding, corrosive and electronic, medical, and natural gases; oil and petrochemical; flavors and fragrances; power, steel and chemical industries; moisture analysis in corrosive streams; environmental; and more.

Gross Stabil Corp. 506
333 Race Street, P.O. Box 368
Coldwater, MI 49036
(517) 278-6121; FAX (517) 278-5523

Gross Stabil, a manufacturer of high-quality, German-made metalworking and woodworking clamps since 1885, will offer its Value Series clamps, regular and heavy-duty clamps, corner clamps, quick-lever clamps and clampliers, as well as many other welding and industrial products.

GSI Lumonics 306
19776 Haggerty Rd.
Livonia, MI 48152-1018
(734) 591-0101; FAX (734) 591-0045
www.gsilumonics.com

Guard-Line, Inc. 2009
215-217 S. Louise St.
Atlanta, TX 75551
(903) 796-4111; FAX (903) 796-7262
www.guardline.com

Gulf Wire Corp. 729
P.O. Box 29849
New Orleans, LA 70189
(504) 254-0062; FAX (504) 254-1220

Gulf Wire, a fully integrated manufacturer of aluminum welding wire, will exhibit its complete line of diamond draw filler metals. Also on display will be its newly expanded stainless filler metal line. Both product lines will be exhibited in the English and metric configuration.

Gullco Int'l Inc. 1135
21568 Alexander Rd.
Oakwood Village
Cleveland, OH 44146
(440) 439-8333; FAX (440) 439-3634
www.gullco.com

Gullco will exhibit its new SAM Sub-Arc MOGGY, a four-wheel drive, heavy-duty carriage with steering. The electronic control will enable the carriage to be used in both the CV and CC mode. The Gullco/Meta Laser Tracker and Tactile Seam Tracker will be shown using state-of the-art electronic motor controls. Also on display will be the Gullco Oscillator and Gullco ceramics will be highlighted together with plate beveling machines

H & B Distributors 1130
14711 Artesia Blvd.
La Mirada, CA 90638
(800) 660-0880; FAX (877) 542-8665
www.ausmultitool.com

H & B Distributors will introduce two Australian-made grinder attachments to the Uniteds States. The Multitool attaches to most any 6- or 8-in. bench grinder andconverts it into a belt and disc grinder that can be used on all metals and to sharpen tungsten electrodes. The tool can be used for super-fast roughing or super-fine finishing and polishing. The Porta-grind converts a 4- or 4½-in. angle grinder into a belt sander

H & H Sales Co., Inc. d/b/a H & H Equipment Co. 1493
P.O. Box 686
Huntertown, IN 46748-0686
(219) 637-3177; FAX (219) 637-6880
www.gtesupersite.com/hhequip

H & M Pipe Beveling Machine Co., Inc. 1161
311 E. Third St.
Tulsa, OK 74120
(918) 582-9984; FAX (918) 582-9989
www.hmpipe.com

H & M will display its line of saddle and band-type pipe cutting and beveling machines for working pipe from 2 to 96 in. in diameter. Included are the Pipe End Prep Lathe 400 end 800 for machining bevels, lands and counter bores on pipe 1 to 8 in.; the new master chain clamps for aligning flanges, elbows and

tees; shape cutting attachments for saddling and mitering pipe; flange pins; pipe alignment clamps; and other pipe-related items.

H & S Tool, Inc. 258
715 Weber Dr.
Wadsworth, OH 44281
(330) 336-4550; FAX (330) 336-9159
www.h-stool.com

Haberle/Ken Bergman & Associates 261
10533 S. Lorel
Oak Lawn, IL 60453
(708) 422-1036; FAX (708) 422-3604
www.haberlausa.com

HACO-Atlantic, Inc. 839
11629 N. Houston Rosslyn Rd.
Houston, TX 77086
(281) 445-3985; FAX (281) 445-3989
www.hacoatlantic.com

Handi Disc/Bits 2209
P.O. Box 851, Bristol, RI 02809
(401) 253-1330; FAX (401) 253-1377
www.handidisc.com

Joseph A. Thomas, Ltd., will display its Handi Disc flexible abrasive wheel and Handi Bits multipurpose drill bits. Also exhibited will be two new products, a seven-piece drill-bit set in a durable vinyl pouch (perfect for the tool box) and an extensive 18-piece bit set.

Harris Welco Div. of J. W. Harris Co. 1332
P.O. Box 69
Kings Mountain, NC 28086
(704) 739-8421; FAX (704) 739-2801
www.jwharris.com

Harris Welco will display GMAW and GTAW production alloys in stainless steel, aluminum, silicon bronze, deoxidized copper, aluminum bronze, phosphorus bronze, mild steel and stainless steel; mild steel flux cored alloys; and production electrodes for stainless steel, aluminum, mild steel, nickel-chromium and Monel. Also to be shown are soldering and brazing alloys including phos/coppers, high silvers, brazing pastes, fluxes, low fuming bronze, antispatter, nozzle gel, super cold galv, cover lenses, tilter plates, tip cleaners, gloves, brass gauges, spark lighters, brushes, ground clamps, wrenches, chipping hammers, cylinder caps, tungsten abrasives, cable, hose and Optrel helmets.

Hawkins Metalworks 1989
708 Twin View
Heath, TX 75032
(972) 771-3708

HE&M Saw 1966
P.O. Box 1148, Pryor, OK 74362
(918) 825-4821; FAX (918) 825-4824
www.hemsaw.com

HE&M Saw will feature more than 40 different models of production band saws for the metal working industry, including vertical, horizontal, plate and double column saws with capacities ranging from 12 x 12 in. to 80 x 80 in.

Heath, Michelle & Andy 1990
P.O. Box 1148, Taos, NM87571
(505) 776-1624

Heck Industries 425
P.O. Box 425, Hartland, MI 48353
(810) 632-5400; FAX (810) 632-6640

E. G. Heller's Son, Inc. 1252
18330 Oxnard St.
Tarzana, CA 91356
(818) 881-0900; FAX (818) 344-8898
www.hellerson.com

E. G. Heller's Son will exhibit plate rolling machines including initial-pinch, double pinch pyramid and four-roll double pinch machines. The four roll machine will also be available in mechanical sizes through 3/8 in. x 5 ft. It will also show its section rolling machine, which includes pyramid and double-pinch section rolls, and a new high-speed press brake and multifunctional ironworker.

Henning Hansen, Inc. 2448
P.O. Box 220
Pickering, Ont. L1V 2R4, Canada
(905) 839-7481; FAX (905) 839-3688

Stork-Herron Testing Labs, Inc. 2125
5405 E. Schaaf Rd.
Cleveland, OH 44131
(216) 524-1450; FAX (216) 524-1459

Stork-Herron Testing Labs provides fundamental properties testing of metals and metal alloys. Its capabilities include mechanical testing, chemical analysis, metallography, failure analysis and welding certification services for private industry, the military and state and Federal governments. Herron's numerous accreditations include A2LA, FQA and TÜV, and it has more than 70 client approvals including aerospace, automotive, commercial, nuclear and government market segments.

High Purity Gas Co. 601
4344 S. Main
Pearland, TX 77581
(281) 482-7007; FAX (281) 482-9216

Hitco Carbon Composites, Inc. 711
1600 W. 135th St.
Gardena, CA 90249
(800) 421-5444; FAX (310) 515-1779
www.agl-hitco.com

Hitco Carbon Composites will highlight Retrasil high-temperature resistant textiles that are silica products designed specifically to replace asbestos. Refrasil retains strength to continuous temperatures of 1800°F. Refrasil Welding Grade Cloth (WGC) products are effective in applications such as welding blankets and screens, personnel protection shields, equipment protection and stress relieving pads. WGC products can protect personnel, equipment and finishes from molten metal spatter and sparks.

Hobart Brothers Co. 1805
400 Trade Square E.
Troy, OH 45373
(937) 332-4000; FAX (937) 332-5224
www.hobartbrothers.com

Hobart will exhibit a comprehensive full line of filler metal products including mild steel electrodes, mild steel solid wires, flux cored and metal cored tubular wires, as well as stainless and hardsurfacing products. The newest improvements and formulations will be featured. Hobart engineers and sales professionals will be on hand to assist visitors in welding solutions and product recommendations.

Hobart Institute of Welding Tech. 1810/2086
400 Trade Square E.
Troy, OH 45373
(800) 332-9448; FAX (937) 332-3200
www.welding.org

The Hobart Institute of Welding Technology will preview its all-new SMAW video courseware and the recently released GMAW video series, both of which meet QC-10 and EG-2.0 standards. Also on display will be the Weld_IT© CD-ROM weld cost estimator and the 700-page weld encyclopedia with engaging graphics for cutting and pasting instructional aids. Information will be available on the Institute's variety of programs including skill career training and customized technical and specialized training courses with certification.

Hobart Welding Equipment 1606
1635 W. Spencer St.
Appleton, WI 54914
(920) 735-4033; FAX (920) 735-4013
www.hobartwelders.com

Hoodlum Welding Gear 2318
12201 Champlin Dr.
Champlin, MN 55316
(612) 712-3740; FAX (612) 422-3838
www.hoodlum-welding.com

Hornell Speedglas, Inc. 447
2374 Edison Blvd.
Twinsburg, OH 44087
(330) 425-8880; FAX (330) 425-4576
www.speedglas.com

Hougen Mfg., Inc. 1041
3001 Hougen Dr.
Swartz Creek, MI 48473
(810) 635-7111; FAX (810) 635-6277
www.hougan.com

Howard Leight 1673
7826 Waterville Rd.
San Diego, CA 92173
(800) 327-1110; FAX (619) 661-8393
www.howardleight.com

Hyd-Mech Saws 435
1079 Parkinson Rd.
P.O. Box 1030
Woodstock, Ont. N4S 8A4, Canada
(519) 539-6341; FAX (519) 539-5126

Hydropedes Insoles 2069
955 Irwin Rd., Barstow, CA 92311
(760) 256-4404; FAX (760) 256-4414
www.hydropedes.com

Hypertherm, Inc. 1652
Etna Rd., P.O. Box 5010
Hanover, NH 03755
(603) 643-3441; FAX (603) 643-5352
www.hypertherm.com

Hyundai Welding Products, Inc. 882
333 Pierce Rd., Ste. 235
Itasca, IL 60143
(630) 250-1511; FAX (630) 250-8905

IBEDA Superflash Gas Safety Equipment 2174
31379 Lorain Rd.
N. Olmsted, OH 44070
(440) 716-9980; FAX (440) 716-9964
www.applied-inc.com/ibeda

Impact Engineering, Inc. 1955
500 E. Biddle St., Jackson, MI 49203
(517) 789-0098; FAX (517) 789-1038
www.impactwelding.com

Featured will be an arc weld quality monitoring system that provides real-time analysis through monitoring, data acquisition, automated process fault detection, WELD SIGNATURE™ analysis and automated diagnostics. The ARCAgent™ 2000 and ARCAgent™ 3000P portable systems analyze current, voltage, gas flow and wire feed to verify weld process operation. The ARClient® software provides data logging, graphical process analysis, SPC and production reporting information.

Imperial Weld Ring Corp. 541
80-88 Front St.
Elizabeth, NJ 07206
(908) 354-0011; FAX (908) 354-9014

Impulse System Technology, Inc. 433
7 Charry Lane
Upper Saddle River, NJ 07458
(201) 825-1049; FAX (201) 825-1049
www.impulse-syst.com

Inco Alloys Int., IAI Welding Products, A Special Metals Co. 723
1401 Burris Rd.
Newton, NC 28658
(828) 465-0352; FAX (828) 464-8993
www.specialmetals.com

Industrial Machine Trader 207
1003 Central Ave.
Fort Dodge, IA 50501
(800) 247-2000; FAX (515) 955-3753
www.vulcanpub.com

Industrial Machine Trader, published by Heartland Industrial Group, is a weekly nationwide publication that brings together buyers and sellers of new and used industrial equipment.

Industrial Machinery Digest 219
One Chase Corporate Dr., Ste. 300
Birmingham, AL 35244
(800) 366-0676; FAX (205) 987-3237
www.indmecdig.com

Industrial Machinery Digest provides leads to potential buyers prequalified by industry type and buying power. Lists are rotated every issue to ensure reaching the most responsive buyer available.

Industrial Market Place 422
7842 N. Lincoln Ave., Skokie, IL 60077
(847) 676-1900; FAX (847) 676-0063
www.industrialmktpl.com

Inertia Friction Welding, Inc. 773
1801 S. Main St.
South Bend, IN 46613
(219) 287-7461; FAX: (219) 289-5984
www.ifweld.com

Innerlogic Inc. 1585
455 Fleming Rd., Charleston, SC 29412
(843) 795-4286; FAX (843) 795-8931
www.plasmacut.com

Intelligent Monitoring Systems, LLC 1970
1365 Horseshoe Dr.
Blue Bell, PA 19422
(610) 278-9325; FAX (610) 278-9325
www.weldingnet.com

The welding monitor system Smart Boss™ will be featured. The system allows an engineer, supervisor or shop owner to oversee the operation on the floor at any time and collect the data necessary to make important decisions such as when to order material and how much, welder training needs, the number of parts produced and the condition of the equipment. Weld parameters also can be recorded for each weld.

Intercon Enterprises, Inc. 1070
1125 Fir Ave., Blaine, WA 98230
(800) 665-6655; FAX (604) 946-6066

Intertech Systems, Inc. 2071
2334 Nassell Rd.
Hoffmen Estates, IL 60195
(847) 839-1920; FAX: (847) 839-9678

Invincible Airflow Systems 1922
P.O. Box 380, Baltic, OH 43804
(330) 897-3200; FAX (330) 897-3400

Highlighted will be six-horsepower welding flux recovery systems designed to save costs for submerged arc welding operations. The machines recover all unfused flux from the work, remove slag or fused particles and return slag-free flux to the hopper. Built for heavy-duty service, the equipment is compact, lightweight, portable and easily installed.

Inweld Corp. 1841
3962 Portland St.
Coplay, PA 18037-0040
(610) 261-1900; FAX (610) 261-0744
www.inweldcorporation.com

On display will be a full range of GMAW and GTAW alloys, tungsten, CO_2 welding wire, covered electrodes, gouging carbons, electrode holders, ground clamps, silver solder, stainless steel wire, phosphor copper, flux-coated and bare bronze alloys, welding cables and aluminum wire. Also shown will be nickel alloys, deox copper, antispatters, nozzle gel, maintenance alloys and point-of-sale items. Product line literature and catalogs will be available, and staff will be on hand to answer questions.

IPR-RAS Welding 2420
12 Mayflower Ln.
Weston, CT 06883
(203) 222-0296; FAX (203) 221-1712
www.ipr-ras.com

IRT-Scanmaster Systems, Inc. 828
5 Congress St., Nashua, NH 03062
(603) 598-6688; FAX (603) 598-6699

ITA, Inc. 871
532 Route 15, Sparta, NJ 07871
(973) 579-3400; FAX (973) 579-322
www.ita.cc

ITW Dykem/Dymon 2103
805 E. Old 56 Highway
Olathe, KS 66061
(800) 443-9536; FAX (800) 323-9536
www.dykem.com

Iwatani Int'l Corp. of America 1685
2050 Center Ave., Ste.425
Fort Lee, NJ 07024
(201) 585-2442; FAX (201) 585-2369
www.iwatani.com

J&S Machine, Inc. 2259
W5901 49th Ave.
Ellsworth, WI 54011
(715) 273-3376; FAX: (715) 273-5241
www.jsmachine.com

Jackson Products, Inc. 1407/1411
2997 Clarkson Rd.
Chesterfield, MO 63017
(636) 207-2750; FAX (636) 207-2810
www.jackprod.com

A complete line of welding accessories and personal protection equipment will be highlighted. Featured will be welding helmets, EQC auto darkening filters, lenses and plates for a wide selection of welding protection, safety caps, face shields, hearing protection, safety glasses and goggles.

James Morton Inc. 1311
P.O. Box 399, 50 Franklin St.
Batavia, NY 14020
(716) 344-1160; FAX (716) 344-0025
www.jamesmorton.com

Jancy Engineering Co. 1485
2735 Hickory Grove Rd.
Davenport, IA 52804
(319) 391-1300; FAX (319) 391-2323
www.jancyslugger.com

Featured will be the Slugger portable, magnetic drilling machine and center-free annular cutting machines. Also on display will be drills, thin metal cutters and Roto Star rotary welding positioner.

Jaz USA, Inc. 755
2300 Maywood Dr.
Bellwood, IL 60104-2518
(877) 529-8722; FAX (877) 529-3291
www.jaz.es

Jepson Power Tools 101
20333 S. Western Ave.
Torrance, CA 90501
(310) 320-3890; FAX (310) 320-1318
www.jepsonpowertools.com

Jesco Industries Inc. 510
950 Anderson Rd.
Litchfield, MI 49252-0388
(517) 542-2903; FAX (517) 542-2501
www.jesco-wipco.com

Featured will be robotic barrier guarding systems for protection around flexible robotic systems, which include welding, assembly, dispensing, machine tending, deburring, material handling, finishing, palletizing and many other applications within a wide range of industries including automotive, aerospace, appliences, off-road and warehouse. Representatives will be on hand to help develop barrier guarding or fence systems.

Jet Wheelblast Equipment 2328
401 Miles Dr., Adrian, MI 49221
(517) 263-0502; FAX (517) 263-0038
www.c4systm.com/JetWheel/

The company will offer a wide variety of dry and wet automated blast cleaning equipment specifically developed for processing fabricated parts and components. In addition, it will feature both conventional impelled control cage blast wheels and its air-injected blast wheels for cosmetic finishes. The company manufacturers self-contained systems for monorail and roller pass through applications, wire mesh conveyor systems, spinner hanger machines and patented multitumblers.

Jetline Engineering, Inc. 1402
15 Goodyear St., Irvine, CA 92618
(949) 851-1515; FAX (949) 951-9237
www.jetline.com

K & K Welding Products, Inc. 1432
595 Telser Rd., Lake Zurich, IL 60047
(847) 540-9400; FAX (847) 540-0197

The company will highlight its GMA welding guns and GTA welding torches and accessories. Also featured will be its robotic torches, cleaning stations, push-pull guns, water coolers and specialty welding products.

Kawasaki Robotics (USA), Inc. 1482
28059 Center Oaks Ct.
Wixom, MI 48393
(248) 305-7610; FAX (248) 305-7818
www.kawasakirobot.com

Kayo Products Co., Ltd. 1964
P.O. Box 118-355
Taipei, Taiwan R.O.C.
886 2 87873050; FAX 886 2 87871937
www.a-kayo.com

Kedman Co. — Huntsman Product Div. 1407/1411
762 S. Redwood Rd.
Salt Lake City, UT 84104
(800) 999-9112; FAX (888) 323-4545

Kedman will showcase its personal protective equipment and welding safety products. Product lines include welding helmets, eletronic lenses, faceshields, safety spectacles, brackets, hearing protection and more. New product introductions at the show this year will feature the Anser welding helmet, four-sensor electronic lens technology and new merchandising displays.

Kemper USA, Inc. 2439
6679 Peachtree Industrial Blvd., Ste N.
Norcross, GA 30092
(770) 416-7070; FAX (770) 416-7306

KETER Consultants 566
8270 Archer Ave.
Willow Springs, IL 60480
(708) 839-0800; FAX: (708) 839-0360
www.keter.com

Kinco Int'l Inc. 2228
9788 S.E. 17th Ave.
Portland, OR 97222-7332
(800) 547-8410; FAX (503) 653-4905
www.kinco.com

Kinco will showcase its complete line of garments. On display will be its full line of leather palm, drivers, cotton, cold weather, string and dipped gloves.

King Bag & Mfg. Co. 743
1500 Spring Lawn Ave.
Cincinnati, OH 45223
(513) 541-5440; FAX (513) 541-6555

The company will feature custom-made products, including welding curtains, blankets and high-temperature cloth items made to user specifications. Also highlighted will be portable welding frames with all accessories, track trolley, strip doors for both indoor and outdoor use, along with rolled goods and strip materials.

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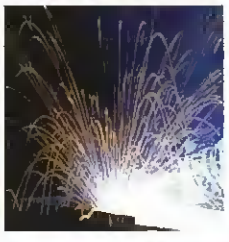

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- Safety Equipment
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75 John Glenn Dr.
Amherst NY 14228-2171
(888) 547-8537; FAX (716) 691-5226
www.kistler.com

Kistler Machines Co. 557
Brunnenweg 15, D-88348
Saugau D-88340, Germany
49 75834177; FAX: 49 75833968

Klimawent-Centre of Ventilation Engineering 1382
Chwaszczynska 194
Gdynia 81-571, Poland
0048 586296480; FAX 0048 586296419

The company will showcase its exhaust and filter-ventilating units for removal of welding fume and dust, including suction arms coacting with fans or an exhaust system, welding stations with fume extraction, filter-ventilating units with exchangeable needled cloth filter sets, filter-ventilating units with automatically cleaned cartridge filters, filter-ventilating units coacting with semiautomatic head for gas-shielded welding and mobile suction arms coacting with a self-tightening exhaust duct.

Klingspor Abrasives, Inc. 2309
2555 Tate Blvd. S.E., P.O. Box 2367
Hickory, NC 28603-2367
(800) 845-5555; FAX (800) 524-8758
www.klingspor.com

Koballoy Co. 601
4344 S. Main, Pearland, TX 77581
(281) 482-7007; FAX (281) 482-9216

Koballoy will display welding filler metals, including the KOBELCO line of welding wires for low-alloy, stainless steel and flux cored welding. An experienced staff will be available to offer assistance for end users and distributors. A modern mobile demonstration trailer will be used for on-site demonstrations.

Kobelco Welding of America Inc. 605
7478 Harwin Dr., Houston, TX 77036
(713) 974-5774; FAX (713) 974-6543
www.kobelcowelding.com

Kohler Engines 852
444 Highland Dr., Kohler, WI 53044
(920) 457-4441; FAX (920) 459-1747
www.kohlerengines.com

Koike Aronson Inc. 1219
635 W. Main St., Arcade, NY 14009
(716) 492-2400; FAX (716) 457-3517
www.koike.com

Koike Aronson, manufacturer of thermal cutting machines, portable cutting machines portable welding carriages, gas apparatus and welding positioning equipment, will present live cutting demonstrations using a CNC programming system. On display will be a variety of new equipment featuring the latest technology in oxyfuel, plasma and laser cutting, and welding positioners, turning rolls and manipulators.

Komatsu Cutting Technologies Inc. 105
265 Ballardvale St.
Wilmington, MA 01887
(978) 658-1650; FAX (978) 658-1655
www.fineplasma.com

Komatsu will feature its Resor™ Fine plasma system, an x-y-axis cutting table for sheet metal and plate up to 1.5 in. thick. The system features patented torch-head technology to produce precision parts with close tolerances, narrow kerf widths, sharp, clean square edges and edge finishes.

Koolant Koolers, Inc. 1436
2625 Emerald Dr.
Kalamazoo, MI 49001-4542
(616) 349-6800; FAX (616) 349-8951

Koolant Koolers will showcase its industrial chillers and coolers for constant temperature control of process fluid, including the cooling of spot, seam and projection resistance welding equipment; lasers; water jet cutting machines; thermal spray systems and plasma torches. Application engineers will be available to assist with proper sizing, or with any custom and OEM requirements.

Krautkramer Branson 2001
50 Industrial Park Rd.
Lewistown, PA 17044
(717) 242-0327; FAX (717) 242-2606
www.krautkramer.com

Krautkramer Branson will exhibit the latest USN "L" and "R" Series portable ultrasonic flaw detectors along with the Benchmark Series of piezocomposite angle beam probes and wedges for weld inspection. Model USLT2000 full-featured flaw detector in a laptop computer with UltraLOG software for spot weld inspection will also be shown. Other products will include USM Series flaw detectors, thickness gauges, hardness testers and eddy current instruments.

Kromer Cap Co., Inc. 1831
759 N. Milwaukee St.
Milwaukee, WI 53202
(414) 276-1800; FAX (414) 276-8440
www.kromercap.com

Kromer Cap will feature its all-cotton welders' headwear. On display will be a number of bright new colors and patterns to join its line of durable washable headwear. Also featured will be a variety of flame-retardent caps and cool-weather hard hat liners.

KS Electron Technologies 2418
20401 Gladwin Ave., Taylor, MI 48180
(734) 374-0400; FAX (734) 374-5620
www.k-set.com

KWIC (Korea Welding Industry Cooperative) 355
36-2, Yoido-Dong, Youngdungpo-ku
Seoul (Manhatten P/O) Korea
82 2 7855504; FAX: 82 2 7853586

La-Co Industries, Inc./ Markal Co. 1116
1201 Pratt Blvd., Elk Grove, IL 60007
(847) 956-7600; FAX (847) 956-9885

La-Co Industries will be featuring its complete line of industrial marking products, which come in stick and liquid form. Several new marking products will be introduced for the first time, and the company will also feature its Thermomelt Heet Stik. Literature and samples will be available.

LAI Co. 1728
7645 Baker St. N.E.
Minneapolis, MN 55432
(612) 780-0060; FAX (612) 784-4740
www.laico.com

LAI will exhibit its new five-axis CO_2 laser workstation with a power output range of 1500–3500 W. The laser features accuracy to 0.001 in., maximum positioning speed of 1180 in./min., continous part processing with zero loading and unloading times and capability to cut round or square tubing up to 30 in. in diameter and 1/2-in. well thickness. Information on the company's laser end precision water jet processing services will be available.

Lantek Systems, Inc. 508
9420 W. Foster Ave., Ste. 100
Chicago, IL 60656
(773) 992-2011; FAX (773) 992-2025
www.lantek-systems.com

Larco Sales Group 1174
13705 26th Ave. N.
Plymouth, MN 55441
(612) 557-7055; FAX (612) 557-1130
www.larcosales.com

The company will showcase its Larco Zone Monitor 5000 safety mat controller. This product features a mat diagnostic LED that alerts the operator to which mat has failed, and an internal diagnostic LED to help with troubleshooting by identifying the specific fault in the system.

Lasag Industrial-Lasers 401
601 Campus Dr., Ste. E-5
Arlington Heights, IL 60004
(847) 593-3021; FAX (847) 593-5062
www.lasag.com

Lasag will feature its compact, flexible, modular pulsed Nd:Yag lasers for high-quality, repeatable welding, cutting and drilling applications. The company offers an on-site lab for feasibility testing.

Laser Machining, Inc. 1628
500 Laser Dr., Somerset, WI 54025
(715) 247-3285; FAX (715) 247-5650
www.lasermachining.com

Laser Mechanisms, Inc. 1865
24730 Crestview Ct.
Farmington Hills, MI 48335
(248) 474-9480; FAX (248) 474-9277
www.lasermech.com

Lenco 1235
P.O. Box 348, Jackson, MO 63755
(573) 243-3141; FAX (573) 243-7122
www.profax-lenco.com

Highlighted will be the complete line of LENCO arc welding accessories, including three styles of electrode holders, ground clamps (both conventional and magnetic), cable connectors, international "dinse type" standard machine plugs, panel receptacles, connectors and GTAW machine plugs, lugs, splicers, cylinder wrenches and chipping hammers. Also featured will be the LENCO L-4000 MARK II series resistant welding machine, LENCOPULL dent pulling system used in auto body repair and a wide variety of auto body repair equipment.

Lenox/American Saw & Mfg. Co. 854
301 Chestnut St.
E. Longmeadow, MA 01028
(800) 628-3030; FAX (413) 525-8867
www.lenoxsaw.com

LeTourneau University 2091
P.O. Box 7001
Longview, TX 75607-7001
(903) 233-3241; FAX: (903) 233-3212
www.letu.edu

Libra Industries, Inc.-Recycling Div. 404
1823-55 W. Webster Ave.
Chicago, IL 60614
(773) 276-7500; FAX (773) 276-3331

Libra Industries will introduce its safety product recycling programs, which emphasize the cost saving aspects of recycling. The company will present examples of recovered materials from scrap and garbage containers, which require minimum paperwork to save thousands of dollars.

Liburdi Dimetrics 1157
404 Armour St.
Davidson, NC 28036
(704) 892-8872; FAX (704) 892-4713
www.liburdi.com

Liburdi will highlight its welding systems, automation technology, advanced coating and services for turbine, aerospace, orbital and industrial applications. Also featured will be an extensive range of orbital tube and pipe systems, industrial welding components and high-precision, high-speed welding power sources for automotive and tube mill applications.

Lincoln Electric Co., The 1439/1639
22801 St. Clair Ave.
Cleveland, OH 44117
(216) 481-8100; FAX (216) 486-1751
www.lincolnelectric.com

Lincoln Electric will feature the Ranger™ line of engine-driven welding machines; the Power MIG™ line of DC wire feeder/welding machines and the new Invertec® V350 Pro, a portable, multiprocess welding

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machine. Also featured will be SuperArc and SuperGlide GMAW wires and Outershield® 71 Elite FCAW wires, robotic systems, point-of-purchase displays, environmental systems, Harris® oxyfuel equipment and Motorsports "Pit Lane" attractions. Personnel will be available to offer solutions to welding needs, including aluminum, stainless steel, gas tungsten arc, plasma arc and pipe welding.

Lockheed Martin Michoud Space Systems 2329
P.O. Box 29304
New Orleans, LA 70189
(504) 257-0463; FAX (504) 257-1210
www.lmco.com/michoud/

LS Industries 1901
710 E. 17th St.
Wichita, KS 67214
(316) 265-7997; FAX (316) 265-0013
www.lsindustries.com

LS Industries will showcase its cleaning equipment for the metalworking industry including conveyorized airless shot blasters for structural steel, fabricated assemblies and parts, cylinder blasters for compressed gas and air cylinders, cabinet blasters, multistage conveyorized pretreatment washers, cabinet washers and vibratory shakers.

Lyall's Labors Ltd. 2090
1305 Summerset, Indianola, IA 50125
(515) 961-0106
www.lyallslabors.com

M&W Mfg. Corp. 2172
P.O. Box 308
Wolf Lake, IN 46796
(219) 827-5560; FAX: (219) 627-6510

M. Braun, Inc. 1946
85 Parker St., Unit 5
Newburyport, MA 01950
(978) 462-1770; FAX (978) 462-1862
www.mbraun.com

Machine Tech Inc. 903
2988 E. 24th Rd., Marseilles, IL 61341
(815) 795-6818; FAX (815) 795-6535

Machine Tools.com 1361
1122 N. LaSalle Blvd.
Chicago, IL 60610
(312) 482-8103; FAX (312) 482-0899
www.machinetools.com

Mack Products Co. 1771
1384 Nird Ave., Lakewood, OH 44107
(216) 226-6100; FAX (216) 226-7430
www.mackproducts.com

Mactech/Stresstech 2024
1007 Tile Dr., P.O. Box 11
Red Wing, MN 55066
(651) 388-7117; FAX (651) 388-0337
www.techgroupusa.com

The two operating companies, Mactech and Stresstech, will highlight their worldwide services in designing and building on-site machining and heat-treating equipment for sale and rent. Also featured will be their on-site heat treating and machining services.

Magnaflux 2102
3624 W. Lake Ave., Glenview, IL 60025
(847) 657-5300; FAX (847) 657-5388
www.magnaflux.com

Magnaflux will premier its chemicals and equipment for nondestructive examination, highlighting a diverse line of liquid penetrant and magnetic particle inspection products available in convenient aerosol kit form.

Magnatech Limited Partnership 2212
8 Kripes Rd., E. Granby, CT 06026
(860) 653-2573; FAX (860) 653-0486
www.magnatech-lp.com

Magnatech will showcase its systems for orbital tube and pipe welding, tube-to-tubesheet welding and weld cladding applications. The Tubemaster and Pipemaster systems will be exhibited for GTA welding with numerous application-specific weld head models. The Pipeliner II, a high-productivity orbital GMAW/FCAW process system, will be demonstrated.

MAN — Modern Applications News 1952
2500 Tamiami Trail N.
Nokomis, FL 34275
(941) 966-9521; FAX (941) 966-2590
www.modernapplicationsnews.com

Mannings USA, Inc. 2236
351-3 Lowery Ct., Groveport, OH 43125
(614) 836-0021; FAX (614) 836-0028
www.manningsusa.com

Mannings USA will feature its on-site thermal heat treatment services and products to the power, petrochemical, steel, manufacturing and fabrication industries. On display will be portable high-frequency induction, electric resistance and high-velocity combustion heat treatment equipment used for applications in the field.

Mark-Tex Corp. 718
160 W. Forest Ave.
Engelwood, NJ 07631
(201) 567-4111; FAX (201) 567-7857
www.mark-tex.com

Mathey Dearman 1535
4344 S. Maybelle Ave.
Tulsa, OK 74107
(918) 447-1286; FAX (918) 447-0188
www.mathey.com

The company will premier its cutting, beveling, clamping and aligning tools for a wide variety of pipe sizes and applications.

New products will be introduced, including the Magnacut magnetic pipe cutting device, Dearman light chain clamps and welding electrode drying ovens. A new free video will be available.

McKay Welding Products 1805
400 Trade Square E.
Troy, OH 45373
(937) 332-4000; FAX (937) 332-5224
www.hobartbrothers.com

McKay will be exhibiting its complete line of premium stainless steel and hard surfacing filler metals. New, as well as highly recognized, stainless and hardsurfacing consumables will be shown. Knowledgeable engineers and sales personnel will be on hand to demonstrate products and offer welding solutions.

MECHAFIN AG 943
Chrummacherstrasse 3
Gerodswil CH8954, Switzerland
41 1 7493060; FAX 41 1 7493070

Mega Mfg./ Piranha-Allsteel 1028
401 S. Washington St.
Hutchinson, KS 67502
(316) 663-6542; FAX (316) 662-1719
www.megamfg.com

Merit Abrasive Products, Inc. 646
201 W. Manville St.
Compton, CA 90220
(800) 421-1936; FAX (800) 472-3094

Metabo Corp. 713
1231 Wilson Dr., W. Chester, PA 19380
(610) 436-5900; FAX (610) 436-9072
www.metabousa.com

Metabo will showcase its portable electric power tools and abrasives for the professional, including a new line of small angle grinders featuring a long lasting motor and new ergonomic design. Also on display will be a recently expanded line of abrasive products engineered for grinding cutting, and finishing applications.

Metal Forming Magazine 856
6363 Oak Tree Blvd.
Independence, OH 44131
(216) 901-8800; FAX (216) 901-9190
www.metalforming.com

MetalForming is edited for decision makers in the precision metalforming industry, including top management, engineering, production, purchasing, sales and financial managers. Editorial content covers industry trends, new technologies, equipment and materials, as well as innovative design and production methods of interest to stampers, precision fabricators, welders, spinners, roll formers and others who process sheet metal.

Metal Mates, Inc. 237
6650 Highland Rd., Ste 217
Waterford, MI 48327
(248) 666-1880; FAX (248) 666-3359

Metal Mates will feature its welding-compatible metal forming lubricants specifically designed for performance in secondary assembly operations. These products leave minimal residuals on parts, allowing welding without wash. Examples and technicel information regarding these products and their uses will be available.

Metal Mizer 461
8180 W. 10th St.
Indianapolis, IN 46214
(317) 271-1542; FAX (317) 273-7007
www.metalmizer.com

Metal Processing Systems, Inc. 1630
1095 National Parkway
Schaumburg, IL 60173
(847) 310-6363; FAX (847) 310-6080

The company will premier its high-power, large-bed, plate lasers. Featured will be the LMXIII series, which utilizes a high-power-density CO_2 laser beam to cut mild steel up to 1-in. thick.

Metorex Inc. 432
Princeton Crossroads Corp. Ctr.
250 Phillips Blvd., Ste. 250
Ewing, NJ 08618
(609) 406-9000; FAX (609) 530-9055
www.metorax.com

MG Systems-Messer 459
W141 N9427 Fountain Blvd.
Menomonee Falls, WI 53051
(262) 255-5520; FAX (262) 255-5170

The company will showcase ComCut, which is ideally suited for the smaller workshop to oxyfuel or plasma cut using CNC at an affordable price. It offers the flexibility to produce parts quickly, accuretely end economically.

MG Welding Products 1954
N94 W14355 Garwin Mace Dr.
Menomonee Falls, WI 53051
(262) 255-5520; FAX (262) 255-5542
www.messer-mg.com

A complete line of high-performance, high-quality maintenance and repair alloys, specialty alloys and stainless steel products will be featured. Experienced personnel will be on hand for technical support.

Micro Air by Metal-Fab, Inc. 1061
P.O. Box 1138, Wichita, KS 67201
(316) 943-2351; FAX (316) 943-2717
www.mtlfab.com

The company will present air cleaners, exhauster arms, downdraft tables and dust collectors designed to control, remove and filter welding smoke and fumes. Cartridge filter models will be on display with the unique Roto Pulse cleaning system in operation.

Midalloy, Inc. 1829
2519 Cassens Dr., Fenton, MO 63026
(314) 349-6000; FAX (314) 349-2240

Miller Electric Mfg. Co. 1606/1601
1635 W. Spencer St.
Appleton, WI 54912
(920) 734-9821; FAX (920) 735-4013
www.millerwelds.com

Miller Electric will present its newest welding technology innovations with live arc demonstrations, including the engine drive, inverter-based PipePro with dual power input, and the the aluminum welding package of XR™ push-pull wire feeder, XR-Edge gooseneck gun and Invision™ 345MP inverter with built-in pulsing programs.

Milwaukee Electric Tool 1016
13135 W. Lisbon Rd.
Brookfield, WI 53005
(414) 783-8632; FAX (414) 783-8529
www.mil-electric-tool.com

Milweld, Inc. 630
P.O. Box 338, Hortonville, WI 54944
(920) 779-0916; FAX (920) 779-0924
www.milweldinc.com

MIM Industries, Inc., A Brother Co. 1822
4301 Lyons Rd.
Miamisburg, OH 45342
(937) 866-4478; FAX (937) 859-6944
www.mimind.com

MIM Industries will feature its expertise at manufacturing specialized automation equipment, which includes its XY welding machine that ensures weld locations are precisely made and utilizes reprogramming for later applications after the initial job is completed.

Mitsubishi Materials U.S.A. Corp 411
17401 Eastman St., Irvine, CA 92614
(949) 862-5100; FAX (949) 862-5180

Miyachi 928
245 E. El Norte St., P.O. Box 5039
Monrovia, CA 91016
(626) 256-4182; FAX (626) 303-5396
www.miyachi1.com

The feature with Miyachi will be its AC and DC resistance welding controls, inverter power supplies, weld checkers, weld heads and a variety of accessories for both fine spot and large-scale resistance welding applications.

MK Products, Inc. 1452
16882 Armstrong Ave.
Irvine, CA 92606
(949) 863-1234; FAX (949) 474-1426
www.mkprod.com

Modular Ventilation Products Inc. 2041
P.O. Box 8358
Freehold, NJ 07728-6356
(888) 247-7101; FAX: (888) 409-2779
www.modularventilation.com

Moldex Metric Inc. 206
10111 W. Jefferson Blvd.
Culver City, CA 90232
(310) 837-6500; FAX (310) 837-9563
www.moldex.com

Monroe Engineering Products, Inc. 564
38400 Woodward Ave., Ste. 241
Bloomfield Hills, MI 48304
(248) 540-8585; FAX (248) 540-6717
www.monroeengineering.com

Moore Industrial Hardware 664
77 Circle Freeway Dr.
Cincinnati, OH 45246-1298
(888) 666-7344; FAX (888) 644-3293
www.mooreindhardware.com

Moore Industrial Hardware will feature its expertise in distributing hard-to-find hardware items manufactured by many suppliers. Products such as hinges, handles and locks will be displayed. A complete catalog showing available items will be sent upon request.

Morgan Advanced Ceramics 2409
Bewdley Rd., Stourport-on-Severn
Worcestershire DY13 8QR, England
44 1299827000; FAX 44 1299872218
www.morganadvancedceramics.com

Morgan Advanced Ceramics will showcase its high-performance silicon nitride weld location pins, GMA welding and plasma cutting nozzles and insulators, GTA nozzles in silicon nitride and pink alumina and new low-porosity ceramic weld backing strips in various designs.

Morsafe 1407/1411
2997 Clarkson Rd.
Chesterfield, MO 63017
(636) 207-2750; FAX (636) 207-2810
www.jackprod.com

Morsafe, a division of Jackson Products, will showcase its complete line of protective products and welding accessories, including electronic ADF (auto-darkening filter) helmets, and

goggles and spectacles equipped with hardened glass or polycarbonate lenses.

Motoman Inc. **1858**
805 Liberty Lane
W. Carrollton, OH 45449
(937) 847-6200; FAX (937) 847-3288
www.motoman.com

On display will be several standard robotic arc welding solutions featuring a robot end controller, complete welding package and total safety environment. Demonstrations will be conducted of welding aluminum and thin steel with alternating current GMAW, low-spatter welding of stainless and mild steel and high-speed welding. A new line of MotoWeld power supplies that use advanced technology for a variety of robotic applications will be introduced.

MQ Power Inc., Div. of MultiQuip **1682**
16910 Wilmington Ave.
Carson, CA 90746
(800) 421-1244; FAX (310) 537-3927
www.multiquip.com

MQ Power will showcase its gasoline- and diesel-powered DC engine-driven welding machines, which come in both CC and CC/CV and perform SMAW, GMAW, FCAW and GTAW. Also featured will be gasoline- and diesel-powered generators from 2.3 to 640 kW.

MVE, Inc. **1816**
3305 County Rd. 42 W.
Burnsville, MN 55306-3803
(770) 720-6765; FAX (770) 479-4603
www.mve-inc.com

N. A. Tech. Inc. **1910**
1317 Washington Ave., Sta 1
Golden, CO 80401
(303)279-7942; FAX: (303) 279-5286
www.natech-inc.com

N.L.F. Protective Products, Inc. **548**
3131 Cedar Cross Ct., Unit 4
Dubuque, IA 52003
(800) 622-8588; FAX (319) 582-5570

Nasco Inc. **2222**
2100 Old Highway 8
St. Paul, MN 55112
(651) 780-2000; FAX (651) 638-1802

National-Standard Co. **1460**
1618 Terminal Rd., Niles, MI 49120
(800) 777-1618; FAX (616) 683-8276

National-Standard will feature the new Satin-Glide 2000 stainless steel welding wire along with its Copper Free welding wires, Tru-Cor cored electrodes and Brush Pack dispensing systems. Personnel will also be available to provide cost anaylsis of certain welding applications.

Natweld-Hi Alloy Corp. **1841**
1600 S. Canal St.
Pittsburgh, PA 15215
(412) 781-4255; FAX (412) 781-4377

NatWeld-Hi Alloy will display a full range of GMAW and GTAW alloys, tungsten, CO_2 wire, electrodes, gouging carbons, electrode holders, ground clamps, solder, stainless steel wire, phosphor copper, flux-coated and bare bronze alloys, welding cables and aluminum wire. Also shown will be nickel alloys, deox copper, antispatters, nozzle gel and maintenance alloys. Product literature and catalogs will be available, and staff will be on hand to answer questions.

Naval Surface Warfare Center (NSWC) **1456**
Carderock Div., Welding & NDE Branch
9500 MacArthur Blvd.
West Bethesda, MD 20817-5700
(301) 227-4996; FAX (301) 227-5576
www.dt.navy.mil

Navy Joining Center (NJC) **1456**
1250 Arthur E. Adams Dr.
Columbus, OH 43221-3585
(614) 688-5111; FAX (614) 688-5001
www.ewi.org

Nederman, Inc. **919**
39115 W. Warren Rd.
Westland, MI 48185
(734) 729-3344; FAX (734) 729-3358
www.nederman.com

Nederman will introduce the new FilterMax, a modular filtration fume/dust collector system available in sizes ranging from 2000–6000 ft^3/min. It requires minimal floor space and comes equipped with a unique cartridge filtration system.

Neutronics Inc. 774
456 Creamery Way
Exton, PA 19341
(610) 524-8800; FAX (610) 524-8807
www.neutronicsinc.com

Neutronics will exhibit its high-performance oxygen analyzers, primarily used in high-purity welding. Featured will be state-of-the-art instrumentation for the analysis and control of gaseous oxygen from ultra low-levels (parts per billion) to 100%.

Newtex Industries, Inc. 2348
8050 Victor Mendon Rd.
Victor, NY 14564
(716) 924-9135; FAX (716) 924-4645

Nikro Industries Inc. 2345
638 N. Iowa St., Villa Park, IL 60181
(630) 530-0558; FAX (630) 530-0740
www.nikro.com

Nippert Co., The 1255
801 Pittsburgh Dr.
Delaware, OH 43015
(740) 363-1981; FAX (740) 368-4384

Nippert will premier its welding electrodes manufactured under the strictest quality control methods

Nissen Co., J. P. 504
P.O. Box 339
Glenside, PA 19038
(215) 886-2025; FAX (215) 886-0707
www.nissenmarkers.com

J. P. Nissen will exhibit and demonstrate its line of markers for the welding industry. These include ball-point metal markers, solid paint markers, feltip paint markers and aerosol paint markers, as well as specialized products intended for fabricating, nuclear and high-temperature applications.

Niton Corp. 613
900 Middlesex Turnpike, Bldg. 8
Billerica, MA 01821
(800) 875-1578; FAX (781) 275-1917
www.niton.com

Niton will showcase its instrumentation for nondestructive alloy analysis, including the XL-800 series alloy analyzer and the new hand-held NITON II X-ray fluorescence (XRF) alloy analyzers. Also featured will be the new PMI-Master Arc/Spark alloy analyzer for analysis of carbon and other alloying and trace elements in metals and metal alloys.

Nitto Kohki 1148
4525 Turnberry Dr.
Hanover Park, IL 60103
(630) 924-9393; FAX (630) 924-0303

NonDestructive Testing Group 431
8181 Broadmoor SE
Caledonia, MI 49316
(800) 748-0208; FAX (616) 891-3565
www.nondestructivetesting.com

Norris Cylinder Co. 1473
P.O. Box 7486
Longview, TX 75607-7486
(903) 237-7604; FAX (903) 237-7654

Norton Co. 1047
1 New Bond Street,
P.O. Box 15008
Worcester, MA 01615-0008
(800) 446-1119; FAX (508) 795-5489
www.nortonabrasives.com

A complete line of abrasive wheels, coated abrasive and nonwoven products for weld grinding, cutting and finishing will be exhibited. New products featured include AVOS® 4-1/2-in. Speed-Lok® kits, 5-in. Speed-Lok Edger discs, Speed-Lok Pistol Grip trial kits and the 7-in. Speed-Lok Edger discs. Right-angle grinder discs for stainless steel and aluminum and two new chip saw wheels for cutting off aluminum will be highlighted.

NSL Analytical Services, Inc. 218
7650 Hub Pkwy.
Cleveland, OH 44125
(216) 447-1550; FAX (216) 447-0718
www.nslanalytical.com

NSL will premier its services as a commercial testing laboratory specializing in the elemental chemistry analysis of ferrous and nonferrous alloys, powdered metals, ceramics and composite materials. Featured will be its various chemistry capabilities, including analysis of titanium, high-temperature alloys and refractaries.

NTT 1612
50 Freeport Rd.
Pittsburgh, PA 15215-1075
(412) 781-4200; FAX (412) 781-1075

Oerlikon Welding Ltd. 2222
Peakdale Rd.
Glossop, Derbyshire SK13 6XG, UK
44 1457 866011; FAX 44 1457 855551

Oetiker, Inc. 614
3305 Wilson St.
Marlette, MI 48453-0217
(517) 635-3621; FAX (517) 635-2157
www.oetiker.com

Oetiker will display its 2-Ear Clamps, which are especially suited for factory maintenance or heavily vibrating equipment. This medium-pressure clamp is widely used for MRO and OEM applications. The one-piece design offers a positive, tamperproof seal without damage to the hose. The clamps ensure adequate closure and compensate for tolerance variation in hose sizes. These clamps are installed on air fluid lines. Oetiker will also showcase its full line of clamping products to suit a diversified range of applications.

Ogden Engineering Corp./ISU 2156
P.O. Box 148
372 W. Division St.
Schererville, IN 46375
(219) 322-5252; FAX: (219) 865-1825
www.ogdeneng.com

OGI/PSU 1988
20000 N.W. Walker Rd.
Beaverton, OR 97006
(503) 748-1177; FAX (503) 748-1678

Narrow-gap-improved electroslag welding will be demonstrated by the Oregon Graduate Institute. The process has been reengineered to provide greatly enhanced reliability, properties and productivity. This technology is being demonstrated to fabricators and state highway departments across the United States through two-day demonstration workshops sponsored by the Federal Highway Administration. Technical information and equipment will be displayed. Application engineers will be available for discussions. Electroslag demonstrations are scheduled each day.

Ohio State Univ., The Welding Engineering 2089
1248 Arthur E. Adams Dr.
Columbus, OH 43221
(614) 292-2545; FAX (614) 292-6842
www.iwse.eng.ohio-state.edu/we

OKI International, Div. of OKI Bering 1773
7584 Reinhold Dr.
Cincinnati, OH 45237
(513) 761-9811; FAX (513) 761-2910
www.oki-bering.com

Olympus America Inc. 710
Two Corporate Center Dr.
Melville, NY 11747
(516) 844-5610; FAX (516) 844-5820
www.olympusipg.com

Olympus America will show its line of fiberscopes, bore-scopes, videoscopes, the PT36-300 pipe camera system and L-VIS large-vessel inspection system, and image analysis equipment for inspecting pipes, tanks and other inaccessible areas. The PT36-300 sends clear, color images from within pipes up to 100 ft long. Portable, lightweight, durable, it can be operated on 100–240 V AC or 12-V DC power. Images can be stored, measured and e-mailed by adding the DSM Digital Store & Measure System. The portable L-VIS system offers high-resolution color video images, telescope poles, pan, tilt, zoom, auto or manual focus.

Omniturn 546
40 Allen Blvd., Farmingdale, NY 11735
(516) 694-9400; FAX (516) 694-9415

Omniturn will provide information on its small precision CNC lathes and retrofits for primary and secondary bar/chucking operations. Raw material/ round bar stock is put into CNC lathes and is machined to specific tolerances according to blueprint.

Onan Corp. 301
1400 73rd Ave. NE
Minneapolis, MN 55432
(612) 574-5000; FAX (612) 574-8289
www.cummins.com

OPTREL AG 1673
10 Thurber Blvd., Smithfield, RI 02917
www.uvex.com

Osborn International 2039
5401 Hamilton Ave.
Cleveland, OH 44114
(216) 361-1900; FAX (216) 361-1913
www.osborn.com

Osborn will display its heavy-duty power brushes, which are used for weld preparation. They quickly remove all types of rust, weld scale, corrosion and other contaminants. The brushes are made with special-analysis steel and stainless steel wire to extend their life and keep them performing at peak efficiency. Wide-face, heavy-duty wheel brushes work well on face preparation, and knot-type and encapsulated cup brushes give the kind of aggressive action needed for any flat-surface preparation.

Osram Sylvania 1574
Hawes St., Towanda, PA 18848
(570) 268-5000; FAX (570) 268-5157
www.sylvania.com

Otos Optical Co., Ltd. 531
149-27, Oock San 1 Dong
Keum Chun-Ku, Seoul, S. Korea
82 2 8628000; FAX 82 2 8693333
www.otos.co.kr

Oxo Welding Equipment Co. 1612
701 W. Water St., Troy, OH 45373
(937) 332-4312; FAX (937) 332-4311

Oxylance Corp. 1911
P.O. Box 310280
Birmingham, AL 35231
(205) 322-9906; FAX (205) 322-4808
www.oxylance.com

P & R Specialty, Inc. 821
1835 W. High St., Piqua, OH 45356
(937) 773-0263; FAX (937) 773-4243
www.wesnet.com/prspecialty

P & R Specialty will exhibit its full line of welding wire spools and plywood reels designed specifically for the welding industry. Also on display will be a full line of plastic spools.

PAC*MIG, Inc. 2060
P.O. Box 2174, Wichita, KS 67201
(318) 269-3040; FAX (316) 269-2404
www.pacmig.com

PAC*MIG will display its patented line of pressurized air-cooled GMAW guns for automatic, semiautomatic and robotic applications, with a special emphasis on robotics. This technology utilizes shop/compressed air to cool the guns. With only 1.8 ft^3/min of air required for cooling, this technology offers the end user an economical, safe and effective alternative for high-production welding environments. Guns are offered in 350-, 400- and 600-A models, all rated at 100% duty cycle.

Pacific Aerospace & Electronics 217
2249 Diamond Point Rd.
Sequim, WA 98382
(360) 683-4187; FAX (360) 683-4168
www.pcth.com

Panametrics, Inc. 328
221 Crescent St., Waltham, MA 02453
(781) 899-2719; FAX (781) 899-1552
www.panametrics.com

Panametrics, which has nearly 40 years of industry experience, will showcase its line of ultrasonic transducers and nondestructive examination equipment, including scanning systems, thickness gauges and digital flaw detectors.

Panasonic Factory Automation 1464/1664
9377 W. Grand, Franklin Park, IL 60131
(847) 288-4400; FAX (847) 288-4684
www.panasonicfa.com

Pandjiris, Inc. 1813
5151 Northrup Ave.
St. Louis, MO 63110
(314) 776-6893; FAX (314) 776-8763
www.pandjiris.com

Pandjiris will demonstrate an automated welding system that incorporates components that can be used in a variety of applications. Experienced welding technicians and application engineers will be available to discuss how these and other components can be configured to meet the needs of specitic automation applications.

Pangborn Corp. 267
580 Pangborn Blvd.
Hagerstown, MD 21742
(301) 739-3500; FAX (301) 739-2279
www.pangborn.com

Pangborn will feature the Model ES-1821 structural descaling blast cleaning system, which provides one-pass cleaning of plate, bars and rolled shapes prior to fabrication. The company offers a complete line of equipment and services for descaling of plate, sheets, strip, wire, bars, billets and slabs; rolled and fabricated structural shapes; miscellaneous weldments; pipe, tubing and gas cylinders; railroad cars and shipping containers; and special systems tailored to meet specific applications, such as mill roll etching machines.

Parweld Ltd. 109
Parweld House, Bewdley Business Park
Long Bank, Bewdley
Worcestershire DY12 2UJ, England
44 1299266800; FAX 44 1299266900

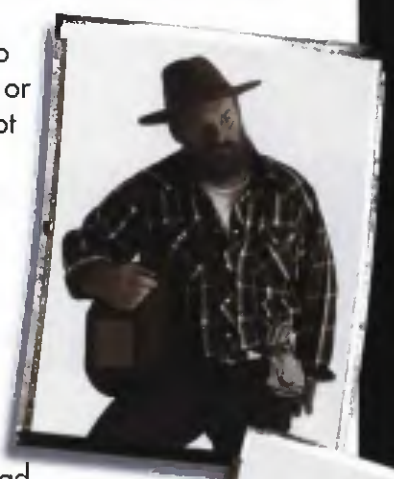
Parweld will feature its line of GMA, GTA and plasma arc welding guns and torches. The company manufactures its own designed and developed products, which are compatible with popular brands. All products conform to EN 50078 and ISO 9001 and carry the CE mark.

Pat Mooney, Inc. 766
31 W. Fullerton Ave.
Addison, IL 60101
(630) 543-6222; FAX (630) 543-5584

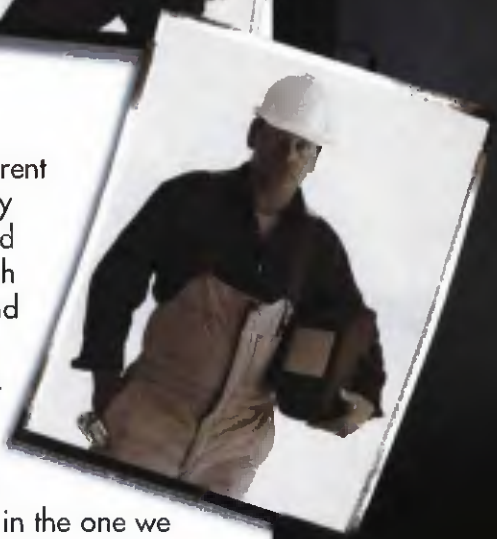
PCI Energy Services 874
One Energy Dr., Lake Bluff, IL 60044
(847) 680-8100; FAX (847) 362-6441
www.pci-energy.com

These guys have found the Anser.™

"When I'm running a bead, I'm making money. But there's no profit in fumbling around inside a welding helmet to switch out a lens or a cover plate. Not only does it take up time, it's frustrating–I've been known to crawl around on the floor looking for a lost spring, or drop and break a piece of glass. That's why I'm glad I've found the Anser.™



"Because of all the different kinds of work we do, my shop used to be cluttered with lots of helmets, each with a different lens. And you know what a pain changing lenses can be. With the new Anser™ helmet from Huntsman®, we keep a stack of lens cartridges and just pop in the one we need when we need it."



Shouldn't you?

The EasyCartridge™ slides in and out the front of the helmet. Simply pull out the cartridge, pull out the spring pack, slide in a new lens (standard or electronic) and pop the spring pack back in place. Change the cover plate quickly, by pulling out the old cover plate and sliding in the new one. Ask your Huntsman® distributor for the Anser.™

The EasyCartridge,™ any way you want it.

The Anser™ accommodates all "Big Window®" size lenses from Huntsman®.

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- **VXL 4x4 4 sensor electronic lens**
- **iVXL universal electronic lens**
- **Solex 180 solar powered lens**

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PCI will showcase its field machining, automated welding, QA/QC services and specialized tooling. The company, which has 30 years' experience, can service a wide variety of industrial users. With a staff of more than 300 experienced supervisors, managers, QA/QC professionals, engineers (welding, mechanical and electronic), CAD operators and technicians, the company brings shop tolerances and controls to the field.

Pearl Abrasives Co. 610
8210 S. Garfield Ave.
Commerce, CA 90040
(562) 927-5561; FAX (562) 928-3857

The company will feature a complete line of bonded and coated abrasives and wire brushes. It will also featuring its SRT (synthetic resinoid technology) grinding wheels, flexible grinding wheels, cutoff wheels and flap discs.

Peddinghaus Corp., Tool Div. 2139
825 75th St., Willowbrook, IL 60521
(800) 786-2448; FAX (630) 655-6316
www.peddinghaus.com

Permadur Industries, Inc. 819
186 Route 206 S., Somerville, NJ 08876
(908) 359-9767; FAX (908) 359-9773
www.permadur.com

Peters, Cherie A., Metalworking Artist 1987
700 Perrie Dr., #203, Elk Grove, IL 60007
(847) 840-6364

Cherie Peters has been a production welder for Duratrack in Elk Grove, Ill., since 1993. She has been creating sculptures for two years. Some are serious and others are whimsical. Most of her sculptures are created spontaneously, and some are from previous drawings. She has had no formal training as a metalworking artist.

Pferd, Inc. 1271
30 Jytek Dr., Leominster, MA 01453
(800) 790-7786; FAX (978) 840-1274
www.pferd.com

The company will feature its line of grinding and cutoff wheels, wire wheel brushes, cup brushes, end brushes, wire hand scratch brushes, pipeline brushes, abrasive filament brushes, maintenance brushes, fiber discs, tungsten carbide burrs, flap wheels, flap discs, nonwoven abrasives, abrasive belts, quick-change discs and PSA discs.

PHI 543
14855 E. Salt Lake Ave.
City of Industry, CA 91746-3133
(626) 968-9686; FAX (626) 333-3610
www.phi-tulip.com

Phoenix Int'l, Inc. 736
8181 N. 64th St., Milwaukee, WI 53218
(414) 431-2600; FAX (414) 438-0238
www.phx-international.com

Phoenix International will show its complete line of the original DryRod® oven for holding, reconditioning and rebaking welding electrodes and bulk flux. Also on display will be the dryWIRE® oven, which holds flux-cored wire in a moisture-free environment and which also can be used as a general industrial oven for pre- or postheat up to 550°F. The Safetube® accommodates 14 lb of electrodes in a watertight, durable container. It also offers a carrying strap with cap tether, nonrolleway shape and safety yellow color.

Photonics Spectra 1735
Berkshire Common, P.O. Box 4949
Pittsfield, MA 01202-4949
(413) 499-0514; FAX (413) 442-3180
www.photonics.com

Photonics Spectra is a photonics magazine serving industries that use photonic technology: lasers, imaging, fiber optics, electro-optics and optoelectronics. The *Photonics Directory* is a four-book set that includes the Corporate Guide, Buyers' Guide, Handbook and Dictionary. Subscriptions are free.

Pietro Galliani S.p.A. 2331
Via Molino Malpasso, 65
Vergato, Bologna 40038, Italy
39 51 910061; FAX 39 51 911055

Pillar/Cycle-Dyne 731
21905 Gateway Rd.
Brookfield, WI 53045
(414) 317-5300; FAX (414) 317-5353
www.pillar.com

Pillar/Cycle-Dyne will demonstrate its induction heating equipment for brazing, soldering, curing, shrink fitting, bonding and other methods of joining and heat treating. A variety of ferrous, nonferrous and aluminum brazed parts will be on display along with shrink fitting, bonding and curing applications.

Pip Co. 336
45-625 Citrus Ave., Ste. C
Indio, CA 92201
(760) 775-3434; FAX (760) 775-6534
www.magnaclamp.com

Plasma Scorpion Schneiden & Schweissen AG 270
Am Forsthaus 45
Geilenkirchen 52511, Germany
49 2451903230; FAX: 49 24519032320
www.plasma-scorpion.de

Plazcraft, A Div. of DovaTech, Ltd. 1428
449 W. Corning Rd., Beecher, IL 60401
(708) 946-2281; FAX (708) 948-6726

Plazcraft will highlight its line of air plasma arc cutting torches. Its products are engineered to provide end users with a low-cost alternative for replacement torches and accessory items, compared to original equipment parts. In addition, a high degree of safety for the end user has been built into the company's torches.

Plymovent Corp. 128
375 Raritan Center Pkwy.
Edison, NJ 08837
(732) 417-0808; FAX (732) 417-1818
www.plymovent.com

Polymet Corp. 1870
10073 Commerce Park Dr.
Cincinnati, OH 45246
(513) 874-3586; FAX (513) 874-2880
www.polymetcorp.com

Polymet will feature its cobalt and nickel solid superalloy small-diameter welding wires. The products are offered on spools or as cut lengths and are used with the GMAW and GTAW processes. It will also display cored welding wires used in numerous industrial applications. These spooled wires are used with the GMAW, SAW, FCAW and twin-arc wire thermal spray processes.

Port-A-Cool/Div. of Gen. Shelters **2104**
P.O. Box 2108, Center, TX 75935
(409) 598-5651; FAX (409) 598-5057
www.generalshelters.com

Port-A-Cool™ will showcase its porteble, evaporative cooling system for use when standard air-conditioning may be unavailable, impractical or cost prohibitive. Operating with water and either electricity or compressed air, the system delivers air flow up to 20 degrees cooler than the surrounding air. It is available in three sizes.

Practical Welding Today/ The Fabricator **618**
833 Featherstone Rd.
Rockford, IL 61107
(815) 399-8775; FAX (815) 484-7701
www.fmametalfeb.org

Practical Welding Today® provides hands-on, practical information on welding end joining processes and machinery such as GMAW, GTAW, SMAW, plasma arc cutting, resistance welding and robotic welding. Free issues of *Practical Welding Today, The Fabricator*® and *TPJ–The Tube & Pipe Journal*® will be available. U.S. subscriptions are tree to qualified individuals. Information on the books, technical conferences and research services available from the Fabricators & Manufacturers Association, International, also will be featured.

Praxair Surface Technologies, Inc. **1245**
1500 Polco St., Indianapolis, IN 46224
(317) 240-2500; FAX (317) 240-2380

Praxair, Inc. **1245**
39 Old Ridgebury Rd.
Danbury, CT 06810
(800) 772-9247; FAX (800) 772-9985
www.praxair.com

Praxair will provide information on cost-effective solutions to metal fabricators' most demanding welding, cutting, thermal spraying, laser processing and thermal treating operations. Through more than 600 locations in North America, the company offers a variety ot gases, equipment and services to help increase productivity, improve quality, lower welding fume levels and reduce production costs. The company will also teature its ProStar family of premium-quality, competitively priced filler metals, gas apparatus, safety products and welding consumables, chemicals and eccessories.

Precision Welding Technologies, Inc. **667**
753 Twinview Pl.
Pleasant Hill, CA 94523
(925) 843-5658; FAX (925) 943-5682

Precision Welding Technologies will feature verious products that complement automated GTAW/PAW and electron beam welding systems. On display will be e precision GTAW/PAW 200-A power supply, stand-alone cepacity discharge arc starter and specialized gas auxiliary/trailing shields for common manual and machine GTAW/PAW torches. The company also provides equipment maintenance services end training, as well as system upgrades for electron beam and fusion welding machines.

Preston-Eastin, Inc. **1479**
5341 E. Independence, Tulsa, OK 74115
(918) 834-5591; FAX (918) 834-5595
www.prestoneastin.com

Preston-Eastin will display its line of standard and robotic positioners.

Prince & Izant Co. **2248**
12333 Plaze Dr., Cleveland, ON 44130
(216) 362-7000; FAX (216) 362-7456

Prince & Izant will highlight its line of brazing alloy and soldering preforms. Examples of rings, washers, slugs, shims and special shapes will be on display. Also featured will be its wire, strip, powder end paste. The company specializes in brazing alloys mede with silver, gold, platinum, palladium, aluminum and copper, as well as a large variety of soldering alloys. The company's tooling and torming capabilities allow it to supply the preform that will best fit a customer's brazing or soldering requirement.

Pro Design Welding Hoods **137**
438 E. Alondra Blvd.
Gardena, CA 90248
(310) 767-1032; FAX (310) 767-1034
www.prodesignwelding.com

Procon Products **320**
910 Ridgley Rd.
Murfreesboro, TN 37129
(615) 890-5710; FAX (615) 896-7729
www.proconpump.com

Procon Products will feature its line of precision pumps. The company has more than 20 euthorized exchange centers located throughout the United States and Canada.

Profax 1235
1603 N. Main, Pearland, TX 77581
(281) 485-6258; FAX (281) 485-8030
www.profax-lenco.com

Project Tool & Die, Inc. 616
6955 Danyeur Rd., Redding, CA 96001
(530) 243-8903; FAX (530) 243-8914

Protem USA/ CSI Tools, Inc. 1213
2700 Partnership Blvd.
Springfield, MO 65803
(800) 258-0133; FAX (417) 831-9363
www.protemusa.com

Protem USA will highlight its tube and pipe portable machining equipment. The company's complete line covers a wide range from ⅜- to 60-in. OD, and can perform four simultaneous machining operations on any machinable alloy. The company's portable machining tools are being used in pharmaceutical processing plants, aerospace, semiconductor, nuclear and fossil fuel power plants, pulp and paper mills, oil refining and pipe welding fabrication shops around the world.

Proteus Industries Inc. 2067
340 Pioneer Way
Mountain View, CA 94041-1577
(650) 964-4163; FAX (650) 965-9355
www.proteusind.com

Pulsar Ltd. 1974
P.O. Box 421, Yavne 81103, Israel
972 8 9427750; FAX 972 8 9427746
www.pulsar.co.il

Punch Press — The Metalworkers Market Place 556
100 Chicago Ave.
Lost Springs, KS 66859
(800) 255-0114; FAX (785) 983-4398

Punch Press (The Metal Workers Marketplace) is a trade publication for the metalworkers industry. The publication reaches manufacturing facilities, machine shops, fabricators, machine dealers and many others with its more than102,000 circulation. It offers direct marketing to potential buyers and sellers in the industrial machine tool industry, and is published in the United States and Canada.

Quality Components Co. 2053
8825 East Ave., P.O. Box 956
Mentor, OH 44060
(440) 255-0606; FAX (440) 255-3223

Raddital 1317
Via Locatelli 96
Biassono (MI) 20046, Italy
039 39 2494478; FAX 039 39 2494296

Raddital will display complete bolt-on and standoff rectifier assemblies for welding machines. Custom and off-the-shelf solutions are available for all GMAW, SMAW and GTAW requirements, whether they are redesigns or new machines, including semi- and fully controlled assemblies. Catalogs and samples will be available.

Radyne Corp. 1074
211 W. Boden St., Milwaukee, WI 53207
(414) 481-8360; FAX (414) 481-8303
www.radyne.com

Radyna will exhibit its air-cooled, compact, solid-state induction power supplies rated at 5 to 25 kW power output that are designed for brazing and soldering applications. A 5-kW unit will be demonstrated on suitable customer-supplied products. Quick Disconnect Tooling and various induction coil designs will also be available for on-site applications. This equipment compliments other units available from 1 to 5000 kW.

Rankin Industries, Inc. 1355
2285 Main St., San Diego, CA 92154
(619) 575-6000; FAX (619) 575-6003

Rankin Industries, a formulator and producer of hardfacing electrodes and wires, will feature its 0.035-in. high-alloy hardfacing wires designed for hardfacing smaller parts that may warp with larger diameters. This addition completes the range from 0.035 to ⅛ in. Also

on display will be the Swesco wire feeder, which delivers thin-stripped, high-alloy wires. The exhibit will include several parts from a variety of industries.

Ransome Co. 1241
3511 W. 12th St., Houston, TX 77008
(713) 868-0682; FAX (713) 868-0649

Ready Welder Corp. 2354
1931 N. Geffey St., Ste. B
San Pedro, CA 90731
(800) 935-3644; FAX (310) 832-9958
www.readywelder.com

Ready Welder will display its Ready Welder II portable, DC-powered GMAW machine and spool gun. The unit is powered by either deep-cycle batteries (18–36 V) or the DC outputs of arc or wire-feed welding machines. At 24 V, the unit welds up to ½-in. steel and ¾-in. aluminum.

Reed Mfg. Co., Inc. 521
P.O. Box 1321, Erie, PA 16512-1321
(800) 666-3691; FAX (800) 456-1697
www.reedmfgco.com

Reed will feature its Combi and Compact electric solderer. Both use resistance heating to melt solder without a flame. The Combi combines soft soldering up to 2 in. (5 cm), silver soldering up to ¾ in. (2 cm) and thawing up to 1 in. (2.5 cm). The Compact soft solders up to ¾ in. A ¾-in. joint can be made in 30 s without damage to nearby pipes, fittings or fixtures.

Reis Robotics/ESAB 1207
1320 Holmes Rd., Elgin, IL 60123
(847) 741-9500; FAX (847) 888-2762
www.relerobotics.com

Resistance Welder Manufacturers' Assoc. 830
1900 Arch St., Philadelphia, PA 19103
(215) 564-3484; FAX (215) 963-9785
www.rwma.org

The Resistance Welder Manufacturers' Association will highlight its membership benefits. The association represents approximately 50 manufacturers of resistance welding machinery, electrodes and component suppliers of such equipment as transformers and controls. Associate members include educators, engineers and consultants to the resistance welding industry. The association conducts spring and fall welding schools, which are open to the public, and publishes educational bulletins and the *Resistance Welding Manual.*

Resistance Welding Products Ltd. 342
9270 Meriborough St., P.O. Box 670
Blenheim, Ont. N0P 1A0, Canada
(519) 676-8173; FAX (519) 676-3329
www.rwpweld.com

Resistance Welding Products will display its resistance welding consumables. Products include dual-kickless (low-reactance), water-cooled single, air-cooled (standard extra flex) shunt cables, including laminated shunts; specialty machined electrodes; fixtures; and cold-formed weld gun adapters and holders. The company offers transformer sales and repairs. The company is a full line supplier, distributing various popular brands.

Revco Industries, Inc. — "Black Stallion" 324
6301 Alondra Blvd.
Paramount, CA 90723
(800) 527-3826; FAX (800) 738-2690
www.revcoindustries.com

Rex-Cut Products, Inc. 552
960 Airport Rd., P.O. Box 2109
Fall River, MA 02720
(800) 225-8182; FAX (800) 638-8501
www.rex-cut.com/-rex-cut

Rick West In.c 575
512 Green Rd.
Bloomington, IN 47403
(812) 332-8062

Robinson Technical Products Midwest 434
3635 W. Ridge Rd., Unit C
Gary, IN 46408
(219) 884-3565; FAX (219) 884-3759

Robotic Accessories Div., Process Equipment Co. 1941
6555 S. State Rte. 202
Tipp City, OH 45371
(937) 667-5705; FAX (937) 667-7602
www.processeq.com

Robotic Accessories will feature its new Ultimatic™ robotic collision sensor, which protects the equipment in a robotic welding cell. Following deflection, the sensor returns back to its original position within ±0.0005 in. (x,y and z) and ±0.017 deg rotationally. The moment and force resistance is pneumatically adjustable, and the user may set the amount of pre-signal compliance. The design is low in profile and lightweight. The special air line is heat and weld spatter resistant.

RobotWorx 1973
5802 Coppock Dr.
Indianapolis, IN 46221
(317) 856-0095; FAX: (317) 856-2965
robots4welding.com

Rofin-Sinar Inc. 1635
45701 Mast St., Plymouth, MI 48170
(734) 455-5400; FAX (734) 455-2741
www.rofin-sinar.com

TRIANGLE ENGINEERING, INC.

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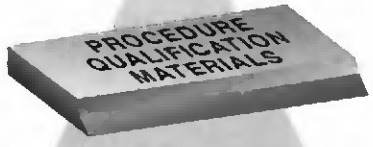

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- Inconel
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- C-Moly
- Hastelloy
- Copper
- Nickel
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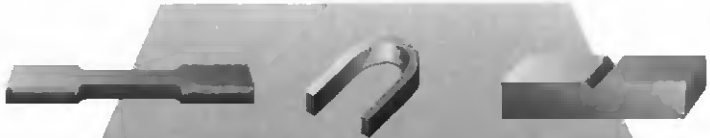

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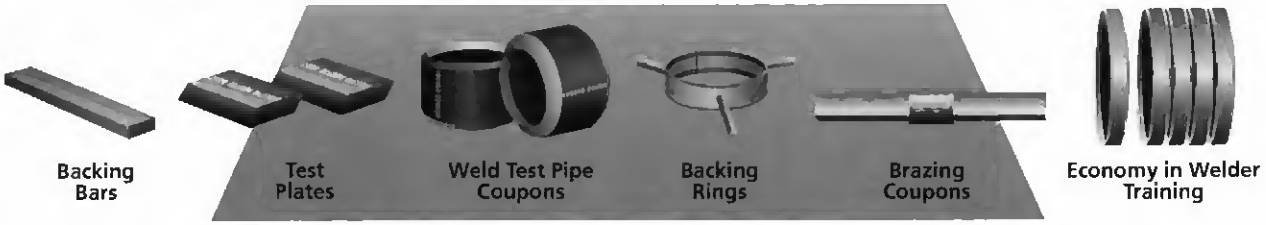

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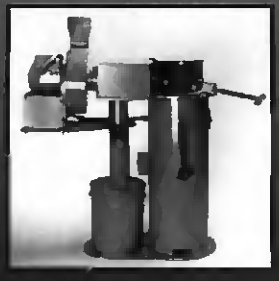

Back Strap Removal Tool

Weld Coupon Abrasive Cutter

Guided Bend Testing Machine

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

Rotin-Sinar will display industrial laser cutting, welding, marking and other application examples processed from its current product line. The product line includes high-frequency CO_2 lasers with powers up to 8 kW, continuous-wave or pulsed Nd:YAG lasers with powers to 2.5 kW, diffusion-cooled lasers with up to 3.5 kW power output, sealed tube CO_2 lasers up to 300 W and diode lasers both low power and with powers in excess of 2 kW for a variety of welding, cutting, marking and surface treatment applications.

Roman Mfg. Inc. 441
861 47th St. S.W.
Grand Rapids, MI 49509
(616) 530-8641; FAX (616) 530-8953
www.romanmfg.com

S.CO.M.E.S. SRL 344
Via Enrico Mattei 6/8
Caatiglione O'Adda 26823, Italy
39 0377901243; FAX 39 0377900206
www.scomes.it

S.CO.M.E.S. will feature its rectifier sets. The company's equipment allows skilled workers to produce rectifiers suitable to the continuous development of markets.

S.I.A.T. S.p.A. Societa Italiana Acciai Trafilati 1072
Via Facini 16, Gemona Del Friuli
Udine 33013, Italy
39 0 432898908; FAX 39 0 432898903

Saf-T-Cart 1044
P.O. Box 1869, Clarksdale, MS 38614
(601) 624-6492; FAX (601) 627-1640

SALD-FLUX srl 2423
Via Friuli, 5
Fizzonasco DI P.E. (MI) 1-20090, Italy
39 02 90420251; FAX 39 02 90420217

Sandvik Steel Co. 1824
P.O. Box 1220, Scranton, PA 18501
(717) 587-5191; FAX (717) 586-8183

Sandvik will feature its stainless steel and high-alloy welding consumables. Products featured include Generation VII GMAW wire; SanPac, a 250-, 500- and 1000-lb-payoff, line-marked GTAW wire; moisture-resistant, -17 covered electrodes; flux-cored electrodes for flat and position welding, and strip and flux for submerged arc and electroslag surfacing.

Schnorrer, Walter ApS Welding Equipment 131
Anker Engelunds Vej 6
Aalborg DK-9200, Denmark
45 96342121; FAX 45 96342122

Schwarzkopf Technologies Corp. 1903
115 Constitution Blvd.
Franklin, MA 02038
(508) 553-3800; FAX (508) 553-3823

Schwarzkopf Technologies, the U.S. affiliate of the Austrian company Plansee AG, will feature its GTA welding electrodes. Its GOLDplus contains 1.5% lanthanum oxide and is free of radioactive constituents. All standard types and sizes are stocked at the company's location in Massachusetts, and they are available through many major welding wholesalers and suppliers.

Sciaky, Inc. 2219
4915 W. 67th St., Chicago, IL 60638
(708) 594-3800; FAX (708) 594-9213
www.sciaky.com

Sciaky will feature its welding systems, including advanced arc, resistance, laser and electron beam systems. The company offers contract welding services and after-sales service throughout the operational life of a customer's equipment. On display will be the Sigma Six weld control, which features a touch-screen display. Industries served are aerospace/defense, automotive and consumer goods.

Scientific Dust Collectors 661
4101 W. 126th St., Alsip, IL 60803
(708) 597-7090; FAX (708) 597-0313
www.scidustcollectors.com

Scotchman Ind. 639
180 E. Highway 14, Box 850
Philip, SD 57567
(605) 859-2542; FAX (605) 859-2499
www.scotchman.com

Sculpture by Kiel 2084
3346 S. Seeley, Chicago, IL 60608
(773) 254-0779; FAX (708) 839-9207

Seal Seat Co. 1843
1200 Monterey Pass Rd.
Monterey Park, CA 91754
(323) 269-1311; FAX (323) 269-0529

Seal Seat will feature its components for use in sealing, controlling and regulating the flow of liquids and gases. The company services the gas welding, medical, fire and aerospace industries, as well as consumer product manufacturers. Components are manufactured from brass, stainless steel, aluminum, plastic, nylon, Teflon and Kel-F. The company's expertise is in bonding rubber to metal using UL-listed and/or recognized rubber compounds.

Circle No. 41 on Readar Info-Card

Segro Colonial Abrasives **1874**
312 S. Pine St., Aberdeen, NC 28315
(800) 334-2151; FAX (600) 732-3299

Selectarc (Forges de Saint-Hippolyte S.A.) **252**
Place Oea Forges
Grandvillara 90600, France
33 384573777; FAX 33 384235790
www.selectarc.com

Selectarc (Forges de Saint-Hippolyte) will feature its special erc welding electrodes: stainless steel, hardfacing, nickel besed, cast iron and nonferrous. Its products are marketed under the company's brand name Selectarc, or under private labels, in more than 65 countries.

Selectrode Industries, Inc. **722**
230 Broadway
Huntington Station, NY 11748
(516) 547-5470; FAX (516) 547-6475
www.selectrode.com

Selectrode will feature its updated product line with moisture-barrier flux formulations. The line includes the company's aluminum electrode, stainless steel, cast iron, bronze and wear-tacing products. The company's formulation increases the moisture-resistance performance of the electrodes by more than 50%. Additionally, the company will be introducing its redesigned abrasion-resistant wear plate.

Sellstrom Mfg. Co. **1223**
One Sellstrom Dr., Palatine, IL 60067
(847) 358-2000; FAX (847) 358-8554
www.sellstrom.com

Semtorq, Inc. **346**
25641 Solon Rd., Bedford, ON 44146
(440) 232-4747; FAX (440) 232-8227
www.semtorq.com

Sentinel, LLC **2128**
1370 Willow Rd., Menlo Park, CA 94025
(650) 323-8270; FAX (650) 323-1742
www.sentinelsafety.com

Sentinel will feature its welding helmet made with DuPont Kevlar-brand fiber molded into a high-temperature phenolic. The 7-oz helmet is burn-through resistant to 800°F. The material meets ANSI Z87.1 requirements, and is flexible to allow access to tight spaces.

Servo-Robot Inc. **2064**
835 Blvd. Clairevue Ouest
St-Bruno, Quebec J3V 6B2, Canada
(450) 653-7868; FAX (450) 653-7869
www.servorobot.com

Servo-Robot will introduce its MOBITRAC portable arc-welding robot, which operates without human supervision; its mini-laser camera, designed tor welding automation, whose applications range from robotic GMAW to submerged arc narrow-gap welding with root geometry measurement capabilities; and FLEXCELL, an automatic weld-gauging and inspection system. Also displayed will be the company's laser sensors and process controllers, all specifically engineered for welding automation and robotics. Its solutions for welding cost reduction and quality control will be demonstrated, including sensors and control systems for joint tracking and finding, adaptive welding and inspection.

Sherwin, Inc. **533**
5530 Borwick Ave.
South Gate, CA 90280
(562) 861-6324; FAX (562) 923-8370

SigmaTEK Corp. **1172**
320 120th Ave. NE, Ste. 200
Bellevue, WA 98005
(425) 709-0711; FAX (425) 709-0717
www.sigmaneat.com

SigmaTEK will feature SigmaNEST, its automatic nesting and NC protile cutting software. The software supports part marking chain and common line cutting, multi-axis bevel contouring, automatic true shape nesting, multi-torch nesting and more. The software can be used with plasma, oxyfuel laser router and water jet cutting machines, along with turret punch presses. The software's true-shape automatic nesting improves machine throughput, tracks remnants, controls inventory and improves time and cost estimates.

Simaco Elettromeccanica SRL **345**
S.S. 235 No. 16
Corte Palasio (LO) 1-26834, Italy
39 0371420567; FAX 39 0371420566
www.simacosrl.it

Simplex Div. Templeton, Kenly & Co., Inc. **402**
2525 Gardner Rd.
Broadview, IL 60153
(708) 865-1500; FAX (708) 865-0894
www.tksimplex.com

SKM Industries Inc. **555**
1012 Underwood Rd.
Olyphant, PA 18447
(570) 383-3062; FAX (570) 383-9482
www.skmproducts.com

The company will feature its SuperMet-Al marker, an all-purpose, oil-based marker. Press the tip on the surface and

squeeze the barrel to dispense paint for drawing fine lines, writing or marking on metal (rough or oily), or all other surfaces. It comes in 13 colors, which includes neon, metallic silver and metallic gold.

Smith Equipment **1612**
2601 Lockheed Ave.
Watertown, SO 57201
(800) 843-7912; FAX (605) 882-2100
www.smithequipment.com

Solar Flux **1867**
P.O. Box 2129
Morehead City, NC 28557
(252) 808-3511; FAX (252) 808-3711
www.solarflux.com

The company will exhibit its line of backup fluxes for welding stainless steel and high-nickel alloys. A 24-page brochure, explaining the common problems in stainless steel and superalloy welding, and the benefits of the company's fluxes, will be available.

Source Production & Equipment Co. **430**
113 Teal St., St. Rose, LA 70087
(504) 464-9471; FAX (504) 467-7685
www.spec150.com

Source Production & Equipment will highlight its SPEC-300 Cobalt-60 gamma radiography system featuring 300-Curie-capacity Cobalt-60. It is constructed of stainless steel and titanium, meets all new safety requirements, is reliable, durable and low maintenance. It can also change ASM without removing the source. The company's booth will feature information on the system, along with a demonstration of the Remote Unsecuring Mechanism (RUM) for use with the SPEC-300 and SPEC-150.

Spanco, Inc. **222**
Hemlock Rd., Morgantown, PA 19031
(610) 286-7200; FAX (610) 286-0085
www.spanco.com

Sparky Abrasives **2056**
4811 Ousharme Or.
Minneapolis, MN 55429
(612) 535-2403; FAX (612) 535-2708

Specialty Gas Concepts Co. **601**
4344 S. Main, Pearland, TX 77581
(281) 482-7007; FAX (281) 482-9216

Spectronics Corp. **429**
956 Brush Hollow Rd.
Westbury, NY 11590
(800) 274-8888; FAX (800) 491-6868
www.spectroline.com

Spectronics will feature its line of black-light (UV) lamps and UV meters for NDE. Newly redesigned UV/VIS meters offer stable, accurate and reliable readings. Lightweight, portable fan-cooled lamps are used for magnetic-particle and liquid-penetrant testing, as well as hydrocarbon contamination detections. Fluorescent dyes for leak detection will also be featured.

SSP **665**
241 Long Leaf Acres Dr.
Wilmington, NC 28405
(910) 452-1974; FAX: (910) 452-1975

Stanco Mfg., Inc. **339**
2004 W. Main, P.O. Box 1148
Atlanta,TX 75551
(903) 796-7936; Fax (903) 796-9237

Stanco will feature its line of gloves, clothing and accessories for industrial workers in high-temperature work environments. These may include welders, steel mill and foundry workers, and chemical plant workers. Products are made from a variety of heat-resistant leathers and high-temperature fabrics, such as Kevlar® and Nomex®.

Staveley NDT/ Conam Inspection **528**
192 Internationale Blvd.
Glendale Heights, IL 60139
(800) 982-6626; FAX (630) 661-0009
www.conaminsp.com

Stein USA **361**
234 Shoreline Dr., New Bern, NC 28562
(252) 635-9890; FAX (252) 635-9473
www.megafil.com

Stein USA, a subsidiary of the German company, Drahtwarenfabrik Drahtzug Stein, will feature its seamless flux cored wires, strip and solid wires for welding. Since developing the manufacturing process in 1966, the company has produced seamless flux cored welding wire used by many shipyards, steel fabricators and pipeline construction worldwide. Seamless flux cored wires offer new technology and performance solutions.

Steiner Industries **801**
5801 N. Tripp Ave., Chicago, IL 60646
(773) 588-3444; FAX (773) 588-3450

Steiner Industries will be celebrating the company's 25th anniversary. As a major manufacturer of welding gloves, protective clothing, welding blankets, curtains and accessories, the company will exhibit a wide range of products. The new product section of the exhibit will feature a new jacket design for a welder's personal protection.

Stel Inverters, Inc. 1261
P.O. Box 52-0961, Miami, FL 33162
(305) 471-9097; FAX (305) 471-9792

Stellar Industries 554
280 W. Third St., P.O. Box 169
Garner, IA 50438
(800) 321-3741; FAX (515) 923-4869
www.stellar-industries.com

Stellar Industries will introduce the Stellarc "smart" welding system, which allows fast, efficient and durable welding operations anywhere. It is powered by a 225-A alternator attached to the vehicle engine and can serve in a number of applications, such as a high-performance battery charger, high-performance booster and a general power source. The unit is light and compact, and can be installed on virtually all North American and imported trucks and pickups.

Stellite Coatings 764
1201 N. Eisenhower Dr.
Goshen, IN 46526
(219) 534-2585; FAX (219) 534-3417
www.stellite.com

Deloro Stellite will feature its cobalt and nickel-based alloys, which are produced in several plants worldwide. The company specializes in components, coatings and consumables. Components are produced in eight different processes, supported by a full machine shop. The coatings division is linked to the company's full line of equipment production, and the consumables line consists of powder, wire, bare rod and electrodes.

Stillwater Technologies, Inc. 836
1040 S. Dorset Rd., Troy, OH 45373
(937) 440-2500; FAX (937) 440-2551
www.stillwatertechnologies.com

Stillwater Technologies will feature its resistance welding products, offering both RWMA standard and customized products. The company has served the contract tooling and machining industry for more than 40 years. The product line includes the following: consumables, tip dressers, resistance welding guns, universal gun parts, location pins and rebuild services for all brands of weld guns and gun arms.

Stoody, A Thermadyne Company 1416/1228
5557 Nashville Rd.
Bowling Green, KY 42101
(502) 781-9777; FAX (502) 843-3984
www.stoody.com

StressTel 221
2790 W. College Ave.
State College, PA 16801
(314) 861-6300; FAX (314) 861-6330
www.stresstel.com

StressTel, an ISO 9001 company, will exhibit its full range of ultrasonic instruments including a new flaw detector, thickness gauges, transducers and stress measurement instruments. Major products include the tough FlawMike; T-Mike gauge series for measurement of pipeline and tank wall loss; the TM1 gauge series for thickness measurement of precision machined components; a full range of dual- and single-element transducers; and its BoltMike stress measurement instruments.

Sumner Mfg. Co., Inc. 1211
7514 Alabonson Rd., Houston, TX 77088
(281) 999-6900; FAX (281) 999-6966

Superior Products, Inc. 864
3786 Ridge Rd., Cleveland, OH 44144
(216) 651-9400; FAX (216) 651-4071
www.superiorprod.com

Survivair 1673
3001 S. Susan St., Santa Ana, CA 92704
(800) 821-7236; FAX (714) 850-0299
www.survivair.com

Swagelok Co. 582
31400 Aurora Rd., Solon, OH 44139
(440) 349-5934; FAX (440) 349-5806

Swagelok will highlight its welding system that provides simplified programming, fixturing and weld documentation in critical systems, where contamination control is a priority. This enhanced orbital gas tungsten arc welding (GTAW) system helps users improve weld consistency while reducing overall time and cost per weld.

Systematics, Inc. 1846
P.O. Box 2429, W. Chester, PA 19380
(610) 696-9040; FAX (610) 430-8714

Tatras, Inc. (d.b.a. Thermacut) 960
P.O. Box 58
Claremont, NH 03743
(603) 542-6715; FAX (603) 542-6715
www.thermacut.com

Thermacut will have on display a full line of TMT replacement plasma torches and parts for all cutting, welding and gouging applications, including the patented "Dura-Torch" and all the "Super-Life" electrodes. The company will also exhibit its own line of Thermacut GMA and GTA torches with replacement parts for all your welding needs,

plus the new "super-life"' contact tips. Also to be displayed is an expanded line of laser cutting lenses and nozzles, plus oxyfuel replacement tips. Factory representatives will be available to answer questions and discuss your individual needs.

Taylor-Wharton Gas Equipment Div. 110
4718 Old Gettysburg Rd., #300
Mechanicsburg, PA 17055
(717) 763-5060; FAX (717) 763-5061
www.taylor-wharton.com

Taylor-Winfield Corp.1848
P.O. Box 500
Brookfield, OH 44403
(330) 448-4464; FAX (330) 448-3538
www.taylor-winfield.com

Taylor-Winfield designs and builds metalworking machinery. The firm will exhibit equipment from three product lines: resistance welding, induction heating and assembly/automation. All pieces of equipment will be operating and feature different degrees of material parts handling and automation. These machines and systems can be designed to customers' specific requirements and can differ greatly in size and function.

TDC Filter Mfg., Inc. 2143
1331 S. 55th Ct.
Cicero, IL 60804
(800) 424-1910; FAX (708) 863-4472
www.tdcfilter.com

TDC Filter Manufacturing is one of the world's largest aftermarket suppliers of air filtration products and services. Quality replacement filters are available for a wide variety of equipment including: Donaldson®, Farr®, Wheelabrator®, and Torit® dust collectors. On company's list of best-selling products you'll find HEPA filters, cartridge filters, Pleat + Plus™ pleated bags, rigid cell filters, filter bags, minipleat V-bank filters and panel filters.

Tec Torch 1852
P.O. Box 1870
San Marcos, CA 92079
(760) 747-3700

Tec Torch is celebrating its 45th anniversary of supplying quality GTA torches to the welding industry. The exhibit will feature the completely revised "Original" Style TEC torches with many proven features such as bulb-style nozzles, high-temperature quartz glass nozzles, tip-of-the-torch water cooling, and high-temperature silicone rubber insulation. Featured will be the "WeldTec" line of torches with many unique features and models not found in other brands of GTA torches, including the patented flex-head models. Also featured will be the "Speedway" Series high-performance GTA welding torches.

Techalloy Co., Inc. 2016
370 Franklin Turnpike
Mahwah, NJ 07430
(201) 529-0900; FAX (201) 529-5392
www.techalloy.com

Techalloy, a Usinor Group company, will have sales personnel available to discuss the brand's full line of nickel and stainless welding consumables and select low-alloy products. The extensive nickel and stainless product line includes imprinted GTA rods, solid wires on spools, coils, reels, drums and Tech-Paks, along with a full offering of Tech-Rod coated electrodes. All products are manufactured in Baltimore, Md., and are warehoused in locations throughout the United States.

Techniweld Alloys & Welding Supplies 2173
4420 Commerce Dr. S.W.
Atlanta, GA 30336
(404) 699-9900; FAX (404) 699-7800

Tecnar Automation Ltd 966
3502 First St.
St. Hubert, Quebec J3Y 8Y5, Canada
(450) 443-5335; FAX (450) 443-4880
www.tecnar-automation.com

Technar will exhibit its Rotoweld 2000 systems, fully automated work cells that integrate machine vision and robotics in a completely dedicated package developed specifically ofr industrial pipe fabrication. Highlighted will be the Twin Workstation, the most advanced version of this technology, which uses high, deposition-rate GMAW procedures. The Twin workstation incorporates two separate work bays, each with its own independently operated rotator. This configuration allows unloading, reloading and work preparation to be performed off-line in one bay without interfering with the ongoing welding in the other bay. The system welds at the rate of approximately 1 in./min (on standard wall pipe).

Tecnomatix Technologies, Inc. 2412
39810 Grand River Ave., Ste. 100
Novi, MI 48375-2101
(248) 471-6140; FAX (248) 471-6147
www.tecnomatix.com

Exhibit will feature the Tecnomatix Digital Factory, a group of interoperable tools for planning, designing and managing manufacturing processes. It helps manufacturers make realiable decisions from the start of a new product introduction — even before product designers start work. The Digital Factory includes process model platform (PMP) for storing manufacturing data and enabling team collaboration; process planning applications for early definition and analysis of manufacturing concepts; production engineering (CAPE) tools for detailed design end optimization of manufacturing processes such as assembly, welding and painting; and group/data management applications for managing projects, processes, versions and changes, as well as Web-based reporting.

Tempil 1612
2901 Hamilton Blvd.
South Plainfield, NJ 07080
(800) 757-8301; FAX (908) 757-9273
www.tempil.com

Texas State Technical College-Welding 1985
3801 Campus Dr., Waco, TX 76701
(254) 867-3549
www.tstc.edu/welding

Thermadyne Holdings 1416/1228
101 S. Hanley Rd., Ste. 300
St. Louis, MO 63105
(314) 746-2177; FAX (314) 746-2324
www.thermadyne.com

Thermal Arc, a Thermadyne Co. 1416/1228
2200 Corporate Dr., Troy, OH 45373
(937) 440-0100; FAX (937) 440-0157
www.thermalarc.com

Thermal Dynamics Corp., a Thermadyne Co. 1416/1228
Industrial Park #2
W. Lebanon, NH 03784
(603) 298-5711; FAX (603) 298-5720
www.thermal-dynamics.com

Thermco Instrument Corp. 1034
1201 W. US Highway 20
LaPorte, IN 46350
(219) 362-6258; FAX (219) 324-3568

Equipment for mixing and analyzing shielding gases for GMA and GTA welding will be on display, including gas mixers for CO_2/argon and oxygen/argon capable of servicing up to 66 welding stations. Also on display will be gas analyzers capable of measuring CO_2/argon, oxygen/argon, and helium/-argon shielding gas mixtures. A digital gas analyzer will be demonstrated with mixtures of CO_2/argon and oxygen/argon. Technical sales staff will be present for consultation.

3M Occupational Health & Environmental Safety 2242
3M Center, Bldg. 275-6W-01
St. Paul, MN 55144
(651) 733-9491; FAX (651) 733-2555

Heat, sparks, odor, harmful particles — these are some of the many factors to consider when selecting respirators for welding, brazing, soldering, and metal pouring. 3M will show a comprehensive line of respiratory solutions for welding applications. From maintenance-free to supplied-air respirators, including elastomeric facepieces and powered air respirators, you'll find the right one for your application. 3M is launching a new maintenance-free respirator, 8515N95. Come to the 3M booth to get your free sample.

Tillman Co., John 316
2555 S. Dominguez Hills Dr.
Compton, CA 90220
(310) 764-0110; FAX (310) 764-0104

John Tillman will offer a broad selection of quality welding and industrial gloves, protective and high-heat clothing, welding curtains and screens, strip curtains, blankets, and other protective welding accessories. The glove line offers specialized products for SMA, GMA and GTA welding, driver/warehouse handling, specialty, and high-heat applications. The protective clothing line includes jackets, cape sleeves, sleeves, work aprons, chaps, pants, overalls, spats and leggings made from leather or fire retardant cotton in various weights.

Timesavers, Inc. 2431
5270 Hanson Ct.
Minneapolis, MN 55429
(800) 537-3811; FAX: (783) 537-9247
www.timesaversinc.com

Titanium Wire Corp. 660
235 Industrial Park Rd.
Frackville, PA 17931
(570) 874-0311; FAX (570) 874-3198
www.titanium.com

TMC-Thermographic Measurements Co. 1766
15021 Wicks Blvd.
San Leandro, CA 94577
(510) 347-4500; FAX (510) 347-4503
www.t-m-c.com

TMC-Thermographic Measurements will introduce the new Thermax MeltStix. MeltStix temperature indicators provide accurate, reliable temperature measurement and simplicity of use for measuring preheat, interpass and postweld heat treatment temperatures. Distributor inquiries welcome. Thermax temperature indicating labels and Thermindex color changing paint will also be on display. All products manufactured by TMC meet a minimum quality standard of BS EN ISO 9001.

TN Technologies 631
2555 H. IH-35
Round Rock, TX 78664
(512) 388-9100; FAX (512) 388-9200
www.tnksi.com

The Metallurgist Pro, from TN Technologies, provides fast and accurate XRF alloy analysis and metals identification in a truly portable device (weighs less than most laptop computers). The ergonomically designed probe can be used on virtually any surface — even on welding rods, bolts and wires. The unit comes pre-programmed with 227 alloys or the user can customize his own alloy list. Options include a hot probe attachment (measure up to 1000°F/537.8°C), bar code reader and external keyboard.

TOCCO, Inc. 2004
1506 Industrial Blvd.
Boaz, AL 35957
(256) 840-2407; FAX (256) 840-2400
www.tocco.com

TOCCO offers a line of induction heating equipment that provides an efficient method of brazing, soldering, and welding similar or dissimilar materials. The technology consists of noncontact heating for rapid and controllable processing a variety of components. Displayed will be typical power units; also, continuous demonstrations will exhibit induction capabilities. Application specialists will be on hand to address your particular requirements.

Tomco Equipment Co. 1031
3340 Rosebud Rd.
Loganville, GA 30052
(800) 832-9262; FAX (770) 978-5881
www.tomcoequipment.com

Top Cat Air Tools 719
761 A Beta Dr., Cleveland, OH 44143
(440) 461-1320; FAX (440) 461-3714
www.tcservice.com

T.C. Service will be displaying its wide range of American-made Top Cat pneumatic handheld tools for welders, fabricators and foundries. Grinders (large & small horizontal, right angle, vertical and die grinders), scalers, needle scalers, chipping hammers and a variety of saws will be available for hands-on inspection. T.C.'s new "low vibration" tools, including their LV-1 scalers, will be featured.

Torit Products-Donaldson Co. 2020
1400 W. 94th St.
Minneapolis, MN 55431
(612) 887-3991; FAX (612) 887-3377
www.torit.com

Trafimet USA, Inc. 405
700 E. Elm Ave., Unit B
La Grange, IL 60525
(708) 579-5893; FAX (708) 579-5884

Tregaskiss Ltd. 1265
2570 N. Talbot Rd.
Windsor, Ont. N0R 1L0, Canada
(519) 737-6966; FAX (519) 737-1530
www.toughgun.com

Tregaskiss will feature its new Tough Gun X, the ultimate GMA welding gun, offering outstanding performance while providing unsurpassed simplicity and convenience for operators and distributors. Based on a proven platform, TOUGH GUN X features air-cooled dependability from 130 to 500 A at 100% duty cycle. Customizing a gun to your specific application is easy: 1) select your required gun amperage and length; 2) select the necessary power pin; 3) select your desired size of tip/liner.

Trendex Information Systems, Inc. 562
4100 Steinberg St.
Saint Laurent, Quebec H4R 2G7
Canada
(514) 333-6373; FAX (514) 333-5705
www.trendexsys.com

Trendex Information Systems will highlight Gastrend, its accounting and cylinder control software designed for the gas and welding equipment distributor. Demonstrations will show the user how to control accounts receivable, accounts payable, general ledger and inventory. Cash sale invoices and orders are entered using bar codes. Customer maintains cylinder control by cylinder level or by serial number. Routrend will demonstrate the ability to create delivery notes off the truck using bar codes.

Tri Tool Inc. 1128
3806 Security Park Dr.
Rancho Cordova, CA 95742
(916) 351-0144; FAX (916) 351-0372
www.tritool.com

Trimark 1805
400 Trade Square E.
Troy, OH 45373
(937) 332-4000; FAX (937) 332-5224
www.hobartbrothers.com

Trimark, the specialist in tubular wire, will be exhibiting a complete line of high-quality tubular and metal-cored wires. Trimark's impressive product line

includes self-shielded flux-cored wires, gas-shielded flux-cored wires for mild steel and low-alloy steels, and metal-cored wires for mild steel and low-alloy applications. All of these are available in a wide variety of package sizes. Trimark engineers and sales staff will be available to answer all of your filler metal questions and make product recommendations.

Trion, Inc. 922
101 McNeil Rd., P.O. Box 780
Sanford, NC 27331-0760
(919) 775-2201; FAX (919) 777-6399
www.trioninc.com

Triple Crown Products, Inc. 1931
814 Ela Ave.
Waterford, WI 53185
(414) 534-7878; FAX (414) 534-7879
www.tcpcaps.com

Trumpf Inc. 1622
111 Hyde Rd.
Farmington, CT 06032
(860) 677-9741; FAX (860) 676-2606

Trumpf Inc. — Laser Technology Center 1622
47809 Galleon Dr.
Plymouth Twn., MI 48170
(734) 354-9770; FAX (734) 354-9769
www.trumpfusa.com

TRW Nelson Div. 1152
7900 W. Ridge Rd.
Elyria, OH 44036-2019
(440) 329-0475; FAX (440) 329-0526

Trystar Cables (Bridgewater Tech., Inc.) 545
2917 Industrial Dr.
Faribault, MN 55021
(507) 333-3990; FAX (507) 333-3991

Trystar Welding Cables manufactures a wide variety of colored welding cables with custom print and/or indent, available on short notice with small minimum footage requirements. Also available is your choice of spooled, boxed, bagged or coiled cable. Trystar also offers a wide variety of custom cable assemblies with connectors, electrode holders and ground clamps.

TUV America 2313
5 Cherry Hill Dr.
Danvers, MA 01923
(978) 739-7012; FAX (978) 762-7637
www.tuvglobal.com

Tweco/Arcair, a Thermadyne Co. 1416/1228
4200 W. Harry St.
Wichita, KS 67208
(316) 942-1421; FAX (316) 946-8140
www.tweco.com

TWI 2061
Granta Park, Great Abington
Cambridge CB1 6AL, United Kingdom
44 223891162; FAX 44 223892588
www.twi.co.uk

TWI is a membership-based organization with more than 3,000 industrial members in 60 countries. It encompasses a professional engineering institution, an international training and certification activity, and a large consultancy and R&D establishment dedicated to transferring technology to industry. Many different joining technologies are covered, including arc, laser beam, electron beam and friction welding; adhesive bonding; brazing; diffusion bonding; mechanical fastening; and microjoining processes. Friction stir welding, software and joinIT™ Internet will be demonstrated, with presentations on industrial services.

Tyrolit North America Inc. 2216
12 Union St.
Westborough, MA 01581
(800) 366-4431; FAX (800) 366-4311
www.tyrolit.com

Tyrolit, the second largest manufacturer of bonded abrasives worldwide, welcomes distributors, manufacturers, and end users to experience a new dimension in raised hub and cut-off wheels ideal for all types of metals, including steel, cast iron, stainless steel, aluminum, copper, and brass. For the first time in the United States, the company's AWS Chicago showcase will include the new Secur Extra UltraThin cut-off wheel and Secur Rondeller, the multipurpose grinding wheel for right-angle grinders.

Uncommon USA Inc. 2054
1125 E. Saint Charles Rd.
Lombard, IL 60148
(630) 268-9672; FAX (630) 268-9655
www.uncommonusa.com

Uni-Hydro, Inc. 475
310 E. Gemini Ave.,Cosmos, MN 56228
(800) 328-0036; FAX (320) 877-7204

Unibraze Corp. 1965
P.O. Box 55269
Houston, TX 77255
(630) 993-9927; FAX (630) 993-9974

Unisource Mfg. Inc. 2422
8040 N.E. 33rd Dr.,Portland, OR 87211
(503) 281-3781; FAX (503) 287-4818
www.unisource-mfg.com

United Abrasives Inc. 1232
Route 66, P.O. Box 75
Willimantic, CT 06226
(860) 456-7131; FAX (860) 456-8341
www.unitedabrasives.com

United Air Specialists, Inc. 805
4440 Creek Rd.,Cincinnati, OH 45242
(800) 992-4422; FAX (513) 891-4171
www.uasinc.com

United Air Specialists will tea-

ture a variety of air cleaning and dust collection systems. SMOG-HOG air cleaning Systems use electrostatic precipitator (ESP) technology to efficiently remove oil smoke and coolant mist generated by welding, grinding, milling, turning, cold heading and other industrial processes. DUST-HOG dust collection systems use a variety of application-specific cartridge filters to meet virtually any dust collection need. In addition to centralized systems, portable units are available.

United Group Programs c/o AWS **0006**
550 N.W. LeJeune Rd.,Miami, FL 33126
(305) 443-9353; FAX (305) 443-7559

United ProArc Corp. **1671**
No. 3-1 Kung Yel 10th Rd.
Ping Chen Ind. Park, Tao Yuan Hsien
Taiwan R.O.C.
886 3 4698970; FAX 886 3 4694499
www.proarc.tw

ProArc will highlight CNC/shape cutting machines, welding positioners, turning rolls, manupulators, longitudinal seamers, E.Z. Arc automatic welding systems, and total solutions for automation. All products are designed and fabricated in Taiwan. The products have already been sold worldwide in 30 countries. Staff will be pleased to answer any specific questions you may have.

Unitrol Electronics, Inc. **341**
702 Landwehr Rd.
Northbrook, IL 60062
(847) 480-0115; FAX (847) 480-0932
www.unitrol-electronics.com

Unitrol Electronics will feature microprocessor-based resistance (spot) welding controls and process water chillers. These controls and chillers include applications for: multiple weld programs, constant current held to less than 1% variance, single-phase and 3-phase applications, cascade systems with complex welding sequences, real-time tip force monitoring and control with differential pressure transducers and automatic pressure setting systems, resistance brazing, simple to use "thumb wheel" activated controls, and process water chillers for energy savings and longer electrode life.

Unittool Punch & Die Co. **130**
P.O. Box 863, Buffalo, NY 14240
(716) 873-8453; FAX (716) 873-8694

Universal Drilling & Cutting Equipment **322**
974 N. Oupage Ave.,
Lombard, IL 60148
(630) 495-9940; FAX (630) 495-9941
www.unibor.com

Universal will be displaying cobalt annular cutters along with a variety of portable magnetic drills. Included with these drills will be the new AIRBOR Magnetic Drill that is controlled by compressed air. Company will also have its new lightweight (26-lb) magnetic drill on display. Booth personnel will demonstrate these products during the show.

Universal Flow Monitors, Inc. **2032**
1755 E. Nine Mile Rd.
Hazel Park, MI 48030
(248) 542-9635; FAX (248) 398-4274
www.flowmeters.com

Universal will show variable-area flow rate indicators, flow switches, and flow transmitters for welding applications. The units monitor cooling water to resistance welding electrodes, cables, transformers, SCRs and Dense Packs. Also to be shown are mass flow meters with indication, programmable alarms, and transmitted outputs for LCD/LED applications of weld shielding gases, gas consumption, and gas leak detection.

Uniweld Products, Inc. **1024**
2850 Ravenswood Rd.
Ft. Lauderdale, FL 33312
(954) 584-2060; FAX (954) 587-0109
www.uniweld.com

Uniweld Products will be show-

TEN GREAT REASONS TO USE A MAGNATECH PIPE WELDING SYSTEM

These ten identical welds were made in one-third the time required for manual welding. Just as important, Magnatech pipe welders make perfect welds a routine occurence.

The total arc time on these ten welds (2" x 0.218" wall) was just 80 minutes with a total cycle time of under 120 minutes.

Mechanized pipe welding is the competitive edge that will allow you to achieve higher productivity and higher quality with reduced labor input.

Whatever your business, Magnatech has a system for your specific application:

1. **Light wall process piping**
2. **Boiler/heat exchanger tube welds**
3. **Heavy wall pressure piping**
4. Oil/gas pipe lines
5. Circumferential/linear welds on vessels
6. Pharmaceutical/food processing sanitary piping
7. Overlay cladding
8. GTAW/GMAW/FCAW processes
9. Butt/socket/fillet welding
10. Rent-Lease-Purchase options

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If you weld pipe, tube or anything round . . . think MAGNATECH. Pipe welding for the next millennium.

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Tel: 860 653-2573 • Fax: 860 653-0486 • Web Site: www.magnatech-lp.com • E-Mail: magnatech.dsd@snet.net

SEE US AT AWS SHOW BOOTH 2212

Circle No. 91 on Reader Info-Card

It's too late

to change "Welding Quality Assurance Management" to "Smart Pros Get It Right the First Time."

- Even though this is a new AWS *Super Seminar* with its singular topic and multiple experts.
- And even though attendees will get lectures, lunches, breaks, handouts, take-home references, and free entry to the AWS Expo in Chicago.
- Never mind that this seminar is scheduled in the best possible slot (Tuesday, April 25 and Wednesday, April 26 during show week leaving plenty of time to visit the Expo, attend free lectures, and in general, hobnob with the who's who of welding).
- Forget that AWS Members get a 25% discount off the registration fee.
- Just ignore that it sounds dainty and get registered.

To register by mail, use the Registration Form in this issue of *Welding Journal* or go online at aws.org and use the secured server.

American Welding Society
550 N.W. LeJeune Rd. • Miami, FL 33126
Visit our website http://www.aws.org

AWS Means Answers in Chicago

check out these continuing education events in this issue

- Arc Welding Sources: How to extract optimum performance from your equipment investment
  Tuesday, April 25
- Process in Standardization of AC and DC Resistance Welding Current Measurements and Instrumeotation
  Tuesday, April 25
- How to Ensure the Weldability of Stainless Steels: The Basics and Avoiding Defects
  Tuesday, April 26 and Wednesday, April 26
- Visual Inspection of Pressure Vessels and Pressure Piping
  Tuesday, April 25
- Corrosion of Welds: Causes and Cures
  Wednesday, April 26
- Design and Planning for Cost Effective Welding
  Wednesday, April 26 and Thursday, April 27
- Road Map to the D1.1 Code
  Thursday, April 27
- What Professionals New to Welding Need to Know about Its Weldability
  Thursday, April 28
- The Why and How of Welding Procedure Specifications: The right way to document your welding controls to save time, money, and maybe, your credibility
  Thursday, April 28
- Visual Inspection Workshop
  Friday, April 28

American Welding Society
550 N.W. LeJeune Rd. • Miami, FL 33126
Visit our website http://www.aws.org

ing its extensive line of gas welding, cutting and brazing equipment, plus a large variety of welding alloys and accessories. High-impact point-of-purchase displays and new products like the "Scorcher" weed and ice burning torch kits will also be shown.

Utah State University (Welding Engineering Technology) 1984
ITE Dept. UMC 6000
Logan, UT 84322-6000
(435) 797-0748; FAX (435) 797-0354
www.engineering.usu.edu/ite/unde

Uvex Safety 1673
10 Thurber Blvd.
Smithfield, RI 02917-1896
(800) 343-3411; FAX (401) 232-1830
www.uvex.com

Vacuum Atmospheres Co. 2424
4652 W. Rosecrans Ave.
Hawthorne, CA 90250
(310) 844-0255; FAX (310) 970-0980

Vacuum Atmospheres is a world leader in the design and manufacture of inert atmosphere glovebox systems for use in welding research and production. Companies such as Boeing, NASA, Hughes and more have sought the company's expertise in providing system solutions. With experience in virtually all types of welding, the firm will work with customers to modify a standard glovebox or provide a custom glovebox system to meet or exceed customer specifications.

Vantage 1571
200 S. 4th St., Albion, IL 62806
(618) 445-5413; FAX (618) 445-5495
www.champlabs.com

Vernon Tool Co. 670
503 Jones Rd., Oceanside, CA 92054
(760) 433-5860; FAX (760) 757-2233
www.vernontool.com

Victor Equipment Co., a Thermadyne Co. 1416/1228
2800 Airport Rd.
Denton, TX 76207
(940) 566-2000; FAX (940) 381-1222
www.victorequip.com

Viking Corp. 2030
3810 N. Toben, Wichita, KS 67226
(800) 835-1096; FAX (316) 634-6658
www.vikingcorporation.com

Viking will show its model GC-111 cylinder blaster used for stripping paint from exterior of welding, medical, acetylene, propane and other cylinders used in industry. The standard unit with a dust collector will remove paint, rust or other contaminants in controlled cycle times of 3-5 minutes each. It then stores the paint and rust in a safe container. A single operator can load, unload and clean up to 120 cylinders each shift.

VTI (USA), Inc. 2070
22 Dobbs Ter.
Scarsdale, NY 10583
(914) 725-6744; FAX (914) 725-4008
www.vti.de

W. A. Whitney Co. 2233
650 Race St.
Rockford, IL 61101
(815) 964-6771; FAX (815) 964-3175
www.wawhitney.com

Wachs Co., E. H. 1039
100 Sheperd St.
Wheeling, IL 60090
(847) 537-8800; FAX (847) 520-1188
www.wachsco.com

Walhonde Tools Inc. 2320
1299 Childress Rd.
S. Charleston, WV 25309
(304) 758-3796; FAX (304) 756-3834
www.walhonde.com

Walter, Inc., J. 524/628
141 Locust St.
Hartford, CT 06114
(860) 724-0321; FAX (860) 724-0779
www.jwalterinc.com

J. Walter will feature a complete range of line finishing abrasives, along with surface conditioning and polishing products, in continuous live demonstrations. The new Enduro-Flex Flap discs and Flexcut flexible grinding wheels will be displayed. Also shown in live continuous demonstrations will be a new stainless steel weld cleaning system, Surfox, along with many other new chemical tools for surface cleaning and protection, metal cutting, lubrication and welding.

Washington Alloy Co. 861
P.O. Box 73909
Puyallup, WA 98375
(800) 558-5825; FAX (253) 841-0411
www.weldingwire.com

Washington Alloy will display various aerospace alloys such as titanium, tungsten, magnesium and nickel alloy wires and electrodes. Also to be shown are production alloys such as stainless steel in flux-cored and covered electrodes and bare wire forms; aluminum in flux-cored rods, covered electrodes and bare GMAW and GTAW wires; and copper-based alloys, such as silicon bronze, aluminum bronze (3 types) and deoxidized copper, all available in both covered electrode and bare wire form. Be sure to stop by and pick up your free AMS and conversion guide, as well as the new Pail-Pack Drum brochure.

Watson Coatings, Inc. 2057
P.O. Box 35067
St Louis, MO 63135
(314) 521-2000; FAX (314) 521-6582
www.watsoncoatings.com

Weartech Intl., Inc. 643
13032 Park St.
Santa Fe Springs, CA 90670
(562) 698-7847; FAX (562) 945-5864
www.weartech.net

Weartech will display it's complete line of cobalt- and nickel-based hardfacing rods and electrodes. Featured will be bare rods and electrodes of different alloys in diameters from 3/32 to 3/8 in. and cobalt-based GMAW wires and PTA powders. Centrifugal, static and investment cast wear-resistant alloy parts will also be exhibited. Brochures explaining all product lines will be available, including the new Autotig 2000 pamphlet.

Weiler Corp. 501
One Wildwood Dr.
Cresco, PA 18326
(570) 595-7495; FAX (570) 595-2002
www.weilercorp.com

For aggressive weld cleaning, check out Weiler's Roughneck wire brushes. Grind and finish with abrasive flap discs. Choose from Tiger Discs for high-production environments; Vortec for high cut rates at a value price; specialty flap discs like Big Cats for irregular surfaces; BobCats for right-angle air tools; or special discs for grinding stainless. For superior grinding on aluminum, ask about our Al-tra Cut discs.

Weld Engineering Co., Inc. 1835
34 Fruit St.
Shrewsbury, MA 01545
(508) 842-2224; FAX (508) 842-3893

Weld Engineering will display its complete line of medium- and heavy-duty submerged arc flux handling systems. Included are air- and electric-powered automatic, portable and tractor units. Also see company's advanced pressure feed and recovery systems. On display will be flux rebake and holding ovens. Live demonstrations of flux recovery will be taking place continuously.

Weld Mold Co. 2436
750 Rickett Rd., Brighton, MI 48116
(810) 229-9521; FAX (810) 229-9580
www.weldmold.com

Weld Mold will feature its tool and die, maintenance and repair, and hardfacing products. You will be able to see high-deposition die welding processes, large-diameter electrode, and high-deposition flux-cored wire. Company's complete line of consumables — tool steel, cobalts, nickels, stainless, hardfacing and more — will be well represented by a knowledgeable sales staff who will be happy to assist you.

Weld-Motion Inc. 118
N2121 Greenville Dr.
Hortonville, WI 54944
(920) 779-0700; FAX (920) 779-0710

Weld Systems Intl., Inc. 1835
506 Bullis Rd., W. Seneca, NY 14224
(716) 834-9662; FAX (416) 674-7139

Weld-Aid Products 752
14650 Dequindre Rd.
Detroit, MI 48212
(313) 883-6977; FAX (313) 883-4930
www.weldaid.com

Weldas Co. 648
128 Seeboard Lane
Franklin, TN 37067
(615) 377-4722; FAX (615) 377-3635
www.nashville.net/~weldas

Weldcoa (Welding Co. of America) 1132
120 N. Railroad Ave.
Northlake, IL 60164
(708) 531-1200; FAX (708) 531-1222
www.weldcoa.com

Weldcraft, a Div. of DovaTech, Ltd. 1428
119 E. Graham Place
Burbank, CA 91502
(818) 846-8181; FAX (818) 845-1542

Weldcraft, a div. of DovaTech, Ltd., enjoys a premier position as a manufacturer of gas tungsten arc (GTAW, or "TIG") torches. Offering a full-line of torches and related accessories, the company recently introduced the Crafter Series products, which represent a significant innovation in GTA welding torches. The products are available nationwide from any welding distributor.

Welders Mall.com 772
P.O. Box 9815
No. St. Paul, MN 55109
(651) 260-5473; FAX: (718) 534-4082
www.weldersmall.com

Welding Design & Fabrication 522
1100 Superior Ave.
Cleveland, OH 44114
(216) 696-7000; FAX (216) 931-9524

Welding Design & Fabrication reaches designers, engineers, managers and supervisors who specify and purchase welding equipment in plants and field sites in the U.S. and Canada that conduct welding and fabricating operations. It reports on processes and equipment, materials, safety, testing, and inspection in the manufacturing

of fabricated-metal products, structural projects and equipment maintenance.

Welding Journal* and *Inspection Trends 0007
550 N.W. LeJeune Rd.
Miami, FL 33126
(305) 443-9353; FAX (305) 443-7404
www.aws.org

Welding Journal is AWS' official monthly magazine, specifically serving the welding and joining processes industry. It includes practical articles, welding product news, industry developments, AWS news, research papers, advertisements, and much more. Winner of nine editorial awards in 1999, including Best-Written Magazine and Best In-Depth Reporting. Also featured will be *The American Welder*, the *Welding Journal's* new stand-alone supplement written specially for the hands-on welder. *Inspection Trends–the Magazine for Materials Inspection and Testing Personnel* will be displayed, as well. Launched in 1998, this new AWS magazine serves the entire nondestructive examination industry, including all AWS Certified Welding Inspectors. Pick up copies of all three magazines and meet editorial and advertising staff members.

Weldline Automation, Inc. 817
1201 N. Las Brisas
Anaheim, CA 92806
(714) 237-7730; FAX (714) 237-7734
www.weldline.com

Weldline Automation will feature its machinery and accessories for automated welding and cutting. This includes a system for plasma cutting tube and pipe in almost any shape. This system will make end cuts and hole cuts for any joint design, including T joints, slant joints, miter joints, rectangular holes and straight cuts. Company will also exhibit a line of tube-to-tubesheet welders, seamers, lathes, side beams, do-it-yourself automation components, and systems for welding pallet racks and tanks

Weldmark 2253
6321 E. 30th St.
P. O. Box 19907
Indianapolis, IN 46219-1907
(317) 562-1483; FAX (317) 562-1484
www.weldmark.com

Weldmatic Inc. 1864
P.O. Box 1322
Columbus, NE 68602
(402) 564-1808; FAX (402) 564-1825

Weldreel Inc. 2130
257 Louis Hurley Rd.
El Dorado, AR 71730
(870) 863-5785; FAX (870) 863-3921

Weldrite Welding Products, Inc. 520
21-00 Rosalie St.
Fairlawn, NJ 07410
(201) 475-8800; FAX (201) 475-0575
www.weldrite.com

Weldsale Co. 901
2151 Oreer St.
Philadelphia, PA 19125
(215) 739-7474; FAX (215) 426-1260
www.weldsale.com

Weldsale will exhibit its unique platens, stands and flex tooling.

Weldship Corp. 428
225 W. 2nd St.
Bethlehem, PA 18015
(610) 861-7330; FAX (610) 861-5175
www.weldship.com

Weldship will feature gas tube trailers, ASME-coded pressure vessel assemblies, and gas and liquid ISO-containers for the storage and transport of compressed, specialty and chemical gases. Hydrostatic, acoustic emission, and nondestructive testing services are provided for customer and company owned equipment. Liquid CO_2 and LPG/propane transport equipment manufactured by the recently acquired Texas Trailer Corp. will also be featured.

Weldtec 1852
P.O. Box 1870
San Marcos, CA 92079
(760) 747-3700

Weldwire Co., Inc. 2218
P.O. Box 60340
King of Prussia, PA 19406
(800) 523-1266; FAX: (610) 265-7806

WEMCO 0010
550 N.W. LeJeune Rd.
Miami, FL 33126
(305) 443-9353; FAX (305) 443-7559

Wentgate Dynaweld, Inc. 2264
630 Silver St., Unit 6/7
P.O. Box 867
Agawam, MA 01001
(413) 789-4600; FAX (413) 786-0508

Wentgate Dynaweld will demonstrate its more than 30 years of experience in electron beam welding systems. The systems can be configured with either a 150 or 60 kV electron gun and power supply sizes ranging from 1 to 30 kW. The exhibition stand will feature a model CW604 18-in. cube electron beam welding unit. This system utilizes a 60kV electron gun and 4kW power supply, capable of 1/2 in. penetration into solid stainless steel at 30 ipm.

Western Enterprises 1839
875 Bassett Rd.
Bay Village, OH 44140
(440) 871-2160; FAX (440) 835-8283

Western will highlight its 40-plus years ofsupplying products for the control, storage and transmission of high-pressure gases to the industrial, medical and specially gas markets. The company offers a complete line of industrial regulators and fittings; new portable oxyacetylene systems; Innovator gas manifold systems; medical regulators, fittings and portable oxygen systems; and Westwinds helium products.

Wheelabrator-BCP 1217
1606 Executive Dr.
La Grange, GA 30240
(706) 884-6884; FAX (706) 884-9940
www.surfacepreparation.com

White Engineering Surfaces Corp. 2142
123 Friends Lane
P.O. Box 880
Newtown, PA 18940
(215) 968-5021; FAX (215) 968-2860

Whitestone Corp. 2131
1661 James Wharf Rd.
White Stone, VA 22578
(804) 435-6725; FAX (804) 435-2428
www.whitestonedirect.com

Williams Advanced Materials 2416
2978 Main St.
Buffalo, NY 14214
(716) 837-1000; FAX (716) 833-2926
www.williams-adv.com

Wilson Industries, Inc. 1736
123 Explorer St.
Pomona, CA 91768
(909) 468-3636; FAX (909) 468-3640
www.wilsonind.com

Wilson Industries will display the latest offerings in the line of flexible safety partitions and industrial curtain products it has been manufacturing since 1957. The company will display free-standing and custom curtain applications featuring Tri-Fold, Glide-N-Fold, and Accordion Fold technologies and Stainless Steel Metal Mesh. Welding blanket fabrics will also be on display. Visit with design specialists to determine solutions for your welding, metal forming, personnel safety, laser beam protection, noise attenuation, heat stress control, and work area separation applications.

Wilton Tool Group 1036
300 S. Hicks Rd.
Palatine, IL 60067
(847) 934-6000; FAX (847) 934-6730
www.wiltoncorp.com

Windy Balloon Co. 224
4455 Torrance Blvd. #803
Torrance, CA 90503
(800) 921-2112; FAX: (310) 763-3035
www.windyballoon.com

Wing Enterprises, Inc. 637
1325 W. Industrial Circle
Springville, UT 84663
(801) 489-3684; FAX (801) 489-3685

Winter Inc. & Co, F.W. 352
Delaware Ave. & Elm St.
Camden, NJ 08102
(609) 963-7490; FAX (609) 963-7463
www.fwwinter.com

WireCrafters Inc. 2314
6208 Strawberry Lane
Louisville, KY 40214
(502) 363-6691; FAX (502) 361-3857
www.wirecrafters.com

WireCrafters will show physical barriers for robotic work cells or integrated systems made from woven wire partitions. This modular bolt-up system provides protection from automated machinery. Standard size wire mesh panels made in a variety of meshes provide a versatile yet cost-effective barrier for your operation. The standard size panels bolt to 2-in. square steel posts that are directly anchored to the floor. Modular parts allow the system to reach any height required.

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(901) 365-3600; FAX (901) 369-4050
www.totalpower.com

Wisconsin Wire Works Inc. 2109
S81 W18878 Apollo Dr.
Muskego, WI 53150
(414) 679-8218; FAX (414) 679-8219
www.wisconsinwireworks.com

WNI 1612
1560 12th St. E.
Palmetto, FL 34221
(800) 964-8645; FAX (941) 729-4518

World Machinery & Saw Systems Co. 2110
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Columbus, OH 43085-1542
(614)438-3013; FAX (614) 438-3083
www.worthingtoncylinders.com

XELUX/L.B.L. Inc. 561
2113 Oxford Rd.
Des Plaines, IL 60018
(847) 297-7929; FAX: (847) 297-4112
www.xflux.com

Yeeda International Co. 662
1100 S.W. Wanamaker Rd., Ste. 18
Topeka, KS 66604
(785) 228-1712; FAX (785) 228-0143

York Sales Co. 2042
3935 Grove Ave.
Gurnee, IL 60031
(847) 662-5206; FAX (847) 662-5290

Young Do Ind. Co., Ltd. 102
8310 S.W. 27th Ter.
Miami, FL 60031
(305) 222-4955; FAX (305) 222-8455

Navy Joining Center
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PAWS Production Implementation Benefits Navy Submarine Construction

General Dynamics, Electric Boat Corp., has purchased a Programmable Automated Welding System (PAWS) for its production facility in Quonset Point, R.I. This robot welding system includes a large servo-controlled gantry equipped with two eight-axis welding robots and the EasyPlan off-line programming software.

PAWS, originally a Navy Advanced Technology Demonstration Project, was fully developed and demonstrated for shipyard use during the Navy Joining Center MANTECH (Manufacturing Technology) project in partnership with MARITECH (Marine Technology).

PAWS is designed to overcome the nonrepetitive, small-batch production and large dimensional variability problems that have limited the use of robotic welding for construction of Navy ships.

Electric Boat selected PAWS after evaluating the performance, reliability and benefits of the pilot production system as part of the NJC project. This evaluation convinced Electric Boat PAWS was a production tool that supports the company's integrated, automated design and construction approach to Navy submarine construction.

This production implementation of PAWS provides Electric Boat with a robotic welding facility that will increase the fabrication efficiency and productivity for large submarine structures. This change in the manufacturing process benefits the Navy through realized cost savings.

PAWS and EasyPlan are available to Navy shipyards and other users from MAST Automation, Inc., and PHT, Inc. For more information on the PAWS project, contact Harvey Castner at (614) 688-5063.

Teaching Factory Announces Upcoming Workshops

The Navy Joining Center Teaching Factory is sponsoring a Titanium Welding Technology workshop and a GTAW Flux workshop.

The Titanium Welding Technology workshop targets the needs of titanium fabricators. Topics will focus on welding procedures and practices for commercially pure titanium. Presentations will include the results of NJC development in support of Navy applications. However, subjects to be covered will be useful to non-Navy fabricators and to those fabricating other titanium alloys. The workshop will include demonstrations of titanium welding and NDE technology.

The GTAW Flux workshop will review new developments in the area of flux-assisted gas tungsten arc welding. The advantages and limitations of using GTAW flux will be presented. Industrial and shipyard experience will be reviewed. Hands-on laboratory demonstrations will follow the technical presentations. Participants are encouraged to share their material/application needs. Participants interested in evaluating the GTAW flux for their parts/applications should contact EWI staff two to three weeks before the seminar.

Titanium Welding Technology
Date: May 23–24
Location: EWI, Columbus, Ohio
Leads: Dennis Harwig & John Talkington

GTAW Flux
Date: May 9
Location: EWI, Columbus, Ohio
Lead: Matt Johnson

For more information or to register, please contact Connie Kotula at the NJC at (614) 688-5156, or e-mail: *connie_kotula@ewi.org*.

NJC to Exhibit at AWS

Visit the NJC at Booth #1456 at the AWS Show in Chicago, April 26–28.

The NJC will demonstrate the Knowledge-Based Inspection System (KBIS), a computer-assisted, knowledge-based ultrasonic test system to improve weld inspection. The system improves the ability to analyze relevant ultrasonic data for welds.

For more information on the AWS Show, call (800) 443-9353 ext. 256.

NJC
Operated by
EWI
The Navy Joining Center
1250 Arthur E. Adams Dr.
Columbus, OH 43221
Phone: (614) 688-5010
FAX: (614) 688-5001
e-mail: NJC@ewi.org
www: *http://www.ewi.org*
Contact: Harvey Castner

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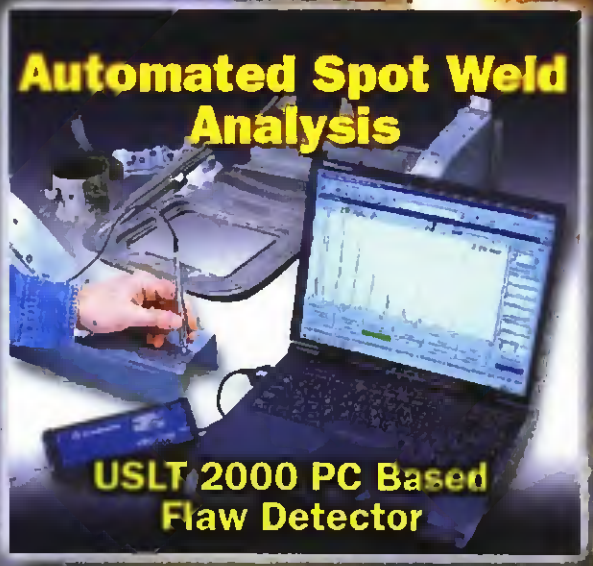

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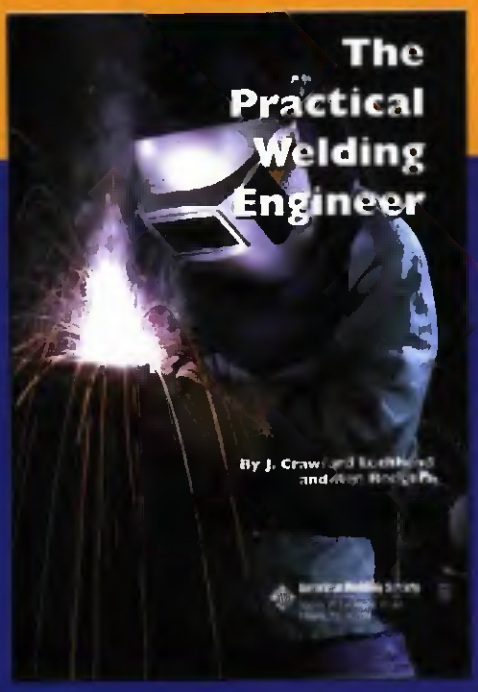

NEW!

The Practical Welding Engineer

This brand-new book offers a practical approach to the application of welding theories. Two expert authors with nearly 60 years of hard-gained experience in heavy engineering offer solid advice in real-world application of welding metallurgy, materials behavior, fracture mechanics, and much more. Key topics include contracts and specifications, selection of welding processes, welding procedure qualification, production welding control, estimating and reducing welding costs, common weld defects, and practical problem solving. By J. Crawford Lochhead and Ken Rodgers, softbound, 160 pages. Published in 2000 by the American Welding Society.

AWS Member.....$36.00
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Brazing Q & A

BY ROBERT L. PEASLEE

Q: We are brazing 304 stainless steel in a continuous furnace, using a nitrogen/hydrogen atmosphere. Normally 11,000 ft³/h nitrogen and 700 ft³/h hydrogen are used as the furnace atmosphere. We have tried dropping just the hydrogen, but this affects the quality of the copper brazed parts. We attempted to braze stainless steel with BNi-5 nickel-based filler metal at the lower end of the brazing range (2100°F) in our standard atmosphere. The results were poor, with little or no flow. We do not know the dew point of the furnace atmosphere, as we lack an instrument to measure it. What is the lowest flow rate of hydrogen that could be used, and what caused this problem? Also, why do we have difficulty brazing BNi-5 filler metal?

A: When brazing any base metal with a substantial quantity of chromium as an alloying element, it is necessary to have a very good dew point in the furnace at the high-temperature end. Since you have no dew-point equipment, you must rely on the footprints you observe on the parts coming out of the furnace. The footprints are an excellent indicator of the atmosphere quality and the brazing quality, which are intertwined.

When copper brazing 304, use a number of test coupons of 304 stainless steel to indicate the quality of the atmosphere. It is necessary to grind down one half of the panel to remove about 0.005 in. of the top layer of the base metal. The reason is some heats of stainless have been hot rolled and pickled and, during this process, have lost the chromium content of the surface of the base metal. If a hot rolled and pickled piece of stainless steel is put in a +80 dew point exothermic atmosphere, it will come out bright and shiny, but the cut edges will be oxidized black. The fact it comes out bright and shiny indicates the chromium has been depleted from the surface and is now brazing to a nickel-iron surface on which copper will flow very readily in a high-dew-point atmosphere. After removing half the surface of the test specimen, place some copper paste or copper wire across the two surfaces. Run the test panel through the brazing furnace, then note the flow on both surfaces. If the copper flows and covers much more area on the unground surface than on the ground surface, it is likely the surface is hot rolled and pickled. Since many copper-brazed parts are machined, they would have no hot rolled and pickled surface, so it is necessary to run the test on base metal that has no hot rolled and pickled surface. With a series of panels having chromium at the surface, run the test panels through from time to time and, in particular, any time the parts appear to have a drop in quality. At this time, you will note there is less flow area on the surface of the test panels.

During the day-to-day operation of the furnace used for copper brazing of 304 stainless steel, look at machined (or formed) parts to see if there is variation in the flow of the copper across the parts' surface outside of the joint; this will indicate changes in the dew point in the furnace. Make sure the variation in flow on the surface results from the atmosphere and not because the surface is devoid of chromium from hot rolling and pickling.

The percent of hydrogen in the final atmosphere varies considerably with different furnaces. Generally, the lowest amount of hydrogen used with stainless steel is 20%. With the use of 1100 ft³/h nitrogen and 700 ft³/h hydrogen, you are running with 39% hydrogen content. When only the hydrogen content of the atmosphere is lowered, the total atmosphere sweep in the furnace is lowered, as is the sweep at the front and back doors of the furnace. This allows more oxygen to remain in the furnace and to diffuse back into the front and back door areas. It is essential when working with a very low dew-point atmosphere to keep the front and back curtains well maintained so they function properly. If you have a nitrogen curtain in the front, the flow rate is important. Usually there are ceramic curtains on the back, and these must be adjusted and replaced when there is too much wear. If a flow rate of 1800 ft³/h is suitable for your furnace to give good braze parts and you wish to lower the hydrogen content, then it is necessary to increase the nitrogen content.

You indicated you tried brazing with BNi-5 at the low end of the temperature range, which would be around 2100°F, and had little to no success. BNi-5 is much more sensitive to the dew point of the atmosphere because it is an atomized nickel alloy with high chromium and silicon. Obtaining satisfactory results with BNi-5 will require a lower dew point in the hot zone of the furnace. The fact that you did not have good results is an indication the dew point was not low enough and the partial pressure of oxygen was too high. Copper, on the other hand, is insensitive to atmosphere quality, so it would readily flow and wet. The limiting element, when copper brazing, is the chromium at the surface of the stainless steel. To braze BNi-5 filler metals, it is necessary to be sure the curtains on either end of the furnace are working efficiently. It may also be necessary to increase the flow of atmosphere to reduce the diffusion of oxygen from the front and back and to remove the oxygen that is outgassed from the parts, both from the surface and from within the base metal. Since you are brazing stainless steel, I assume the furnace has a full muffle and it and the muffle joints are kept in good repair.

If you wish to nickel braze stainless steel in your furnace at 2050°F, it would be best to use BNi-7 or a similar brazing filler metal, such as NB 51, with chromium in the range of 25%. These higher-chromium filler metals work well with the nitrogen/hydrogen atmospheres when used with a light press-fit, as they are much less sensitive to atmosphere quality than BNi-5.

If you watch the footprints on the parts coming out of the furnace, these indicators will tell you when there is a change in the furnace atmosphere and resulting braze quality. In conjunction with these footprints, you will want to look at the various items of maintenance on your furnace. You will soon be able to tie the maintenance problem with the footprints you see out of the back end of the furnace. ♦

R. L. PEASLEE is Vice President, Wall Colmonoy Corp., Madison Heights, Mich. This article is based on a column prepared for the AWS Detroit Brazing and Soldering Division's newsletter. Reader questions may be sent to Mr. Peaslee c/o Welding Journal, *550 N.W. LeJeune Rd., Miami, FL 33126.*

Coming Events

Conferences and Exhibitions

◆ **International Brazing and Soldering Conference and Exhibition.** April 2–4, Albuquerque, N.Mex. Sponsored by the American Welding Society. Contact: AWS Conferences Dept., 550 N.W. LeJeune Rd., Miami, FL 33126, (800) 443-9353 ext. 223 or (305) 443-9353 ext. 223, FAX: (305) 443-1552.

Tube 2000, International Tube and Pipe Fair. April 3–7, Düsseldorf, Germany. Contact: Messe Düsseldorf North America, 150 N. Michigan Ave., Ste. 2920, Chicago, IL 60601, (312) 781-5180, FAX: (312) 781-5188.

Rapid Prototyping & Manufacturing 2000 Conference and Exposition. April 11–13, Rosemont Convention Center, Rosemont, Ill. Organized by the Society of Manufacturing Engineers. Contact: SME Customer Service: One SME Dr., Dearborn, MI 48121, (800) 733-4763 ext. 1600 or (313) 271-1500 ext. 1600, FAX: (313) 271-2861.

Japan International Welding Show 2000. April 12–15, Osaka International Trade Fair Grounds, Japan. Sponsored by the Japan Welding Engineering Society. Contact: Sanpo Publications, Inc., Sanpo Sakuma Bldg., 1-11, Kanda Sakuma-cho, Chiyoda-ku, Tokyo 101-0025, Japan, +81 3 3258 6411, FAX: +81 3 3258 6430.

◆ **The 2000 AWS International Welding and Fabricating Exposition and Annual Convention.** April 24–28, McCormick Place, Chicago, Ill. Sponsored by the American Welding Society. Contact: AWS Conventions and Expositions Dept., 550 N.W. LeJeune Rd., Miami, FL 33126, (800) 443-9353 ext. 256 or (305) 443-9353 ext. 256, FAX: (305) 442-7451.

International Thermal Spray Conference and Exposition. May 8–11, Palais des Congrès de Montréal, Montréal, Québec, Canada. Sponsored by the ASM Thermal Spray Society, DVS and IIW. Contact: Geo E. Fern Co., 1100 Gest St., Cincinnati, OH 45203, FAX: (513) 621-4439.

31st International Symposium on Robotics (ISR 2000). May 14–17, Montréal, Canada. Contact: Canadian Federation for Robotics, c/o Golden Planners, Inc., 126 York St., Ste. 301, Ottawa, ON K1N 5T5, Canada, (613) 241-9333, FAX: (613) 565-2173.

SAMPE 2000 — International Symposium/Exhibition. May 21–25, Long Beach Convention Center, Long Beach, Calif. Sponsored by the Society for the Advancement of Material and Process Engineering (SAMPE). Contact: SAMPE, 1161 Parkview Dr., Covina, CA 91724, (626) 331-0616 ext. 610, FAX: (626) 332-8929.

EASTEC 2000 Advanced Productivity Exposition (APEX). May 23–25, Eastern States Exposition Grounds, West Springfield, Mass. Contact: Society of Manufacturing Engineers, One SME Dr., Dearborn, MI 48121, (800) 733-4763 ext. 1600 or (313) 271-1500 ext. 1600, FAX: (313) 271-2861.

Lasers for Manufacturing Conference. May 24–26, Arlington Heights, Ill. Cosponsored by the Laser Institute of America and the Society of Manufacturing Engineers. Contact: LIA, 13501 Ingenuity Dr., Ste. 128, Orlando, FL 32826, (407) 380-1553, FAX: (407) 380-5588.

Offshore Newfoundland Petroleum Show. June 21–22, St. John's Memorial Stadium, Newfoundland, Canada. Contact: Southex Exhibitions Inc., #605, 999 – 8 St. SW, Calgary, AB, Canada T2R 1J5, (403) 209-3566 or (888) 799-2545, FAX: (403) 245-8649.

EPRI Cooling Tower Conference. August 23–24, Snow King Resort, Jackson Hole, Wyo. Contact: Brent Lancaster, CCM, Conference Coordinator, (704) 547-6017.

4th Conference on Aerospace Materials, Processes and Environmental Technology. September 18–20, Von Braun Center, Huntsville, Ala. Contact: Dawn Cross, Marshall Space Flight Center, (256) 544-1835.

Materials Solutions 2000. October 9–12, Cervantes Convention Center, St. Louis, Mo. Contact: ASM International, (440) 338-5151.

◆ **Second International Conference on Education in Welding.** October 15–17, Denmark. Cosponsored by the Institute for the Joining of Materials (JOM Institute) and the American Welding Society. Contact: JOM Institute, Klintehøj, Vænge 21, 3460 Birkerod, Denmark, +45 45 82 80 95, FAX: +45 45 94 08 55.

ICOMES 2000 — 6th International Conference of Mechanical Engineering Societies. November 18–22, Shanghai, China. Organized by the Chinese Mechanical Engineering Society (CMES). Contact: CMES, 46 Sanlihe Rd., Beijing 100823, P. R. China, 010 68511753, FAX: 010 68533613.

Educational Opportunities

Thielsch Engineering Spring 2000 Seminars. April 3–7, Crown Plaza Hotel at the Crossings, Warwick, R.I. For more information, contact: Thielsch Engineering, 195 Frances Ave., Cranston, RI 02910, (401) 467-6454, FAX: (401) 467-2398.

◆ **How to Weld Titanium.** April 25, at the AWS Show, McCormick Place, Chicago. Sponsored by AWS and ITA. Contact: AWS Conferences, 550 NW LeJeune Rd., Miami, FL 33126, (800) 443-9353 ext. 223, FAX: (305) 443-1552.

◆ **Introduction to Thermal Spray: Processes, Coatings & Applications.** April 25, at the AWS Show, McCormick Place, Chicago, Ill. Sponsored by AWS and TSS. Contact: AWS Conferences, 550 NW LeJeune Rd., Miami, FL 33126, (800) 443-9353 ext. 223, FAX: (305) 443-1552.

◆ **Automated/Robotic Welding Seminar.** April 26, at the AWS Show, McCormick Place, Chicago, Ill. Sponsored by AWS and SME. Contact: AWS Conferences, 550 NW LeJeune Rd., Miami, FL 33126, (800) 443-9353 ext. 223, FAX: (305) 443-1552.

Note: A diamond (◆) denotes an AWS-sponsored event.

♦ **AWS Cleveland Section Regional Conference on Hardfacing.** May 16–18, Cleveland, Ohio. Sponsored by the AWS Cleveland Section and hosted by The Lincoln Electric Co. Contact: Jackie Marley, The Lincoln Electric Co., 22801 St. Clair Ave., Cleveland, OH 44117, (216) 383-2240.

Modern Furnace Brazing Course. May 17–19, Troy, Mich. Conducted by Wall Colmonoy Corp. Contact: Marianne Huesing, Wall Colmonoy Corp., 30261 Stephenson Hwy., Madison Heights, MI 48071, (248) 585-6400 ext. 248, FAX: (248) 585-7960.

Laser Safety Officer Course. June 5–9, St. Louis, Mo. Sponsored by the Laser Institute of America. Contact: LIA, 13501 Ingenuity Dr., Ste. 128, Orlando, FL 32826, (407) 380-1553, FAX: (407) 380-5588.

Industrial Ventilation Courses. June 12–15, Tropicana Hotel, Las Vegas, Nev. Conducted by the UAB School of Engineering. Contact: UAB School of Engineering, Professional Development, 1075 13th St. S., Birmingham, AL 35294, (205) 934-8994, FAX: (205) 934-8437.

2000 Motorsports Welding School. June 19–23, August 21–25, Cleveland, Ohio. Conducted by The Lincoln Electric Co. For information and complete schedule, contact: Lincoln Electric Motorsports Welding School, 22801 St. Clair Ave., Cleveland, OH 44117, (216) 383-2259, FAX: (216) 383-8025.

EPRI Nuclear Plant Performance Improvement Seminar (NPPI). August 7–8, Swissôtel Chicago, Chicago, Ill. Contact: Brent Lancaster, CCM Conference Manager, EPRI, 1300 W. T. Harris Blvd., Charlotte, NC 28262, (704) 547-6017, FAX: (704) 547-6168.

♦ **D1.1: 2000 Structural Welding Code — Steel.** A five-day seminar. Sponsored by AWS. For more information and complete schedule, contact: AWS Conferences, 550 NW LeJeune Rd., Miami, FL 33126, (800) 443-9353 ext. 223, FAX: (305) 443-1552.

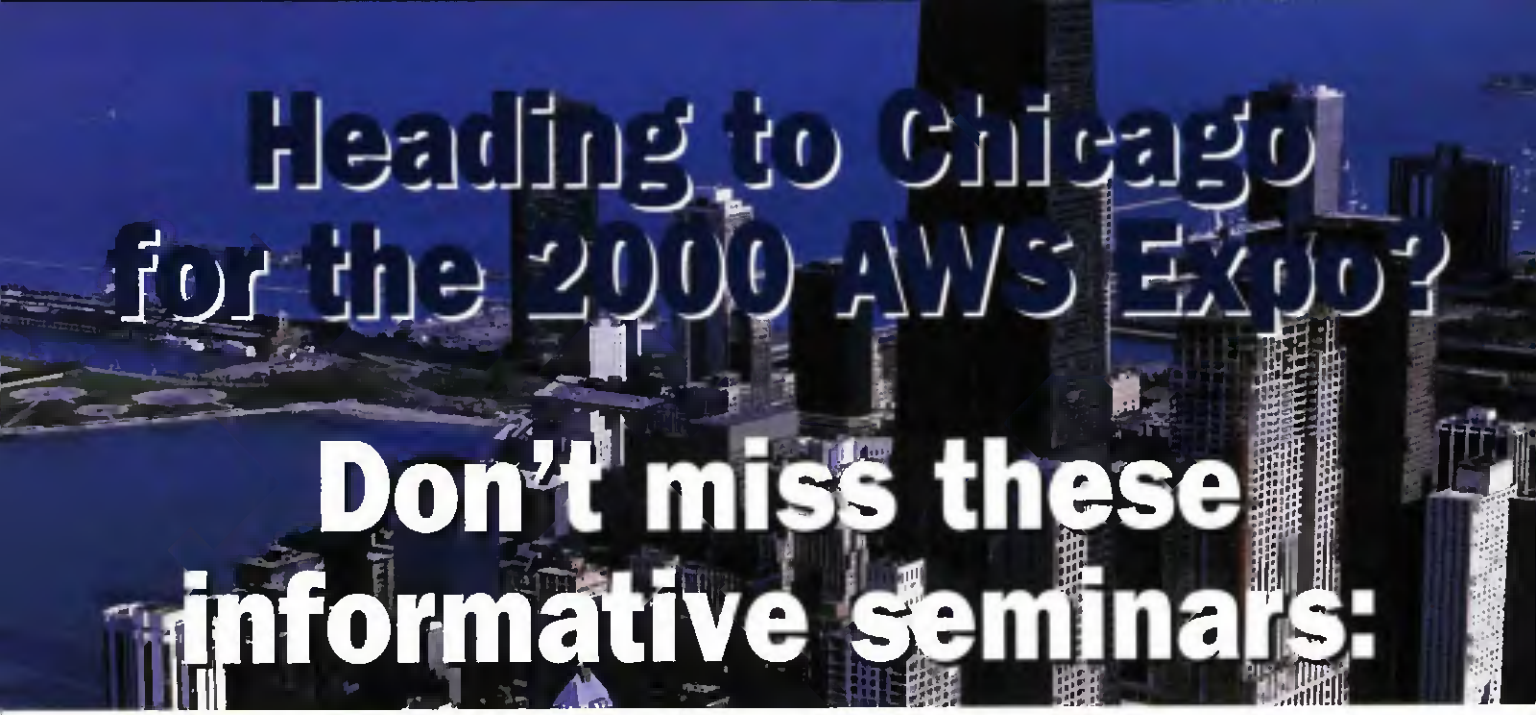
Structural Welding: Design and Specification Seminars. Conducted by the Steel Structures Technology Center (SSTC). For 2000 schedule and locations, contact: SSTC, (248) 344-2910, FAX: (248) 344-2911.

AWS 2000 Schedule — CWI/CWE Seminars and Exams

Exam application must be submitted six weeks before exam date. For exam information and application, contact the AWS Certification Dept., (800) 443-9353 ext. 273. For seminar information, contact the AWS Education Dept., (800) 443-9353 ext. 229. To preregister for a seminar, call AWS Customer Service, (800) 334-9353.

Cities	Inspection Seminars	CWI/CWE Exams
Anchorage, Alaska	Oct. 16–20 (API 1104 clinic also offered)	Oct. 21
Atlanta, Ga.	Oct. 30–Nov.3	Nov. 4
Baltimore, Md.	EXAM ONLY	Oct. 7
Baton Rouge, La.	May 1–5 (SCWI also offered)	May 6
Beaumont, Tex. (API 104 clinic/	June 5–9 SCWI also offered)	June 10
Beaumont, Tex.	Nov. 13–17 (API 1104 clinic/ SCWI also offered)	Nov. 18
Birmingham, Ala.	EXAM ONLY	May 27
Boston, Mass.	Sept. 18–22	Sept. 23
Charlotte, N.C.	EXAM ONLY	Sept. 9
Chicago, Ill.	EXAM ONLY	Nov. 18
Cincinnati, Ohio	EXAM ONLY	Sept. 9
Columbus, Ohio	May 15–19	May 20
Denver, Colo.	Sept. 25–29	Sept. 30
Detroit, Mich.	June 12–16	June 17
Fresno, Calif.	EXAM ONLY	Sept. 2
Hartford, Conn.	July 24–28	July 29
Houston, Tex.	Aug. 7–11 (API 1104 clinic/ SCWI also offered)	Aug. 12
Idaho Falls, Idaho	June 12–16	June 17
Indianapolis, Ind.	Aug. 14–18	Aug. 19
Kansas City, Mo.	Aug. 21–25	Aug. 26
Knoxville, Tenn.	EXAM ONLY	Aug. 5
Las Vegas, Nev.	Aug. 14–18 (API 1104 clinic also offered)	Aug. 19
Long Beach, Calif.	May 8–12	May 13
Long Beach, Calif.	Nov. 6–10	Nov. 11
Los Angeles, Calif.	EXAM ONLY	Oct. 14

Cities	Inspection Seminars	CWI/CWE Exams
Louisville, Ky.	EXAM ONLY	June 3
Louisville, Ky.	July 17–21	July 22
Miami, Fla.	EXAM ONLY	May 18
Miami, Fla.	June 26–30	July 1
Miami, Fla.	EXAM ONLY	July 20
Miami, Fla.	EXAM ONLY	Aug. 17
Miami, Fla.	EXAM ONLY	Sept. 21
Miami, Fla.	EXAM ONLY	Oct. 19
Miami, Fla.	Dec. 4–8	Dec. 9
Milwaukee, Wis.	Aug. 21–25	Aug. 26
Nashville, Tenn.	May 8–12 (API 1104 clinic also offered)	May 13
Nashville, Tenn.	Oct. 30–Nov. 3	Nov. 4
New Orleans, La.	Sept. 18–22 (API 1104 clinic also offered)	Sept. 23
Norfolk, Va.	Oct. 23–27	Oct. 28
Philadelphia, Pa.	EXAM ONLY	Sept. 16
Pittsburgh, Pa.	May 1–5	May 6
Portland, Ore.	Oct. 16–20	Oct. 21
Rochester, N.Y.	Nov. 6–10	Nov. 11
Saint Louis, Mo.	May 15–19	May 20
Saint Louis, Mo.	EXAM ONLY	Nov. 4
Salt Lake City, Utah	EXAM ONLY	Sept. 16
San Antonio, Tex.	Oct. 9–13 (API 1104 clinic also offered)	Oct. 14
San Diego, Calif.	July 10–14	July 15
San Fernando, Calif.	EXAM ONLY	June 24
San Francisco, Calif.	Oct. 2–6	Oct. 7
Savannah, Ga.	May 8–12	May 13
Seattle, Wash.	Oct. 2–6	Oct. 7
Spokane, Wash.	May 15–19	May 20
Tulsa, Okla.	Sept. 25–29 (SCWI also offered)	Sept. 30
York, Pa.	July 24–28	July 29



Heading to Chicago for the 2000 AWS Expo?

Don't miss these informative seminars:

Introduction to Thermal Spray: Processes, Coatings, and Applications

Tuesday, April 25, 12 noon – 5:00 p.m.

Excellent pre-Expo preparation if you're looking to buy thermal spray equipment. Take part in this program on an incredible process from a veteran instructor and recognized researcher. The course leader will start with plasma spray, high velocity oxyfuel spray, detonation gun deposition, and advanced wire arc processes. Then, metallic, cermet and ceramic coating structures and properties will be reviewed, followed by the how-to's of determining application suitability — including wear, corrosion, thermal barrier, electromagnetism, and other important variables.

$75 (tuition, breaks, handouts and entry to Expo)

TSS
ASM Thermal Spray Society

How to Weld Titanium

Tuesday, April 25, 9:00 a.m. – 5:00 p.m.

This program emphasizes design variables and alloy selection and is aimed at the senior technician to the engineer-level professional. Titanium metallurgy, heat treatment, welding process selection, weld defects, and control will be covered. Video footage of titanium welding by an expert gives attendees a bird's-eye look at proper technique.

$240 for AWS Members (tuition, a copy of *The Practical Reference Guide to Welding Titanium*, lunch, breaks, and pass to Expo)

Welding In Food Industry Applications
A one-day conference

for professionals who are responsible for welding that has to serve in hygienic applications.

Wednesday, April 26, 9:00 a.m. – 5:00 p.m.

Six experts will cover these topics:

- Stainless Steels: Properties for Food Industry Use
- Introducing AWS' D18.1 Specification
- Basics of Design and Welding of Food Processing Equipment
- Preparation for Welding and Welding Procedures
- Clean-in-Place Application in Food Processing and Pharmaceutical Industries
- Inspection of Welds for Food Service

$295 for AWS Members (tuition, copy of *Specification for Welding of Austenitic Stainless Steel Tube and Piping Systems in Sanitary Applications*, lunch, breaks, pass to Expo)

American Welding Society
D18 Committe on Welding in Sanitary Applications

Business Strategies for Welding

Wednesday, April 26, 8:30 a.m. – 5:00 p.m.

This new course is specifically designed for professionals who are not proficient in welding, but do have job responsibilities closely aligned to the welding process. This course will expand your knowledge of welding by providing information to enhance the efficiency of your welding operation, assist in the selection and retention of employees, and provide your welders with the tools necessary to achieve extraordinary results.

$345 (tuition, handouts, lunch, breaks, and pass to Expo)

Fabricators & Manufacturers Association, International

Aluminum Welding

A two-day *Super Seminar*

Thursday April 27, 8:15 a.m - 5:00 p.m. and Friday April 28, 8:15 a.m. – 12 noon

A singular topic/ multiple experts seminar designed to explain aluminum welding down to the bare metal.

If you are responsible for designing, engineering, or fabricating aluminum structures, get two days of insider hints, tips, advice, and no-nonsense introduction from a seminar that's been brought back again and again by popular demand since 1966.

Day 1 Sessions

- Fundamentals of Materials, Safety and Health
- Aluminum Welding Metallurgy
- Joining Processes

Day 2 Sessions

- Design, Quality and Performance
- New Processes

16 specific presentations including GMAW, GTAW, brazing, soldering, friction stir welding, robotic welding, and high energy beam welding of aluminum.

$450 for AWS Members (tuition, copy of D1.2:1999 *Structural Welding Code — Aluminum*, AA's *Welding Aluminum Theory and Practice* and *Aluminum Standards and Data*, lunches, breaks, and pass to Expo)

The Aluminum Association

To register fast, use the secured server on www.aws.org. While you're at the AWS website, plan your tour of the 2000 AWS Expo by using the electronic show floor. You can also use the Registration Form in this issue of Welding Journal.

American Welding Society
550 NW LeJeune Road
Miami, FL 33126
Visit our website at http://www.aws.org

SOCIETY NEWS

By Susan Campbell

♦ Chicago Plays Host to the 2000 AWS International Welding and Fabricating Exposition and Annual Convention

The 2000 AWS International Welding and Fabricating Exposition and the 81st Annual Convention open at McCormick Place in downtown Chicago, Ill., on April 25 and run through the 28. The business meeting officially convenes on Tuesday, April 25, with AWS President Robert Teuscher presiding. This session is followed by the Comfort A. Adams Lecture, presented this year by Dr. Tarasankar DebRoy. DebRoy, a professor of materials sciences and engineering at Pennsylvania State University, will present his paper titled "Computer Modeling — A Path to Understand the Science of Welding." In addition, Tuesday marks the beginning of approximately 25 technical sessions. For details on topics, dates and times, look through the Professional Program in this issue. The Exposition opens on Wednesday, April 26, with an extravaganza of welding and fabricating equipment. The Show will be hosted by incoming AWS President L. William Myers.

Visiting Chicago

Although there are plenty of show-related events and activities to keep one busy, Chicago is a city that shouldn't be missed. The city of the Big Shoulders offers everything from world-class art museums to down-and-dirty blues clubs, from gourmet restaurants to mouth-watering hot dogs and pizza. If it's architecture that interests you, Chicago features buildings in the Chicago School, art deco, modernism and post-modernism styles. You'll also find scores of homes by Frank Lloyd Wright, including his own home and studio (for tour information, call 708-848-1976).

Of course, there won't be time to see everything, but the following is a sample of what you will find in the city. To make the best use of your time there, you may want to stop by one of the Visitor Information Centers. They can provide information on Chicago's points of interest, shopping, dining and sightseeing. They offer maps, brochures and guides covering attractions, tours, night life, services and more. You can stop by the Information Center located in the McCormick Place Complex during show hours or one of the other centers conveniently located at

♦ Chicago Cultural Center, 77 E. Randolph St., Mon.–Fri. 10 a.m.–6 p.m.; Sat. 10 a.m.–5 p.m.; 312-744-2400

♦ Chicago Water Works, 163 E. Pearson at Michigan Ave., Mon.–Sat. 7:30 a.m.–7 p.m.; Sun. 10 a.m.–6 p.m.; 312-527-4668.

♦ ~~Illinois Market Place~~, Navy Pier, 700 E. Grand Ave., Sun.–Thurs. 10 a.m.–9 p.m.; Fri.–Sat. 10 a.m.–12 p.m.; 312-832-0010.

Buckingham Fountain on South Lake Shore Drive was presented to the city in 1927 by Kate Buckingham in memory of her brother Clarence.

Cultural Chicago

The **Art Institute of Chicago**, 111 S. Michigan Ave., 312-443-3600, is world famous for its collection of French Impressionist and Post-impressionist paintings. Monet, Seurat, Renoir and Caillebotte are just a few of the artists represented. Displayed in the galleries are the art of ancient, medieval and Renaissance Europe; Asia; decorative arts (including the Thorne Miniature Rooms); contemporary arts; and departments of prints and drawings, architecture and photography.

At the **Museum of Science and Industry**, 5700 S. Lake Shore Dr., 773-684-1414, you will find exhibits such as the Coal Mine, a World War II U-505 German submarine and a fully restored Pioneer Zephyr train. The Omnimax Theatre is a big attraction in the Henry Crown Space Center with its five-story domed screen.

If your interest is architecture, a tour of the city is a must. A great place to find the tour for you is the **Chicago Architecture Foundation**, 312- 922-8687. This nonprofit organization offers more than 60 neighborhood and suburban tours, as well as tours of the Loop on foot, bus or by boat.

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AWS PUBLICATIONS

♦AWS Resistance Welding Specification Now Available

The American Welding Society (AWS) has completed the latest edition of *Specification for Resistance Welding of Carbon and Low-Alloy Steels* (AWSC1.4M/C1.4:1999). This ANSI-approved specification provides for a program covering the minimum shear-strength and weld button diameter requirements for carbon steel and low-alloy steel sheet resistance and projection welds. Developed by the AWS Committee on Resistance Welding and the AWS Task Group on Resistance Welding of Coated and Uncoated Carbon and Low-Alloy Steels, this specification contains guidance from the experts in resistance welding.

Specification for Resistance Welding of Carbon and Low-Alloy Steels includes nine sections on a variety of subjects, including welding procedure requirements, preproduction requirements and safety and health concerns. The specification also includes six tables and five figures.

Specification for Resistance Welding of Carbon and Low-Alloy Steels is 20 pages, measures 8½ x 11 in. and is softbound. The list price is $32; $24 for AWS members.

♦AWS Releases 'The Practical Welding Engineer'

Written to present a "practical" approach to the application of welding theories, the American Welding Society's latest publication, *The Practical Welding Engineer*, is designed for anyone with a basic knowledge of welding and looking for more detailed information and experience. Written by J. Crawford Lochhead and Ken Rodgers, both of Brown and Root McDermott Fabricators, Ltd., *The Practical Welding Engineer* will make a valuable addition to any welding library.

Going beyond theoretical explanations of welding problems, *The Practical Welding Engineer* contains detailed chapters on such diverse subjects as the selection of welding processes and equipment, practical problem solving and common defects and solutions. Recognizing its "practical" focus, the book begins with a chapter describing the role of the welding engineer and also advises how to estimate and reduce welding costs. It concludes with numerous tables, charts and figures to make welding engineering concepts easier to understand.

Softbound and 152-pages long, *The Practical Welding Engineer* lists for $48; $36 for AWS members, with discounts available for bulk orders.

♦Revisions on Two Guides for Evaluating Welds Published

The American Welding Society has completed revisions on two valuable guides for evaluating welds: *Guide for the Nondestructive Examination of Welds* (AWS B1.10:1999) and *Guide for Visual Inspection of Welds* (AWS B1.11:2000). Each was developed by the AWS Committee on Methods of Inspection and is approved by the American National Standards Institute (ANSI).

Guide for the Nondestructive Examination of Welds describes the various NDE methods commonly used to examine welds. The guide also indicates which methods are best for detecting various types of discontinuties. It includes sections on numerous types of examination, including visual, penetrant, magnetic, radiographic, ultrasonic, electromagnetic and leak testing. *Guide for the Nondestructive Examination of Welds* is 42 pages and lists for $72; $54 for AWS members.

Guide for Visual Inspection of Welds contains detailed information on the visual examination of welds, including sections on inspection prerequisites, fundamentals, surface conditions and equipment. The guide also contains sketches and full-color photographs to illustrate commonly found weld problems. *Guide for Visual Inspection of Welds* is 36 pages and also lists for $72; $54 for AWS members.♦

Copies can be ordered by calling AWS Customer Service at (800) 334-9353, (305) 334-9353 outside the United States, Monday through Friday, 8 a.m. to 5 p.m. EST, or through the AWS Web site at www.aws.org. *Additional information on AWS's programs and publications can also be found on the Web site.*♦

♦ Second International Conference on Education in Welding

The Institute for the Joining of Materials (JOM) has announced the Second International Conference on Education in Welding to be held October 15–17 in Denmark. The goals of this conference are to enhance the transfer of welding technologies through education, help meet the industrial need for qualified personnel knowledgeable in codes and standards for fabrication and to present guidelines for qualification programs and instructor effectiveness. It is expected this conference will provide an open forum to explore the various approaches to education and training currently in practice throughout the world. In addition, there will be an opportunity for the exhibiting of teaching aids, standards and software. Contributions in the way of papers, workshops and other presentations are cordially invited. Please submit a short abstract or brief description directly to JOM Institute, Klintehøj Vænge 21, DK-3460 Birkerød, Denmark; e-mail *jom_aus@post10.tele.dk; or* FAX 45 45 94 08 55.♦

The Windy City

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Chicago's Most Popular Destinations

Grant Park's **Buckingham Fountain** (see page 209), 500 S. Lake Shore Dr., 312-742-7529, is a Beaux-arts marvel in pink marble with four bronze seahorses. It was presented to the city in 1927 as a gift from Kate Buckingham in honor of her brother, Clarence. The water sprays up 150 ft, and in the evenings, the fountain is lit with 780 colored lights that are synchronized to music.

Navy Pier, 300 Lake Shore Drive, 815-459-0680, juts one mile out into Lake Michigan on the town's near north side. It offers food, entertainment, shopping and attractions, including a Ferris wheel and a carousel. The view of the city from the end the pier is incomparable.

The **Lincoln Park Conservatory**, 2400 N. Stockton Dr., 312-742-7529, includes lush greenery from all over the world. The Easter/spring flower show is fantastic. Equally lush is the **Garfield Park Conservatory**, 300 N. Central Park Ave., 312-746-5100. It maintains the largest public horticultural collection under glass in the world. Like Lincoln Park, impressive flower and greenery shows change with the seasons.

Shedd Aquarium, 1200 S. Lake Shore Dr., 312-939-2438, is one of the largest indoor aquariums in the world. The Caribbean Coral Reef exhibit and the Pacific Northwest marine environment are must-sees for lovers of sea life.

For a dazzling view of the Chicago skyline, try the **Hancock Observatory**, 888-875-8439, 875 N. Michigan Ave., where an elevator whisks you 94 stories in 39 seconds. A skywalk with screens allow you to feel the wind for which Chicago is famous. The **Sears Tower**, 233 S. Wacker Dr., 312-875-9696, although no longer the world's tallest building, offers a hard-to-beat view from its Sky Deck. Visibility is between 40 and 50 miles on a clear day. A free eight-minute film, *Over Chicago*, is shown in the Over Chicago Cinema on the lower level of the deck.

Chicago is a virtual paradise for shoppers. Be sure to stroll the Magnificent Mile, otherwise known as N. Michigan Ave., where the Marshall Field's flagship store awaits.

Chicago's breathtaking skyline.

Dining

With countless restaurants and cuisines to choose from, one would be hard-pressed to choose the most popular. Luckily, the folks at Zagat Survey has done it for us. According to the Zagat's latest survey, the five most popular restaurants are, **Charlie Trotter's**, 816 W. Armitage Ave., 773-248-6228; **Le Francais**, 269 N. Milwaukee Ave., Wheeling, 847-541-7470; **Ambria**, 2300 N. Lincoln Park West, 773-472-5959; **Everest**, One Financial Plaza, 440 S. LaSalle St., 40th Fl., 312-663-8920; and **Frontera Grill**, 445 N. Clark St., 312-661-1434.

For a quick bite of authentic Chicago fare, try a Chicago Dog from **Gold Coast Dogs**, 418 N. State St., 312-527-1222. They are served topped with mustard, chopped onion, tomatoes, cucumbers, relish, a pickle spear, peppers and celery salt. Also be sure to try Chicago's famous deep-dish pizza. You can get it where it was first made, **Pizzeria Uno**, 29 E. Ohio St., 312-943-2400.

Remember, Chicago is a city meant to be seen on foot, so don't forget to bring a pair of good walking shoes and your jacket. After all, it is the Windy City. ♦

♦ SWEET HOME CHICAGO – A Guide to Local Blues Clubs

No visit to Chicago would be complete without a stop in one of the many blues clubs that thrive in this historic "Home of the Blues." Whether your preference is rockin' blues, down home blues, or classic Chicago electric blues, you'll find plenty of entertainment at the many visitor-friendly clubs in the Loop area and in the neighborhoods to the north.

Centrally located on the south edge of downtown Chicago, **Buddy Guy's Legends** club (754 S. Wabash) is close to all major hotels and is within walking distance from most major attractions, such as Grant Park, the Chicago Art Institute and the lakefront. Open until 2:00 a.m. every night, the club serves up tempting Cajun cuisine and delivers the real deal in soulful blues acts — sometimes even the world-famous Buddy Guy, himself.

Also downtown, the **House of Blues** (329 N. Dearborn) offers a variety of top-name blues-based musical acts, in addition to an excellent dinner and snack menu. While enjoying the music, take some time to look at the historical blues memorabilia lining the walls.

Blue Chicago has two locations on the near north side — 536 N. Clark (at Ohio) and 736 N. Clark (at Superior) — both in the River North entertainment district and within walking distance from major hotels and fine restaurants. These clubs regularly book major acts, including jump blues and blues rockers. There is a cover charge of $5.00 to $7.00, but one cover is good for admission to both clubs. Check out the Blue Chicago store for a variety of blues-related apparel, artwork and other souvenirs.

A little farther north, **B.L.U.E.S.** (2519 N. Halstead) features traditional Chicago electric blues in a tightly packed lounge that often puts you right in front of the bandstand. Just up the street, **Kingston Mines** (2548 N. Halstead) has been featuring blues rockers and folk blues for well over 30 years. Both of these clubs offer some of the best music around in a truly authentic setting. **Rosa**'s (3420 W. Armitage), billed as "Chicago's Friendliest Blues Lounge," is also on the near northwest side, just a ten-minute cab ride from downtown. Rosa's was named the Number One Blues Club in the city by *Chicago Magazine* in 1998. ♦ *Jeff Weber, Publisher*

AWS WELCOMES NEW SUPPORTING COMPANIES

New Educational Institutions

Long Beach City College
Pacific Coast Campus
1305 E. Pacific Coast Hwy.
Long Beach, CA 90806

North High School - Welding
Evansville-Vanderburgh School Corp.
2319 Stringtown Rd.
Evansville, IN 47711

Northland Pioneer College
P.O. Box 610
Holbrook, AZ 86025

North Lawrence
Vocational-Technical Center
P.O. Box 729
Bedford, IN 47421

New Supporting Companies

Canica International, Inc.
234 Picard
St. Eustache, Quebec
Canada J7R 5A1

Overly Door Company
574 West Otterman St.
Greensburg, PA 15601

PHPK Technologies Inc.
535 Enterprise Dr.
Westerville, OH 43081

♦ Sustaining Member Dues Update

Effective immediately, the following adjustments have been implemented for AWS Sustaining Member Company Memberships:

Dues: The annual dues are $700, domestic; $800, international; plus a $500 initiation fee. Included are up to ten members allocated under the annual fee.

Benefits: Sustaining Member benefits include 1) the AWS library of codes and standards (a $5500 value), with subsequent revisions; 2) ten AWS individual memberships for employees or customers; 3) usage of the AWS Sustaining Company Member logo; 4) an annual bound volume of the *Welding Journal*; 5) company recognition in the *Welding Journal* and at the AWS Expo; 6) free hyperlink from the AWS Web site; and 7) a Sustaining Company Member wall plaque.

For information on becoming an AWS Sustaining Member Company, contact Martha Concepcion, Membership/Customer Services Dept., AWS, 550 LeJeune Rd., Miami, FL 33126; (800) 443-9353 ext. 259; FAX (305) 443-7559.♦

♦ Volunteers Needed for AWS Safety and Health Subcommittee

The American Welding Society is seeking volunteers to serve on the SH4 Safety and Health Subcommittee on Labeling and Safe Practices. The SH4 Subcommittee produces the AWS *Safety and Health Fact Sheets*; ANSI/AWS F2.2, *Lens Shade Selector*; ANSI/AWS F4.1, *Recommended Safety Practices for Preparation for Welding and Cutting of Containers and Piping*; and safety pamphlets dealing with arc welding, brazing, oxyfuel welding and fire safety. If you are interested in actively participating, please call the SH4 Committee Secretary, Steve Hedrick, at (800) 443-9353 ext. 305 to request a committee application.♦

♦ The 2000 AWS Convention and Exposition in Chicago

Everything you need to know about welding is available once a year under one roof at the American Welding Society's Annual Convention and Exposition. This year's Expo and Convention at McCormick Place in downtown Chicago runs from April 25 through 28. The 2000 Expo will showcase the latest advances in welding and fabrication from more than 600 exhibitors. In excess of 25,000 attendees are expected to visit the Expo to see the latest in automatic, robotic, laser and every other type of welding technology and accessory.

Highlights of the 2000 Expo include an expanded professional program, including an aluminum welding seminar, one on welding in food processing applications and the ever popular Road Map to the D1.1 Code; live welding demonstrations by industry leaders; the annual AWS Awards Ceremony, Officers' Reception and the Comfort A. Adams Memorial Lecture. And don't miss the hundreds of exhibitors showcasing the latest advances in welding and fabricating technology.

Complete details on the AWS Exposition and Convention, including a free show pass and coupons, are in the Expo Advance Program, available on-line at *www.aws.org* or by calling (800) 443-9353 ext. 256, (305) 443-9353 ext. 256 outside the United States.♦

♦ AWS Membership

Member Grades	As of March 1, 2000
Sustaining	326
Member	43,050
Transitional	41
Student	4,869
Honorary	29
Life	1,358
Retired	260
Total	**49,933**

♦Sustaining Member Companies

Franklin Electric Co., Inc.
400 E. Spring Street
Bluffton, IN 45714
(219) 287-5430

Franklin Electric Company is one of the world's largest manufacturers of submersible electric motors and a leading producer of engineered specialty electric motor products and electronic drives and controls used by original equipment manufacturers (OEMs) around the world in a wide variety of residential, industrial and municipal applications.

The principal application for Franklin's submersible electric motors is providing the electric motors for water well pumping systems. These submersible motors are also used in underground gasoline and diesel fuel storage pumping systems and wastewater handling systems.

Franklin's engineered specialty electric motor products and electronic drives and controls are used in a wide variety of industrial products including gasoline dispensers, paint sprayers, electric hoists, explosion-proof vapor exhaust fans, vacuum pumping systems, livestock feeding systems and soft ice cream machines.

With 2300 employees worldwide, Franklin Electric is a global manufacturer with 12 manufacturing/distribution facilities located in the United States, Germany, the Czech Republic, Italy, Mexico, Australia, China and South Africa. ♦

♦Student Chapters, Send Us Your News

Student Chapters are encouraged to send reports of their meetings, activities and events, along with photographs, for publication in the *Welding Journal*'s Student Activities department.

Send your meeting/event reports to Susan Campbell, Asst. Editor, Welding Journal, 550 N.W. LeJeune Rd., Miami, FL 33126.

Reports can also be faxed to (305) 443-4704 or e-mailed to *campbell@aws.org*. ♦

Robinson Industries, Inc.
P. O. Box 100
400 Robinson Drive
Zelienople, PA 16063-0100
(724) 452-6121

Since 1892, Robinson Industries has offered high-quality products to its customers and has provided air-moving equipment for the steel, cement, aluminum, ceramic, petrochemical, paper, coal, mining, power generation, air pollution control and many other industries.

Robinson engineers, manufactures, repairs and rebuilds heavy-duty fans at its facility in Zelienople, Pa., at its wholly owned subsidiaries Robinson Fans Florida, Inc., Lakeland, Fla., and Robinson Fans West in Salt Lake City, Utah. Robinson's wholly owned subsidiary, Robinson's Fans Service and Equipment Co., Inc., Trussville, Ala., provides fan repair, installation and modification of fans in the field. ♦

X-Ergon
P.O. Box 152102
Irving, TX 75015-2102
(800) 527-9916

X-Ergon originated in 1973 and since its inception has grown into a company with representation throughout the United States. Initially started as a marketer of maintenance-engineered welding products, X-Ergon has expanded into a full-line metal maintenance source. Its products' effectiveness, safety and ease of use have made it into one of the industry's fastest-growing companies.

The exclusive X-Ergon CHEM-A-TIZED™ process of metal joining assures a superior job. In addition to electrodes, brazing alloys, solders and fluxes, the product line includes abrasives, polymer repair compounds, adhesives, tools and accessories for performing all types of metal joining, drilling, cutting and finishing.

Almost every business or industry does in-house maintenance that requires metal repair products. The responsibilities of maintenance personnel are constantly increasing, and as the work load grows, so will the demand for the company's products. ♦

Mauritzon Inc.
3939 W. Belden Avenue
Chicago, IL 60647
(773) 235-6000

Today, Mauritzon is one of the nation's largest, most diversified industrial textile wholesale manufacturers. The company operates out of a 110,000-sq-ft facility and converts more than 250,000,000 sq ft of fabric per year. Products produced by the company include welding curtains, screens, blankets and roll goods; roll track partitions; thermal tapes, ropes and tubing; high-temperature gloves and mitts; equipment, athletic, field, truck and pool covers; cargo restraint assemblies; drain, construction and building enclosure tarps; privacy screening and fencing; warehouse divider curtains and track systems; strip doors for warehouses and welding; and hardware, including grommets, snaps, Dee rings and webbing.

Through five generations of family ownership, Mauritzon has been dedicated to a tradition of personal service. The company prides itself on high standards of quality at the best prices available. ♦

♦ The Welding Industry Celebrates the 130th Anniversary of the Birth of E. O. Paton

March 5th marked the 130th anniversary of the birth of Eugenii Oskarovich Paton. Paton is recognized as the founder of one of the major research institutes in the field of welding and allied technologies, the E. O. Paton Electric Welding Institute in Kiev, Ukraine. The Paton Institute has been developing advanced technologies for almost 70 years.

Eugenii Oskarovich Paton

Paton studied engineering at the Dresden Polytechnic Institute in Germany in 1894 and at the Petersburg Institute of Railway Engineers in Russia in 1896. After completing his studies, he became a professor, and, for more than 30 years, he lectured in Petersburg, Moscow and finally in Kiev at the Polytechnic Institute. During this time, Paton wrote numerous manuals on bridge construction. Several dozen of these manuals were used to construct bridges that later won awards.

In 1929, he organized a welding laboratory and a welding committee to provide solutions to the problems of welding production at that time. In 1934, he founded the Electric Welding Institute at the Academy of Sciences of Ukraine.

Under Paton's leadership, submerged arc welding (SAW) was developed by the end of 1939, and the fundamental work in the process was reported in his publication *High-Speed Automatic Welding under a Layer of Flux*.

During World War II, the Institute concentrated its efforts under Paton's supervision on introducing submerged arc welding to the production of armaments and ammunition. Machines for automatic welding of tank bodies were mounted and put into operation in the Soviet Union's military manufacturing facilities. During the second half of 1942, the Soviet industry was producing more tanks than that of Germany.

In 1944, Paton returned to Kiev and the Electric Welding Institute. He expanded the theoretical and experimental work on the weldability of steels. He also developed the electroslag welding process and, later, the electroslag remelting process. Through his guidance, many complicated problems were solved, among them mass production of large-diameter welded pipes, accelerated construction of pipelines and building of large storage tanks by the coiling method.

The pinnacle of Paton's career was the construction of an all-welded bridge across the Dnieper River in Kiev. Sadly, he passed away three months before the bridge was inaugurated in 1953.

In 1965 the Presidium of the Academy of Sciences, Ukraine, began awarding the E. O. Paton Award for Outstanding Scientific Achievement in the Field of Advanced Methods of Materials Processing. To honor him, in 1999 the International Institute of Welding introduced the E. O. Paton Prize, which is awarded to persons who have made a great contribution or performed outstanding applied investigations and developments in the field of promising technologies of welding and allied process.

E. O. Paton's institute continues today, led by academician B. E. Paton. ♦

♦ Notice of Annual Meeting, American Welding Society

The Annual Meeting of the members of the American Welding Society will be held on Tuesday, April 25, beginning at 9 a.m. at McCormick Place, Chicago, Ill.

The Regular business of the Society will be conducted, including election of officers and ten members of the Board of Directors. Any business properly brought before the membership will be considered. ♦

♦ Nominations Sought for National Officers

AWS members who wish to nominate candidates for President, Vice President and Director-at-Large on the AWS Board of Directors for the term starting June 1, 2001, may present the nomination in person at the opening session of the National Nominating Committee Meeting scheduled for 10 a.m., Wednesday, April 26, 2000, at McCormick Place, Chicago, Ill., during the AWS International Welding and Fabricating Exposition.

Nominations must be accompanied by 20 copies of biographical material on each candidate, including a written statement by the candidate as to his or her willingness and ability to serve if nominated and elected, and a 5- x 7- in. black-and-white or color photograph. ♦

♦ 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, Assistant Editor
American Welding Society
550 N.W. LeJeune Rd.
Miami, FL 33126
Telephone, (305) 443-9353 ext. 244,
FAX: (305) 443-7404
e-mail: *campbell@ aws.org* ♦

SAFETY AND HEALTH

T O P I C S

♦ Style Guidelines for Safety and Health Documents Fact Sheet No. 15

Introduction

Style for welding and cutting documents means three things: matter and manner; form and content; style and format. Style refers not only to what is said but also how it is stated and presented to the reader.

Early Style Methods and Features

The style and format for welding and cutting documents have evolved with time. Ten or fifteen years ago, documents contained the following features:

♦ Commands or directives telling what to do without explaining the consequences of not doing it.

♦ Frequent use of the passive voice rather than the active voice.

♦ Use of underling for emphasis.

Early Style Methods and Features

♦ "A check-off list should be used by the welding operator."

♦ "Proper quality control procedures should be used."

Reasons For Not Using the Early Style

The AWS Safety and Health Committee recommends the early method not be used for the following reasons:

♦ The older style of writing does not give or imply the consequences of the failure to act as directed.

♦ The older style does not tell how to avoid the consequences when it is possible to do so.

Current Style Methods and Features

Currently, it is recommended documents state the hazards and include the consequences, as well as how to avoid them. The stylistic features are as follows:

♦ Use the active voice.

♦ Use strong, clear, action verbs in the imperative mood.

♦ Use short, direct sentences.

Use of Precautionary Labeling

Signal Words

There are three signal words used to identify the levels of hazard in ANSI Z535.4 — DANGER, WARNING and CAUTION. Wherever possible, reserve these words for use on labels only. Avoid the use of signal words in prose. Use the word "precautionary" instead of signal words for text.

Current Style Examples

♦ "Use a checklist. Do not skip any items. Omitting steps can cause personal injury or equipment damage."

♦ "Use proper quality control procedures to meet intended performance requirements and to minimize costs."

Background of Current Style

The current writing style evolves from precautionary labeling practices and arises from the obligation standards and codes have to users, as well as from an industry-wide concern for the well being of its customers. The writing method needs to **warn and instruct** the reader about the **normal use and reasonably foreseeable misuse and abuse** of a product or process as is used in current precautionary labeling practices. The instruction literature that accompanies a product or process is considered as part of that practice.

♦ The **warn** part of the requirement is met by a statement of the hazard and consequences of the failure to act as specified.

♦ The **instruct** part of the requirement is met by explaining how to avoid the hazard and consequences.

♦ It is not mandatory to have a particular order to the statements. It can be **warn and instruct** or **instruct and warn.** Either sequence is satisfactory, though **warn and instruct** is preferred.

♦ This order preference is based on current precautionary labeling practices that warn first and instruct second.

SAFETY AND HEALTH

T O P I C S

♦ For all safety and health information published by the American Welding Socicty, try to follow the **warn and instruct** requirements for the **normal use** as well as for the foresecable **misuse and abuse** of the product or process.

Format Suggestions

Several formats satisfy these requirements. The two most popular are the following:

♦ Put all information in one or two sentences.

♦ Use an entry statement containing the warning (statement of hazard and its consequences) followed by a list of simple instructions telling how to avoid the hazard, such as the following typical example from NEMA EW 6:

WARNING: ELECTRIC SHOCK can kill; FUMES AND GASES can be hazardous; ARC RAYS can injure eyes and burn skin.

♦ Do not touch live electrical parts.

♦ Keep your head out of the fumes.

♦ Wear dry insulating gloves and clothing.

♦ Use enough ventilation or exhaust at the arc to keep fumes and gases from your breathing zone and the general area.

♦ Wear correct eye, ear and body protection.

♦ Read and follow the manufacturer's instructions, employer's safety practices and Material Safety Data Sheets (MSDSs).

Features of the Current Method

♦ Use simple, clear, precise words.

♦ Use the active voice instead of the passive voice in sentence structure.

♦ Use the imperative mood of the verbs to give commands or directives.

Summary

Remember the primary purpose of any instructions, but especially those containing safcty or health information.

♦ Quickly get to the point to keep the reader's attention and save time.

♦ Be clear, direct and simple in communicating all the reader needs to know.

♦ Use easy-to-read short lists to follow the preferred method.

Information Sources

National Electrical Manufacturer's Association. *Guidelines For Precautionary Labeling for Arc Welding and Cutting Products*, EW 6. National Electrical Manufacturers' Association, Washington, D.C.

National Electrical Manufacturers' Association. *Manual for NEMA Standards Publications*, NEMA NS 1-1983. National Electrical Manufacturers' Association, Washington, D.C.

American National Standards Institute (ANSI). *Style Manual for Preparation of Proposed American National Standards*, ANSI X3/90-1887 X, S, M,T. Available from American National Standards Institute, 11 West 42nd St., New York, NY 10036.

American National Standards Institute (ANSI). *Product Safety Signs and Labels*, ANSI Z535.4. Available from American National Standards Institute, 11 West 42nd St., New York, NY 10036. ♦

The Safety and Health Fact Sheets, *2nd ed., cover all aspects of safety and health applicable to welding and cutting. The* Fact Sheets *include 20 pages on subjects such as fumes and gases, radiation, noise and electrical hazards. Compiled in 1998. Price for AWS members is $24; nonmembers, $32. Copies of* Safety and Health Fact Sheets *can be ordered by calling AWS Customer Service at (800) 334-9353, or (305) 443-9353 ext. 280 outside the United States, Monday through Friday, 8 a.m. to 5 p.m. Eastern Standard Time.*

♦1999 District and Section Awards

The following AWS members have been presented with either their Section or District Meritorious Awards for 1999.

♦1999 District Meritorious Award

District 21	Nanette Samanich
District 21	Michael Sullivan

♦1999 Section Meritorious Award

Pat Bumcrott	Long Beach/Orangc County
Stan Louis	California Central Coast

♦ Youths from Ghana Dream of a Welding Club

Recently, American Welding Society (AWS) President Robert Teuscher received a letter from three youths from Ghana expressing their dream of forming a welding club for young Africans. American Welding Society member Eric S. Boateng and aspiring members Lewis T. Ohemeng and Christian Hammond wrote the letter outlining their plans for the American-African Youth Welding Club (AAYWC). They wrote of the tremendous wealth of talent, intelligence and optimism about welding they have seen in the youth in Africa, and they wrote of the lack of basic necessities such as training and information. They hope to fill this gap through the implementation of the AAYWC.

The purpose of the AAYWC would be to share ideas, learn and explore the many opportunities in the field of welding. It would also provide students with a platform to meet and interact with welding professionals, thus seeing firsthand that a career in welding can provide good pay and benefits to those who are willing to work hard and learn the art of welding.

The organizers are basing the club on the principles of education, access to information and the latest technology, exchange programs and training.

To meet these goals, the trio foresees conferences, lectures, seminars, conventions and expositions hosted abroad and locally for the youth. They would also like to see an exchange program developed between the AAYWC and AWS student chapters. This would give members of both organizations the opportunity to not only share information about welding but to also learn about each other's culture and lifestyle. Their hope is to set up a host family program in both countries so students could choose to stay for months with one family or travel the country, moving from one host family to another.

Ohemeng, Hammond and Boateng said education and training will be the top priority of the AAYWC. They hope to establish a bond with AWS Student Chapters to encourage the sharing of ideas and interests between students and to present welding as a viable career. The three also hope the AAYWC will be able to provide financial support for the continuing education and training of its members.

Organizers of the American Youth Welding Club are, from left, Lewis T. Ohemeng, Christian Hammond and Eric S. Boateng. Boateng is also a member of the American Welding Society.

Ohemeng, Hammond and Boateng feel African youths are an ambitious and exuberant group who are eager to learn the art of welding but lack access to information and financial support. They feel there is an urgent need for the AAYWC to foster friendship and interaction between the United States and Africa to discuss the challenges and prospects in welding for the next generation.

Anyone interested in helping to sponsor the American-African Youth Welding Club can contact Eric Sefa Boateng at P.O. Box 15862, Accra-North, Ghana, West Africa, or via e-mail at boatsefa@hotmail.com. ♦

♦ IACOM Members Meet in Dallas

Members of the Industry Action Committee (IACOM) leadership met in Dallas, Texas, on January 18. Attending the meeting were, counterclockwise, Douglas Beck; John Coffey; Secretary Chuck Fassinger, AWS associate executive director; Chair Ernest Levert, AWS vice president; Steve Bollhorst; Bryan George; and Vice Chair Lee Kvidahl, past AWS president.

♦ B2 Committee Holds Fall Meeting

Members of the B2 Procedure and Performance Qualification Committee met in Pittsburgh, Pa., September 26–28.

♦ AWS Official Honored by Lexington Who's Who Registry

The American Welding Society (AWS) announced Dr. Nelson Wall, AWS deputy executive director emeritus, has been named to the 1999/2000 edition of the Lexington *Who's Who Registry of Executives and Professionals*. The directory is dedicated to the recognition of individuals who have demonstrated outstanding leadership and achievement in their field and includes biographical information on executives and professionals from hundreds of occupations.

Nelson Wall

Originally from Cuba, Wall has been with the American Welding Society since 1981. Wall earned a bachelor of science degree in mechanical engineering from Georgia Tech University and a doctorate degree in political science from the University of Havana. In addition to his role at AWS, Dr. Wall is also an active member of the Pan American Coalition of Welding Institutions and the Pacific Ocean Coalition of Welding Associations, two not-for-profit organizations that provide a forum for international welding organizations. He also serves as secretary for the Federation of Materials Societies, a Washington, D.C., based coalition of research and education associations. ♦

♦ CAN WE TALK?

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

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♦ Rybicki to Chair C2 Committee on Thermal Spraying

Edmund F. Rybicki

Edmund F. Rybicki has been selected to chair the American Welding Society's C2 Committee on Thermal Spraying.

Rybicki is professor and chair of the Mechanical Engineering Faculty at the University of Tulsa. Before joining the University of Tulsa, he worked at Battelle Columbus Laboratories for eleven years, rising to manager of the Residual Stress Projects Office. While at Battelle, his work was in the area of finite element analysis to predict and control residual stresses in welded pipes and pressure vessels.

Rybicki's work on residual stresses continues at the University of Tulsa. He and his coworkers developed methods for the experimental evaluation of residual stresses in thermal spray coatings, thermal barrier coatings, welds and weld cladding.

Other areas of Rybicki's work include controlling residual stresses to improve fatigue life of thermal spray coatings, evaluating thermal spray coatings to replace chrome plating, the effects of residual stresses on the bond strength for thermal spray coatings and debonding of composite materials.

Professor Rybicki has authored or coauthored 71 papers in refereed journals, 115 papers in conference proceedings and 193 talks at technical meetings. The results of his welding residual stress work have been used by the U.S. Army, U.S. Navy, the electric power generating industry and the automotive industry. He is a coauthor of seven papers that received awards from international conferences and journals. One award is the A. F. Davis Silver Medal Award from the American Welding Society for a paper published in the *Welding Journal* in 1993. He is a registered professional engineer, has one patent, is a Distinguished Member of AWS and is a Fellow in the American Society of Mechanical Engineers. ♦

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 N.W. LeJeune Rd., Miami, Fl. 33126, telephone (305) 443-9353.

April 24, C7B Subcommittee on Electron Beam Welding and Cutting. Chicago, Ill. Standards preparation meeting. Staff contact: E. F. Mitchell.

April 24, C7C Subcommittee on Laser Beam Welding and Cutting. Chicago, Ill. Standards preparation meeting. Staff contact: E. F. Mitchell.

April 24, D10 Committee on Piping and Tubing. Chicago, Ill. Standards preparation meeting. Staff contact: T. R. Potter.

April 25, A1 Committee on Metric Practice. Chicago, Ill. Standards preparation meeting. Staff contact: J. L. Gayler.

April 25, C2 Committee on Thermal Spraying. Chicago, Ill. General meeting. Staff contact: E. F. Mitchell.

April 25, C2A Subcommittee on Machine Element Repair and Restoration. Chicago, Ill. Standards preparation meeting. Staff contact: E. F. Mitchell.

April 25, C2B SSPC/NACE/AWS Tri-Society Thermal Spray Committee on the Corrosion Protection of Steel. Chicago, Ill. Standards preparation meeting. Staff contact: E. F. Mitchell.

April 25, C2F Subcommittee on Thermal Spray Operator Qualification. Chicago, Ill. Standards preparation meeting. Staff contact: E. F. Mitchell.

April 25, C5I Subcommittee on Plasma Arc Welding. Chicago, Ill. Standards preparation meeting. Staff contact: M. O. Kulp.

April 25, C5J Subcommittee on Plasma Arc Cutting. Chicago, Ill. Standards preparation meeting. Staff contact: M. O. Kulp.

April 25, C7 Committee on High Energy Beam Welding and Cutting. Chicago, Ill. General meeting. Staff contact: E. F. Mitchell.

April 25, D10 Committee on Piping and Tubing. Chicago, Ill. Standards preparation meeting. Staff contact: T. R. Potter.

April 25, D14A Subcommittee on Industrial and Mill Cranes. Chicago, Ill. Standards preparation meeting. Staff contact: M. O. Kulp.

April 25, D14C Subcommittee on Earthmoving and Construction Equipment. Chicago, Ill. Standards preparation meeting. Staff contact: M. O. Kulp.

April 25, D14E Subcommittee on Welding of Presses. Chicago, Ill. Standards preparation meeting. Staff contact: M. O. Kulp.

April 25, D17D Subcommittee on Resistance Welding. Chicago, Ill. Standards preparation meeting. Staff contact: E. F. Mitchell.

April 25, D18 Committee on Welding and Sanitary Applications. Chicago, Ill. Standards preparation meeting. Staff contact: L. P. Connor.

April 25, D1BA Subcommittee on Qualification. Chicago, Ill. Standards preparation meeting. Staff contact: L. P. Connor.

April 25, G2E Subcommittee on Stainless Steel Alloys. Chicago, Ill. Standards preparation meeting. Staff contact: T. R. Potter.

April 26, A5C Subcommittee on Aluminum Alloy Filler Metals. Chicago, Ill. General meeting. Staff contact: R. K. Gupta.

April 26, A5U Subcommittee on Surfacing Materials for Thermal Spraying. Chicago, Ill. Standards preparation meeting. Staff contact: R. K. Gupta.

April 26, A10 Committee on Instrumentation for Welding. Chicago, Ill. General meeting. Staff contact: C. B. Pollock.

April 26, B1 Committee on Methods of Inspection. Chicago, Ill. Standards preparation meeting. Staff contact: L. P. Connor.

April 26, C1 Committee on Resistance Welding. Chicago, Ill. General meeting. Staff contact: E. F. Mitchell.

April 26, C4 Committee on Oxyfuel Gas Welding and Cutting. Chicago, Ill. General meeting. Staff contact: M. O. Kulp.

April 26, C6 Committee on Friction Welding. Chicago, Ill. Standards preparation meeting. Staff contact: T. R. Potter.

April 26, D9 Committee on the Welding, Brazing and Soldering of Sheet Metal. Chicago, Ill. Standards preparation meeting. Staff contact: J. L. Gayler.

April 26, D11 Committee on Welding Iron Castings. Chicago, Ill. General meeting. Staff contact: M. O. Kulp.

April 26, D14 Committee on Machinery and Equipment. Chicago, Ill. General meeting. Staff contact: M. O. Kulp.

April 26, D14B Subcommittee on General Design and Practices. Chicago, Ill. Standards preparation meeting. Staff contact: M. O. Kulp.

April 26, D17D Subcommittee on Resistance Welding. Chicago, Ill. Standards preparation meeting. Staff contact: E. F. Mitchell.

April 26, D17J Subcommittee on Friction Stir Welding. Chicago, Ill. Standards preparation meeting. Staff contact: E. F. Mitchell.

April 26, D17X D17 Executive Subcommittee. Chicago, Ill. General meeting. Staff contact: E. F. Mitchell.

April 26, G2C Subcommittee on Nickel Alloys. Chicago, Ill. Standards preparation meeting. Staff contact: T. R. Potter.

— continued on next page

♦ Award Pins Available for Technical Committee Volunteers

Service pins for Technical Committee volunteers and Technical Activities Committee members are available from the American Welding Society.

Three pins are offered, one each for 10, 20 or 30 years of service. The service does not have to be continuous, but simultaneous service on two committees does not count double. Thus, 5 years on a Technical Committee concurrent with 5 years on the Technical Activities Committee only counts for 5 years.

If you believe you are eligible for a service award pin, please list your committees and the calendar years of service and send it to Leonard P. Connor, Technical Services Division, American Welding Society, 550 N.W. LeJeune Rd., Miami, FL 33126. ♦

♦ Members Needed for AWS Committee on Instrumentation

The American Welding Society is looking for volunteers to serve on the newly formed Committee on Instrumentation for Welding.

The Committee will develop standards on instrumentation of welding equipment as well as measurement and data collection techniques for all welding processes. Its first efforts will include current and force standards and data collection and storage techniques for resistance welding. The first meeting of the committee will take place April 26 during the AWS Convention and Exposition in Chicago.

If you are interested in participating in this work, please contact A10 Committee Secretary Chris Pollock at (800) 443-9353 ext. 304. ♦

♦ B5 Committee Members Wanted

The American Welding Society is looking for volunteers to serve on some of its volunteer committees. The subcommittees of the B5 Qualification Committee develop qualification standards for welding personnel and welding facilities. At this time, the following subcommittees are looking for individuals in the welding industry or academia who are interested in contributing to setting standards: B5B, Subcommittee on Welding Inspector Specialists; B5G, Subcommittee on Welding Fabricators; B5H, Subcommittee on Underwater Welding Inspectors; B5I, Subcommittee on Welding Supervisors; B5J, Subcommittee on Welder Test Facilities; B5K, Subcommittee on NDE Personnel; and B5N, Subcommittee on Welding Salespersons. Please call John Gayler at (800) 443-9353 ext. 472 to request a committee application. ♦

♦ D17J Subcommittee Members Wanted

The American Welding Society's D17 Committee on Welding in the Aircraft and Aerospace Industries has formed a new subcommittee. The D17J Subcommittee (Friction Stir Welding for Aircraft and Aerospace Applications) is looking for volunteers. The charter of this subcommittee is to produce one or more standards for recommended practices for aircraft and aerospace friction stir welding applications.

Doug Waldron of the Boeing Co., chairman of the D17J Subcommittee, can be reached at (714) 896-5313. Vice Chairman Jeff Ding of NASA can be reached at (256) 544-2700. To request a committee application, please call Ed Mitchell, AWS, at (800) 443-9353 ext. 254. The next meeting is scheduled for October 28–29 at NASA's Kennedy Space Center. ♦

TECHNICAL COMMITTEE MEETINGS

—continued from page 219

April 27, B1 Committee on Methods of Inspection. Chicago, Ill. Standards preparation meeting. Staff contact: L. P. Connor.

April 27, C5 Committee on Arc Welding and Cutting. Chicago, Ill. General meeting. Staff contact: M. O. Kulp.

April 27, C5C Subcommittee on Gas Tungsten Arc Welding. Chicago, Ill. Standards preparation meeting. Staff contact: M. O. Kulp.

April 27, C5O Subcommittee on Shielding Gases. Chicago, Ill. Standards preparation meeting. Staff contact: M. O. Kulp.

April 27, D14G Subcommittee on Welding of Rotating Equipment. Chicago, Ill. Standards preparation meeting. Staff contact: M. O. Kulp.

April 26, D16 Committee on Robotic and Automatic Welding. Chicago, Ill. Standards preparation meeting. Staff contact: T. R. Potter.

April 27, D17 Committee on Welding in the Aircraft and Aerospace Industries. Chicago, Ill. Standards preparation and general meeting. Staff contact: E. F. Mitchell.

April 27, G2 Committee nn Joining Metals and Alloys. Chicago, Ill. General meeting. Staff contact: T. R. Potter.

April 27, G2D Subcommittee on Reactive Alloys. Chicago, Ill. General meeting. Staff contact: T. R. Potter.

April 28, D17 Committee on Welding in the Aircraft and Aerospace Industries. Chicago, Ill. Standards preparation and general meeting. Staff contact: E. F. Mitchell.

Notes: A "standards preparation" meeting's primary purpose is to work on a specific document. A "general meeting" means no work is contemplated on a specific standard. The committee's standards may be reviewed or discussed, but no formal action is expected.

STANDARD

N O T I C E S

AWS was approved as an accredited standards-preparing organization by the American National Standards Institute (ANSI) in 1979. AWS rules, as approved by ANSI, require that all standards be open to public review for comment during the approval process. This column also advises of ANSI approval of documents. The following standards are submitted for public review. A copy may be obtained by sending the amount shown to AWS Technical Dept., 550 N.W. Lejeune Rd., Miami, FL 33126, or by calling (800) 334-9353.

Revised Standards Approved by ANSI:

B4.0M:200X, *Standard Methods for Mechanical Testing of Welds*. Revised standard. $29.95. [ANSI Public Review expires April 25.]

G1.10M:200X, *Guide for the Evaluation of Hot Gas, Hot Gas Extrusion, and Heated Tool Butt Thermoplastic Welds*. New standard. $9.00. [ANSI Public Review expires May 9.]

ISO Standards for Public Review

ISO/DIS 544, *Welding Consumables — Technical Delivery Conditions for Welding Filler Metals — Type of Product, Dimensions, Tolerance and Markings*. Standard. $2.75. [ANSI Public Review expires April 31.]

ISO/DIS 5817, *Welding-Fusion-Welded Joints in Steel, Nickel, Titanium and Their Alloys (Beam Welding Excluded) — Quality Levels for Imperfections*. Standard. $5.25. [ANSI Public Review expires May 31.]

New Standards Approved by ANSI:

B2.1-4-217:1999, *Standard Welding Procedure Specification (WPS) for Gas Tungsten Arc Welding of Chromium-Molybdenum Steel (M-4/P-4, Group 1 or 2), ER80S-B2, ⅛ through ½ in. Thick, As-Welded Condition, ⅛ through ¼ in. Thick, PWHT Condition, Primarily Pipe Applications*. Approval date: December 8, 1999.

B2.1-4-218:1999, *Standard Welding Procedure Specification (WPS) for Shielded Metal Arc Welding of Chromium-Molybdenum Steel (M-4/P-4, Group 1 or 2), E8018-B2, ⅛ through ½ in. Thick, As-Welded Condition, ⅛ through 1½ in. Thick, PWHT Condition, Primarily Pipe Applications*. Approval date: December 8, 1999.

B2.1-4-219:1999, *Standard Welding Procedure Specification (WPS) for Gas Tungsten Arc Welding Followed by Shielded Metal Arc Welding of Chromium-Molybdenum Steel (M-4/P-4, Group 1 or 2), ⅛ through ½ in. Thick, As-Welded Condition, ⅛ through 1½ in. Thick, PWHT Condition, ER80S-B2 and E8018-B2, Primarily Pipe Applications*. Approval date: December 8, 1999.

B2.1-4-220:1999, *Standard Welding Procedure Specification (WPS) for Gas Tungsten Arc Welding (Consumable Insert Root) of Chromium-Molybdenum Steel (M-4/P-4, Group 1 or 2), E8018-B2, ⅛ through ½ in. Thick, As-Welded Condition, ⅛ through ¼ in. Thick, PWHT Condition, IN515 and ER80S-B2, Primarily Pipe Applications*. Approval date: December 8, 1999.

B2.1-4-221:1999, *Standard Welding Procedure Specification (WPS) for Gas Tungsten Arc Welding (Consumable Insert Root) Followed by Shielded Metal Arc Welding of Chromium-Molybdenum Steel (M-4/P-4, Group 1 or 2), ⅛ through ½ in. Thick, As-Welded Condition, ⅛ through 1½ in. Thick, PWHT Condition, IN515, ER80S-B2 and E8018-B2, Primarily Pipe Applications*. Approval date: December 8, 1999.

B2.1-5A-222:1999, *Standard Welding Procedure Specification (WPS) for Gas Tungsten Arc Welding of Chromium-Molybdenum Steel (M-5A/P-5A), ER90S-B3, ⅛ through ½ in. Thick, As-Welded Condition, ⅛ through ¼ in. Thick, PWHT Condition, Primarily Pipe Applications*. Approval date: December 8, 1999.

B2.1-5A-223:1999, *Standard Welding Procedure Specification (WPS) for Shielded Metal Arc Welding of Chromium-Molybdenum Steel (M-5A/P-5A), E9018-B3, ⅛ through ½ in. Thick, As-Welded Condition, ⅛ through 1½ in. Thick, PWHT Condition, Primarily Pipe Applications*. Approval date: December 8, 1999.

B2.1-5A-224:1999, *Standard Welding Procedure Specification (WPS) for Gas Tungsten Arc Welding Followed by Shielded Metal Arc Welding of Chromium-Molybdenum Steel (M-5A/P-5A), ⅛ through ½ in. Thick, As-Welded Condition, ⅛ through 1½ in. Thick, PWHT Condition, ER90S-B3 and E9018-B3, Primarily Pipe Applications*. Approval date: December 8, 1999.

B2.1-5A-225:1999, *Standard Welding Procedure Specification (WPS) for Gas Tungsten Arc Welding (Consumable Insert Root) of Chromium-Molybdenum Steel (M-5A/P-5A), ⅛ through ½ in. Thick, As-Welded Condition, ⅛ through ¼ in. Thick, PWHT Condition, IN521 and ER90X-B3, Primarily Pipe Applications*. Approval date: December 8, 1999.

B2.1-5A-226:1999, *Standard Welding Procedure Specification (WPS) for Gas Tungsten Arc Welding (Consumable Insert Root) Followed by Shielded Metal Arc Welding of Chromium-Molybdenum Steel (M-5A/P-5A), ⅛ through ½ in. Thick, As-Welded Condition, ⅛ through 1½ in. Thick, PWHT Condition, IN521, ER90S-B3, and E9018-B3, Primarily Pipe Applications*. Approval date: December 8, 1999.

C1.1M/C1.1:2000, *Recommended Practices for Resistance Welding*. Approval date: January 31, 2000.

C4.5M:2000, *Uniform Designation System for Oxyfuel Nozzles*. Approval date: February 2, 2000.

SECTION NEWS

Instructor Jack Paige, right, awarding the AWS Boston Section's $500 scholarship to student Brian Hemingway.

Guest speaker Frank G. Armao, left, with New Jersey Section member Bob Bartley.

Guest speaker Tom Pumphrey, right, with Lincoln Electric colleague Seann Bradley at the Long Island Section's February meeting.

Gloucester Co. Vo-Tech welding instructor Dan Roskiewich, right, with some of his students at the Philadelphia Section's February meeting.

Guest speaker Dennis Klingman, center, Bayard DeMaillie, left, and Seann Bradley, all from The Lincoln Electric Co., at the Long Island Section's January meeting

DISTRICT 1

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

♦ BOSTON
JANUARY 10
Speakers: **Brian Sullivan**, district manager, and **Brendan McLellan**, sales representative.
Affiliation: The Lincoln Electric Co.
Topic: GMAW waveforms and their practical applications.
Activities: Members participated in demonstrations of a surface tension transfer system, pulsed spray arc system and wave designer software. Brian Hemingway was awarded a $500 scholarship.

DISTRICT 2

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

♦ LONG ISLAND
JANUARY 13
Speaker: **Dennis Klingman**, director of technical training.
Affiliation: The Lincoln Electric Co., Cleveland, Ohio.
Topic: Welding in the motor sports industry.

FEBRUARY 10
Speaker: **Tom Pumphrey**.
Affiliation: The Lincoln Electric Co.
Topic: Fume extraction equipment.

♦ PHILADELPHIA
FEBRUARY 7
Speaker: **Pat Belsole**.
Affiliation: Hypertherm.
Topic: Plasma arc cutting

♦ NEW JERSEY
FEBRUARY 15
Speaker: **Frank G. Armao**, sr. application engineer.
Affiliation: The Lincoln Electric Co.
Topic: Aluminum fabrication and welding; GTAW and GMAW alloys and how they differ; CV vs. CC vs. pulsed GMAW properties of aluminum and how they affect welding; and controlling the output wave shape.
Activity: This was a joint meeting with ASM International.

Southwest Virginia Section Chairman Claude Holcomb, left, with Tower Automotive production supervisor Mike Grimm at the Section's January tour.

DISTRICT 3

Director: Claudia B. Kaufman
Phone: (717) 252-9787

♦ YORK-CENTRAL PENNSYLVANIA
JANUARY 6
Speaker: **Shirley Bollinger**, past president.
Affiliation: American Welding Society, Miami, Fla.
Topic: Experiences as an AWS president, and what the future holds for AWS
Activity: Plaques and certificates were awarded to Past Section Chairmen for years of service.

DISTRICT 4

Director: Roy C. Lanier
Phone: (919) 321-4285

♦ SOUTHWEST VIRGINIA
JANUARY 19
Activity: The Section toured the Tower Automotive plant in Roanoke, Va.

FEBRUARY 16
Activities: The Section visited the Volvo Trucks, N. A., facility in Dublin, Va. District 4 Director **Roy Lanier** presented a plaque of appreciation to Chairman **Claude Holcomb.**

DISTRICT 5

Director: Boris A. Bernstein
Phone: (787) 883-8383

♦ SOUTH FLORIDA
FEBRUARY 3
Speakers: **David J. Landon**, corporate welding engineer.
Affiliation: Vermeer Manufacturing.
Topic: Vermeer's welder training program and the company's product line.

Florida West Coast Chairman Al Sedory, right, presenting a speaker's award to Ed Beck.

Florida West Coast Chairman Al Sedory, left, presenting a speaker's award to David Sprenkel.

♦ FLORIDA WEST COAST
DECEMBER 8, 1999
Speaker: **Carl Miller**, account manager.
Affiliation: FANUC Robotics, Suwanee, Ga.
Topic: An overview of welding work cells and part positioners.
Activity: **Walt Arnold** was presented with the District and Section Meritorious Awards. **Dan Gordon** received the District and Section CWI of the Year Awards.

JANUARY 12
Speaker: **Ed Beck**.
Affiliation: LAW Engineering.
Topic: How to achieve the specified quality of welding.

FEBRUARY 9
Speaker: **David Sprenkel**, manager.
Affiliation: ITW Hobart Brothers.
Topic: Metal cored electrodes.

♦ SOUTH CAROLINA
JANUARY 20
Activity: The Section held its annual

Southwest Virginia Section Chairman Claude Holcomb, left, receiving a plaque of appreciation from District 4 Director Roy Lanier.

Florida West Coast chairman Al Sedory, right, congratulating Walt Arnold on receiving the District and Section Meritorious Awards.

Weld-A-Rama with new product displays and demonstrations at Trident Technical College.

DISTRICT 6

Director: Gerald R. Crawmer
Phone: (518) 385-0570

♦ NIAGARA FRONTIER
JANUARY 13
Activity: The Section held a Cut the Rail Contest. Many students from the BOCES welding class were present to try to win a cutting outfit. **Bill Hanly** won first place with a time of 52 s. The Section provided pizza and soft drinks for all attending the contest.

♦ OLEAN-BRADFORD
JANUARY 18
Speaker: **Steve Mazur.**
Affiliation: Cooperheat.
Topic: Local stress relief.

DISTRICT 7

Director: Larry C. Heckendorn
Phone: (614) 457-2640

South Carolina Section First Vice Chairman Tom Huckabee, left, and Chairman Bill Lindsey at the Section's annual Weld-A-Rama.

Olean-Bradford Section Chairman Rich DePue, right, with guest speaker Steve Mazur, center, and Jim Carturight.

Chattanooga Section Chairman L. Richard Daffron, left, thanking guest speaker Wayne Turner.

Ladies from the Nashville Section at the Holiday Party/Ladies' Night function, where they were each presented with a crystal Christmas bell.

Raffle winner Daryl Steiner, left, accepting his new welding machine from Mobile Section Chairman Mike Barnett.

DISTRICT 8

Director: Harrell E. Bennett
Phone: (423) 478-3624

♦ NASHVILLE
DECEMBER 18, 1999
Activities: The Section held its Annual Holiday Party/Ladies' Night. A special award was presented to Past Chairman Roy Petty, and Christmas bells were presented to all women attending the event.

♦ MEMPHIS
JANUARY 6
Speaker: **Craig Humphreys**, sales representative.
Affiliations: Hypertherm.
Topic: Plasma cutting techniques.

♦ CHATTANOOGA
JANUARY 20
Speaker: **Wayne Turner**, quality engineer.
Affiliation: ABB Combustion.
Topic: Weld power supply maintenance.

♦ NORTHEAST MISSISSIPPI
JANUARY 20
Activities: The Section toured the Flexsteel plant in Starkville, Miss. The Section's Nominating Committee was selected for next year.

DISTRICT 9

Director: O.J. Templet
Phone: (225) 343-4806

♦ MOBILE
NOVEMBER 18, 1999
Activity: The Section held its scholarship drawing. The Lincoln Electric Co. and Miller Electric Mfg. Co. each donated a welding machine for the raffle. All proceeds went to the Section Scholarship Fund. **Daryl Steiner** won the Miller equipment and **Larry Martin** received the Lincoln equipment.

JANUARY 20
Speaker: **William B. "Bill" Smith III**, vice president/director of technical services.
Affiliation: IPSCO Steel, Axis, Ala.
Topic: New IPSCO Steel mini-mill under construction in the Mobile area.

♦ NEW ORLEANS
JANUARY 18
Speaker: **Jeremy Barr**.
Affiliation: Air Liquide America Corp.
Topic: Benefits of the AWS scholarships.

DISTRICT 10

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

♦ CLEVELAND
NOVEMBER 9, 1999
Speaker: **Chip Rathwell**.
Affiliation: Lorain County Community College
Activity: The Section toured the Stockie Humanities and Fine Arts Center where there was an exhibition of welded art.

JANUARY 11
Activity: The Section toured The Lincoln Electric Co. plant to see new technologies in aluminum welding, plasma cutting, GTA and GMA welding.

1999-2000 AWS Millennium Membership Campaign

AWS is currently 54,000 members strong. Imagine how much stronger we would be if each of our members took just a few minutes to encourage one of their colleagues to join AWS. We could potentially boast a membership of nearly 108,000 – making us one of the largest associations in the world...and giving us the resources necessary to expand your benefits as an AWS Member. Plus, in appreciation of your instrumental role in helping us increase our membership base, you will receive a variety of awards and prizes for your involvement. The more members you sponsor, the more rewards you receive.

We've worked out a "Big Ten" list of reasons our members think AWS is the resource for staying on top of today's fabricating industry. You already know what AWS does for you. Why not take a moment or two to point out some of these reasons to one of your co-workers?

Top Ten Reasons to be an AWS Member:

1. The prestige of being an AWS member is knowing that you belong to the premier society for materials joining professionals.
2. To build your network of peers and professionals by attending local Section meetings and utilizing the AWS bulletin board.
3. Because the *Welding Journal* provides invaluable information through informative articles, charts, graphs, and pictorials.
4. To receive a substantial 25% discount on all AWS publications and deep discounts on training events.
5. Because learning opportunities through our AWS seminars and conferences allow you to make important contacts and increase knowledge.
6. To advance your career using Résumé–*Link*, AWS' exclusive résumé referral service.
7. To gain access to technical knowledge with 200+ publications available.
8. For discounts on travel accommodations, insurance and more.
9. To strengthen your leadership skills by serving as a Section officer or committee member.
10. To encourage the next generation with AWS scholarships through the AWS Foundation and discounted student memberships.

PRIZE CATEGORIES

President's Honor Roll:
Recruit 1-5 regular new members and receive an AWS Key Chain and 25 AWS Dollars.

President's Club:
Recruit 6-10 regular new members and receive American Welder™ Gear engraved crystal mug and 50 AWS Dollars.

President's Roundtable:
Recruit 11-19 regular new members and receive an AWS T-shirt and 100 AWS Dollars.

President's Guild:
Recruit 20 or more regular new members and receive "Shelton Ritter Member Proposer Award" certificate plaque, one year free membership, 250 AWS Dollars and membership in the Winner's Circle.

Winner's Circle:
All members who recruit 20 or more new members will be honored with a profile in the *Welding Journal*, a spotlight at the annual Awards Ceremony and recognition in the AWS Membership booth at the AWS Expo.

SPECIAL PRIZES

Participants will also be eligible to win prizes in specialized categories. Prizes will be awarded at the close of the Millennium Campaign.

Sponsor of the Year:
The individual who sponsors the greatest number of new, full members during the campaign will receive a plaque, an all-expense-paid trip for two to the 2001 AWS Expo in Cleveland, a free membership renewal and recognition at the Awards Luncheon at the Exposition.

Student Sponsor Prize:
Student members who sponsor two or more new student members will receive an AWS T-shirt. The AWS member who sponsors the most student members will receive a free one-year AWS membership and 100 AWS Dollars.

International Sponsor Prize:
Each member residing outside of the United States, Canada and Mexico sponsoring at least one new member receives a complimentary AWS membership renewal and 100 AWS Dollars.

LUCK OF THE DRAW

For every new member you sponsor, your name is entered into a quarterly drawing. The more new members you sponsor, the greater your chances of winning. Prizes will be awarded in August and November 1999, as well as in February and June 2000.

Prizes Include:

- Swiss Army Knife
- 1-page, black/white ad in the *Welding Journal*
- Complimentary AWS membership renewal
- 100 AWS Dollars, good toward the future purchase of any AWS-produced offering such as a publication, conference, seminar, or certification exam.
- American Welder™ Gear
- AWS Key Chain

SUPER SECTION CHALLENGE

The Sections in each District that achieve the highest net percentage increase and the largest numerical increase (respectively) before the June 2000 deadline will each win a prize of 500 AWS Dollars.

American Welding Society
550 N.W. LeJeune Rd. • Miami, FL 33126
Visit our website http://www.aws.org

Mobile Section Chairman Johnny Dedeaux, right, presenting a speaker's plaque to Bill Smith.

New Orleans members during their January meeting.

Cleveland Section members admiring a welded sculpture during their November tour of the Stockie Humanities and Fine Arts Center.

FEBRUARY 8
Activities: The Section hosted a Q&A session. Panel members included **Dan Warde**, **Phil Goyetchie**, **Bob Gardner**, **Bob A. Liekandrovic** and **Mark Haynes**. District 10 Director **Vic Matthews** presented Section awards to **Bob Gardner** and **Tom Hunt**.

♦ MAHONING VALLEY
JANUARY 27
Activity: The Section held the year's first meeting of the officers and Exective Committee members to plan the remainder of the year.
Note: The Section would like to thank its 1999/2000 donors for their patronage. The donors are Brilex Industries, Inc.; Columbiana Boiler, Inc.; Girard Machine Co., Inc.; Lyco Manufacturing; Oliver Steel; Praxair; Roth Brothers; Steel Craft, Inc.; Cedar Steel; Fab Art; Liberty Fabricating and Steel; Northeast Fabricators, Inc.; O'Neal Steel; Rance Industries, Inc.; Specialty Fab; AGA Gas; and Uni-Fab Inc.

Cleveland Section Education Chairman Paul Null, left, discussing new welding techniques with an employee of The Lincoln Electric Co. during the Section's January tour.

♦ CENTRAL MICHIGAN
JANUARY 18
Speaker: **Steve Ivkovitch**, partner.
Affiliation: Impact Engineering, Inc., Jackson, Mich.
Topic: GMAW monitoring systems.

DISTRICT 11

Director: Scott C. Chapple
Phone: (913) 241-7242

♦ NORTHERN MICHIGAN
JANUARY 25
Speaker: **Donald E. Jenkins**, account manager, welding sales.
Affiliation: FANUC Robotics.
Topic: What's new in robotic welding and cutting.

♦ UPPER PENINSULA
OCTOBER 20, 1999
Activity: The Section toured the Dairy Equipment Co. (DEC) manufacturing plant. Twenty-one students from Madison Area Technical College attended.

FEBRUARY 8
Speaker: **Pat O'Hara**, campus dean.
Affiliation: Northeast Wisconsin Technical College.
Activity: The Section toured the college and Wisconsin Job Center during a joint meeting with the local International Maintenance Institute chapter.

Cleveland Section First Vice Chairman Richard Harris, left, with Past Chairman Jim Myers.

DISTRICT 12

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

♦ LAKESHORE
JANUARY 19
Speaker: **Phillip J. Fiedler**, systems control manager.
Affiliation: Genesis Systems.
Topic: Developments in information management for robotic welding systems.

DISTRICT 13

Director: J. L. Hunter
(309) 888-8956

♦ ILLINOIS VALLEY
JANUARY 27
Speaker: **Gary Klingel**, test and results engineer.
Affiliation: Illinois Power Generating Plant.
Activities: Awards were presented at dinner by District 13 Director

Lakeshore Section Chairman Lee Dahlen, right, thanking guest speaker Phillip Fiedler.

Tulsa Section member and welding instructor John Knapp,right, with Chad Barber, one of his students, who received a $500 scholarship from the Section.

Jesse Hunter to **Joe Piano**, **Bernard Piotrowski** and **Louis Galassi** (accepted by **Pat Galassi**) for their dedication to the Section. After dinner, members toured the Illinois Power Generating Plant, which is a fossil-fueled generating plant.

DISTRICT 14

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

♦MISSISSIPPI VALLEY
NOVEMBER 11, 1999
Speaker: **David Essig**.
Affiliation: AWS Mississippi Valley Section Chairman.
Activity: The results of a survey distributed at the October meeting were discussed. Dates for plant tours and speakers were arranged.

JANUARY 20
Speaker: **David Essig**.
Affiliation: AWS Mississippi Valley Section Chairman.
Activity: The agenda for the rest of the year was discussed. **Roger Guyer** was appointed acting vice chairman until June.

♦ST. LOUIS
JANUARY 20
Activity: The Section was hosted by

From left to right are, Manny Servantes, Tom Novak, Ben Thompson, Don Bego and Claude Cooper at the St. Louis Section's January plant tour.

Tulsa Section First Vice Chairman Shannon Fanning with John Allison, left, and Alex Thurocy, right, of the Tulsa Technology Center, Riverside Campus.

Chrysler and toured the Dodge four-door truck production line.

♦NORTHERN PLAINS
JANUARY 13
Speaker: **Lynn Mcad**, shielding gas specialist
Affiliation: Praxair, Fargo, N.D.
Topic: Shielding gas selection factors, influences on profitability, quality and fume generation.
Activity: Section Chairman **Tim Schwanz** presented the District Private Sector Educator Award to First Vice Chairman **Dave Lynnes**.

FEBRUARY 16
Speakers: **Gary Hart**, **Joe Lambrecht** and **Mark Salz**.
Affiliations: MG Industries, Thermal Dynamics and Miller Electric Mfg. Co.
Topic: A roundtable discussion of trends and issues concerning the welding industries, as well as new equipment.

DISTRICT 15

Director: J. D. Heikkinen
Phone: (218) 741-9693

Northern Plains First Vice Chairman David Lynnes gives a different shielding gas a try as Mick Tronson of Praxair observes.

East Texas Chairman Yoni Adonyi, right, with guest speaker John Barsom.

DISTRICT 16

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

♦NEBRASKA
JANUARY 20
Activity: Section members toured the Fort Calhoun Nuclear Power Station.

DISTRICT 17

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

♦TULSA
JANUARY 11
Activity: The Section held a regular monthly executive meeting. Chad Barber and Clay Simmons, both students at Tulsa Technical Center, Lemly Campus, were presented with $500 scholarships.

JANUARY 25
Speaker: **Alex Thurocy**, evening superintendent.

Houston Section Foundation Representative Angie Hill Price looks on as, from right, Second Vice Chairman Chris Bloch presents scholarships to Joel Schmitz and Jason Howell.

Posing with their awards at the San Antonio Section's February meeting are, from left, Peter Johnston, District 18 Director Jim Appledorn and Ramond Madrid.

Affiliation: Tulsa Technology Center, Riverside Campus (TTC-RC).
Topic: The Mission of TTC-RC
Activity: The Section toured the TTC-RC facilities.

♦EAST TEXAS
JANUARY 20
Speaker: **John Barsom**, research fellow (retired).
Affiliation: U.S. Steel, Pittsburgh, Pa.
Topic: Legal and ethical implications of weld failures.

DISTRICT 18

Director: J. M. Appledorn
Phone: (281) 847-9444

♦HOUSTON
JANUARY 19
Speaker: **Don Burgart**.
Affiliation: Ransome Co., Houston, Tex.
Topic: New developments in fixturing, positioning and automated welding applications.

FEBRUARY 16
Speaker: **Vic Lubieniecki**.
Affiliation: ArcSmith, Dallas, Tex.
Topic: Safe operation of oxyfuel equipment and regulators.

Houston Section Second Vice Chairman Chris Bloch, right, presents a speaker's gift to Vic Lubieniecki.

Southern Colorado Section guest speaker Myron Delgado demonstrating heating and cutting using alternative fuel gases.

Activity: The Section held Student's Night. Texas A&M mechanical engineering and welding students attended the meeting.

♦SABINE
JANUARY 20
Speaker: **Dennis Pearson**, vice president.
Affiliation: Car-Ber Testing, Sarnia, Ontario, Canada.
Topic: Hydrostatic Testing.
Activity: District 18 Director **Jim Appledorn** presented the District CWI of the Year Award to **Alton Wolf**. **James Amy** received the District Meritorious Award. **Morris Weeks** was honored with the District Educator Award.

FEBRUARY 17
Speaker: **David Walston**.
Affiliation: Occ-Med Systems, Beaumont, Tex.
Topic: Industrial terrorism.
Activity: Nominations for next year's officers and directors were announced.

♦SAN ANTONIO
FEBRUARY 10
Speaker: **James Appledorn**, District 18 Director.
Affiliation: AWS, and The Lincoln Electric Co.

District 18 Director Jim Appledorn, right, presenting the District Meritorious Award to James Amy of the Sabine Section.

Topic: A "virtual tour" of AWS headquarters, its departments and personnel, and the latest developments in GMAW utilizing the surface tension transfer process.
Activity: **Peter Johnston** was awarded with a 25-Year AWS Silver Certificate and **Ramond Madrid** received the CWI of the Year Award.

DISTRICT 19

Director: R. D. (Rich) Kellum
Phone: (541) 924-0188

♦OREGON
FEBRUARY 1
Speaker: **Frank Armao**.
Affiliation: The Lincoln Electric Co.
Topic: Fundamentals and recent developments in GMA welding aluminum.

DISTRICT 20

Director: Neil R. Kirsch
Phone: (970) 842-5695

♦SOUTHERN COLORADO
FEBRUARY 1
Speaker: **Myron Delgado**.
Affiliation: Harris Calorific.
Topic: Heating and cutting using alternative fuel gases.

DISTRICT 21

Director: F. R. Schneider
Phone: (619) 693-1657

San Francisco Chairman Mike Urioste, right, with guest speaker Brian Bay and Lisa Thomas at the Section's joint meeting with ASM International.

DISTRICT 22

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

♦ SAN FRANCISCO

JANUARY 12
Speaker: **Brian K. Bay**, asst. professor.
Affiliation: University of California - Davis, Department of Orthopedic Surgery.
Topic: Digital volume correlation.
Activity: This was a joint meeting with ASM International.

FEBRUARY 2
Speaker: **Andre M. Lopez**, structural welder, owner.
Affiliation: All Metals Welding, San Francisco, Calif.
Topic: FCAW using AWS A520: E71T-8.
Activity: Doug Williams received the CWI of the Year Award.

San Francisco guest speaker Andre M. Lopez demonstrates FCAW.

STUDENT ACTIVITIES

♦ MADISON-BELOIT

OCTOBER 20
Activity: Twenty-one students from the Madison Area Technical College toured the Dairy Equipment Co. plant. Dairy Equipment Co. is a manufacturer of stainless steel milking systems and tank coolers.

Student members from the Madison Area Technical College during a plant tour of the Dairy Equipment Co.

SECTION EVENTS

C A L E N D A R

♦ DELAWARE

All meetings are held the second Wednesday of each month.

APRIL 12
Speaker: **Richard Brennan.**
Topic: DOT and HAZMAT.
Location: McGlynn's Pub and Restaurant in People's Plaza, Glasgow, Del.

MAY 10
Activity: Student/Vendor Night and Welding Truck Competition at Delcastle Technical High School, Wilmington, Del.

♦ LONG ISLAND

Dinner meetings held at Antuns, 244 Old Country Rd., Hicksville, N.Y., telephone (516) 681-3300. A social hour with open bar and hors d'oeuvres begins at 6:00 p.m., dinner at 7:00 p.m. and the presentation at 8:00 p.m.

APRIL 13
Topic: Electric Boat.

MAY 11
Activity: Awards night.

♦ MOBILE

Meetings will be held on the third Thursday of each month from September through May. Unless otherwise noted, social hour begins at 6:00 p.m., dinner at 6:30 p.m. and the evening's speaker at 7:30 p.m.

APRIL 20
Activity: Plant tour.
Location: Bender Shipbuilding & Repair Co., Inc.

MAY 16
Activities: End-of-year activities. Election of officers, District Conference recap, presentation of Section scholarships and awards, recognition of past chairmen and special service members.

♦ NORTHEAST MISSISSIPPI

APRIL 2
Activity: The dinner meeting will be at Lake Tia 'O' Khata, Louisville, Miss., followed by a tour of the Taylor Machine facility.

MAY 12
Activity: The Section will hold its dinner meeting at Bill & Jim's in Aberdeen, Miss. It will be Ladies' Night and Officer Installation Night.

♦ SANTA CLARA VALLEY

Unless otherwise noted, sign-in for the meetings is 6:30 to 7:00 p.m., dinner follows at 7:00 to 8:00 p.m. and the evening's presentation is from 8:00 to 9:00 p.m. at Harry's Hofbrau in San Jose.

APRIL 11
Speaker: **Barry Goodacre.**
Topic: United Airlines.
Location: High-temperature brazing of aerospace parts.

♦ 1999–2000 Member-Get-A-Member Campaign

The format for recognizing participants in the AWS Member-Get-A-Member campaign has changed from a "points system" to that of a system where members are recognized for the actual number of members they sponsor. Campaign categories are outlined on page 225 of this issue.

If you have any questions regarding your member proposer points, please call the Membership Department at (800) 443-9353 ext. 269.

Winner's Circle

(Individuals sponsoring 20 or more new members beginning June 1, 1999.)

J. D. Compton, *San Fernando Valley* — 43
N. C. Wall, *South Florida* — 42
E. H. Ezell, *Mobile* — 28
B. A. Mikeska, *Houston* — 24

President's Guild

(Individuals sponsoring 20 or more new members between June 1, 1999, and May 31, 2000.)

J. D. Compton, *San Fernando Valley* — 43
N. C. Wall, *South Florida* — 42
E. H. Ezell, *Mobile* — 28
B. A. Mikeska, *Houston* — 24

President's Roundtable

(Individuals sponsoring 11–19 new members between June 1, 1999, and May 31, 2000.)

W. L. Shreve, *Fox Valley* — 17
R. L. Peaslee, *Detroit B & S* — 16
R. Wray, *Nebraska* — 16

President's Club

(Individuals sponsoring 6–10 new members between June 1, 1999, and May 31, 2000.)

W. Sturge, *New York* — 10
W. R. Beck, *Rochester* — 9
R. J. Davis, *New Orleans* — 8
P. Baldwin, *Peoria* — 8
G. W. Taylor, *Pascagoula* — 8
R. Morgan, *Northwest Ohio* — 8
J. J. Daugherty, *Louisville* — 7
F. A. Juckem, *Madison-Beloit* — 7
J. T. Merzthal, *Peru* — 7
P. G. Childers, *Oklahoma City* — 6
R. L. Fidge, *Baton Rouge* — 6
J. Jones, *North Texas* — 6
J. H. Neal, *Eastern Carolinas* — 6
R. Purvis, *Sacramento* — 6
E. S. Ruiz, *Puerto Rico* — 6
H. T. Timmerman, *Central Texas* — 6
S. O. Ufuah, *New York* — 6
S. R. Zwilling, *Louisville* — 6

President's Honor Roll

(Individuals sponsoring 1–5 new members between June 1, 1999, and May 31, 2000. Only those sponsoring 2 or more AWS Regular Members are listed.)

C. L. Graves, *Delaware* — 5
P. O'Leary, *Eastern Idaho/Montana* — 5
J. G. Pierce, *Columbus* — 5
J. Saucier, *Pascagoula* — 5
F. J. Wernet, *Lehigh Valley* — 5
G. Woomer, *Johnstown-Altoona* — 5
D. Fairchild, *Houston* — 4
H. Jackson, *Los Angeles/Inland Empire* — 4
C. Lauridsen, *Florida Space Coast* — 4
R. L. Ledford, Jr., *Birmingham* — 4
E. D. Levert, *North Texas* — 4
H. R. Madron, *Maryland* — 4
W. L. Shreve, *Northwest Ohio* — 4
K. M. Ali, *Saudi Arabia* — 3
B. A. Bernstein, *Puerto Rico* — 3
C. A. Castille, Jr., *Acadiana* — 3
A. L. Castro, *Puerto Rico* — 3
C. T. Corey, *Northern N.Y.* — 3
L. DeFreitas, *Santa Clara Valley* — 3
W. Galvery Jr., *Long Bch/Orange Cnty* — 3
G. Gavela, *L.A./Inland Empire* — 3
R. Grays, *Kern* — 3
J. Knapp, *Tulsa* — 3
E. H. Ley, *Pittsburgh* — 3
G. E. Mayfield, *Tulsa* — 3
W. P. Miller, Jr., *New Jersey* — 3
J. W. Morris, *Mobile* — 3
S. L. Petty, *Peoria* — 3
J. D. Sanders, *Houston* — 3
R. J. Samanich, *Nevada* — 3
C. F. Schiner, *Western Michigan* — 3
J. H. Smith, Jr., *Mobile* — 3
J. K. Smith, *Tri-River* — 3
B. H. Suckow, *Northern Plains* — 3
M. Uddin, *Pakistan* — 3
R. D. Zabel, *Southeast Nebraska* — 3
T. R. Alberts, *Southwest Virginia* — 2
J. N. Carney, *Western Michigan* — 2
J. Chaparro, *Mexico* — 2
B. A. Chin, *Birmingham* — 2
D. V. Day, *Corpus Christi* — 2
J. M. DeDeaux, *Mobile* — 2
H. W. Ebert, *New Jersey* — 2
J. A. Grantham, *Colorado* — 2
D. L. Hatfield, *Tulsa* — 2
J. P. Hennessy, *Fox Valley* — 2
D. L. Horsman, *Tulsa* — 2
J. W. Jaeger, *Southern Colorado* — 2
K. E. Johnson, *Olean-Bradford* — 2
R. S. Johnson, *Detroit* — 2
S. E. Johnson, *Central Texas* — 2
W. H. Kielhorn, *East Texas* — 2
D. Klingman, *Cleveland* — 2
O. C. Kooi, *Malaysia* — 2
S. K. C. Liu, *Colorado* — 2
M. V. Medrano, *San Diego* — 2
G. Menser, *Long Bch/Orange Cnty* — 2
P. Mulville, *Southern Colorado* — 2
T. J. Murphy, *Canada* — 2
N. Nakwek, *Thailand* — 2
D. A. Nance, *Indiana* — 2
T. L. Newman, *Tri-River* — 2
E. E. Nurman, *Ozark* — 2
J. Norris, *Sangamon Valley* — 2
R. Norris, *Maine* — 2
T. S. Nottingham, *Puget Sound* — 2
D. W. Parker, *Idaho/Montana* — 2
J. L. Padilla, *Mexico* — 2
J. E. Pernell, *L.A./Inland Empire* — 2
M. D. Pittman, *Shreveport* — 2
M. R. Pointer, *Sierra Nevada* — 2
G. A. Rubino, *Venezuela* — 2
O. G. Shair-Ali, *San Francisco* — 2
A. T. Sheppard, *Cleveland* — 2
C. D. Smith, *Mobile* — 2
A. W. Steven, *Memphis* — 2
M. D. Swigart, *Dayton* — 2
M. Tait, *Los Angeles/Inland Empire* — 2
C.-L. Tsai, *Taiwan* — 2
M. R. Tryon, *Utah* — 2
D. J. Wohfeil, *Detroit* — 2
R. Worden, Jr., *Washington, D.C.* — 2
D. A. Wright, *Kansas City* — 2

Student Sponsors

(Individuals sponsoring 3 or more AWS Student Members are listed.)

D. M. Boldt, *Portland* — 39
J. G. Owens, *Baton Rouge* — 24
D. Serrano, *Puerto Rico* — 21
M. R. Anderson, *Indiana* — 19
K. R. Geist, *Puget Sound* — 18
P. G. Walker, *Ozark* — 18
P. Baldwin, *Peoria* — 15
K. A. Ellis, *Maryland* — 13
J. H. Smith, Jr., *Mobile* — 13
W. P. Miller, Jr., *New Jersey* — 11
J. R. Cox, *Northern Plains* — 10
J. D. Compton, *San Fernando Valley* — 7
W. Sturge, *Long Island* — 7
S. P. Siviski, *Maine* — 6
R. Grays, *Kern* — 5
R. L. Ledford, Jr. *Birmingham* — 5
S. Green, *North Texas* — 5
M. Tait, *Los Angeles/Inland Empire* — 4
A. Honegger, *Los Angeles/Inland Empire* — 3

GUIDE TO AWS SERVICES

550 N.W. LeJeune Rd., Miami, FL 33126
Phone (800) 443-9353; Telex 51-9245; FAX (305) 443-7559
Internet: www.aws.org
Phone extensions appear in parentheses.

AWS PRESIDENT

Robert J. Teuscher, Manager,
Welding Applications
Airgas
3574 Christy Ridge Rd.
Sedalia, CO 80135

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Frank R. Tarafa (252)

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Corporate Director
Joe Cilli (258)

HUMAN RESOURCES

Director
Luisa Hernandez (266)

INTERNATIONAL INSTITUTE OF WELDING

Information (294)

Provides liaison activities involving other professional societies and standards organizations, nationally and internationally.

GOVERNMENT LIAISON SERVICES

Hugh K. Webster
Webster, Chamberlain & Bean
Washington, D.C.
(202) 466-2976
FAX (202) 835-0243

Identifies sources of funding for welding education and research & development. Monitors legislative and regulatory issues important to the industry.

WELDING EQUIPMENT MANUFACTURERS COMMITTEE

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Richard L. Alley (217)

INDUSTRY ACTION COMMITTEE

Associate Executive Director
Charles R. Fassinger (297)

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Nannette M. Zapata (308)

Corporate Director of Adminstrative Services
Jim Lankford (214)

Promotes Society programs and activities to AWS members, the welding community and the general public.

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CONVENTION & EXPOSITIONS

Exhibiting Information (221, 256)

Managing Director
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Organizes the week-long annual AWS International Welding and Fabricating Exposition and Convention. Regulates space assignments, registration materials and other Expo activities.

PUBLICATION SERVICES

Division Information (348)

Managing Director
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WELDING JOURNAL

Publisher
Jeff Weber (246)

Editor
Andrew Cullison (249)

National Sales Director
Rob Saltzstein (243)

WELDING HANDBOOK

Welding Handbook Editor
Annette O'Brien (303)

Publishes AWS's monthly magazine, the *Welding Journal*, which provides information on the state of the welding industry, its technology and Society activities. Publishes the *Welding Handbook* and books on general welding subjects.

MEMBER/CUSTOMER SERVICES

Department Information (261)

Managing Director
Cassie R. Burrell (253)

Assistant Director
Rhenda A. Mayo (260)

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

CERTIFICATION PROGRAMS/ BUSINESS DEVELOPMENT

Director
Anna Petroski (481)

For customized certification and educational programs to industry and government.

EDUCATION

Director
James R. Cunningham (219)

Information on education products, projects and programs. CWI, SCWI and other seminars designed for assistance in Certification. Responsible for the S.E.N.S.E. beginning welder program and dissemination of education information on the Web.

CONFERENCES

Director
Giselle I. Rodriguez (278)

Responsible for national and local conferences, seminars, individual corporate programs and home study courses on industry topics ranging from the basics to the leading edge of technology.

CERTIFICATION

Information and application materials on certifying welders, welding inspectors and educators. (273)

Managing Director
Wendy S. Reeve (215)

Awards & Fellows

Managing Director
Wendy S. Reeve (215)

Coordinates awards and AWS Fellow nominees

TELEWELD

FAX: (305) 443-5951

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

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Leonard P. Connor (302) Standards Activities Director, Qualification, Inspection, Food Processing Equipment

Andrew R. Davis (466) International Standards Program Manager, Welding in Marine Construction

Stephen P. Hedrick (305) Safety and Health Manager, Symbols and Definitions

Engineers

Hardy H. Campbell III (300) Structural

Rakesh Gupta (301) Filler Metals

Christopher B. Pollock (304) Brazing, Soldering, Testing, Railroads, Computerization, Instrumentation

Tim Potter (309) Robotics, Joining of Metals and Alloys, Piping and Tubing, Friction Welding

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John L. Gayler (472) Metric Practices, Sheet Metal, Plastics and Composites, Personnel Qualification

ORDER DEPARTMENT
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(305) 443-9353

Publication orders.
Seminar and conference registrations.

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

Senior Publications Coordinator

Rosalinda O'Neill (451)

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

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

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

Please contact any of the staff listed on the previous page or AWS President Robert J. Teuscher, Airgas, 306 S. Chestnut, Colorado Springs, CO 80905.

AWS FOUNDATION, INC.

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Miami, FL 33126
(305) 445-6628
(800) 443-9353, ext. 293
Or e-mail: bobw@aws.org

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

♦ Nominees for National Office

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

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

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

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

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

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

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

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

This material should be sent to Shirley Bollinger, Chairman, National Nominating Committee, American Welding Society, 550 N.W. LeJeune Rd., Miami, FL 33126.

The next meeting of the National Nominating Committee is currently scheduled for Wednesday, April 26, 2000, in Chicago, Ill. The terms of office for candidates nominated at this meeting will commence June 1, 2001. ♦

♦ Honorary-Meritorious Awards

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

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

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

George E. Willis Award: This award is administered by the American Welding Society and sponsored by The Lincoln Electric Company 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. ♦

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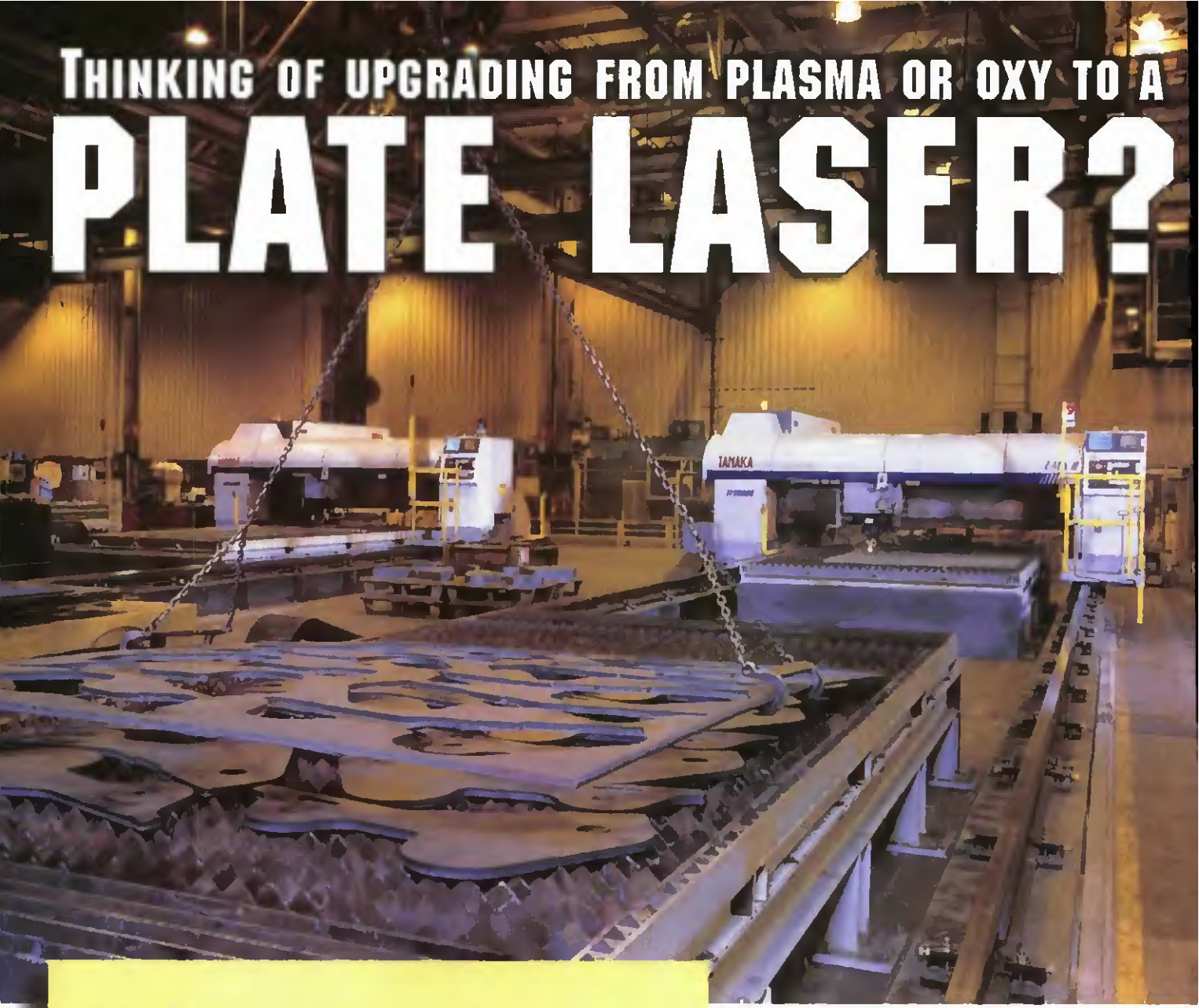

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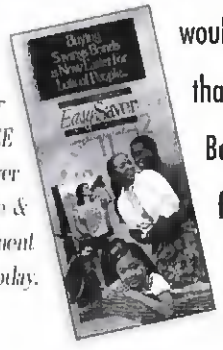

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A public service of this publication

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SEE US AT AWS SHOW BOOTH 1271 **Circle No. 113 on Reader Info-Card** TAKE QUALITY AT ITS WORD!

New Literature

For more information, circle number on Reader Information Card.

Catalog Assists in Welding Machine Selection

A full-line equipment catalog, complete with helpful hints and tips designed to make selecting a welding machine or

plasma arc cutting machine easier, is now available. The 24-page, full-color catalog includes a simple five-step process that helps readers choose the product that best matches their need and skill level. A product selector guide then provides an overview of each product and its typical applications. The catalog also includes a glossary of welding terms and a technical tips section that provides helpful hints for the various welding and cutting processes.

Hobart Welders 225
600 W. Main St., Troy, OH 45373

Statistical Process Control Software Brochure Available

A six-page, full-color brochure outlining the company's statistical process control software is being offered. The program is designed for networked plant computing environments that require an enterprise-wide approach to quality management. The software includes complete facilities for real-time data collection, charting, monitoring, analysis, messaging and reporting across geographically distributed facilities. The

brochure explains how the software can help manufacturers improve product quality, reduce costs, boost productivity, improve traceability and meet strict contract requirements. Product features are accompanied by a series of screen images that illustrate the user-friendly design and high-resolution charting capabilities. The program runs on Windows® 95, 98, NT and 2000. A free demonstration version can be downloaded on the Internet at *www.zontec-spc.com*.

Zontec Inc. 226
1389 Kemper Meadow Dr., Cincinnati, OH 45240

Book on Deburring and Edge Finishing Published

The *Deburring and Edge Finishing Handbook* has been published by the Society of Manufacturing Engineers (SME). Written by noted authority, LaRoux Gillespie, this book is a comprehensive study on burr removal and the treatment of edges. This 400-page hardcover book has more than 300 illustrations and details 100 internationally recognized deburring and edge finishing processes. In addition, it covers a wide range of mechanical, thermal, chemical, electrical and manual techniques. This deburring technology guide describes how to identify and evaluate the most efficient and cost-effective deburring options for specific applications.

— continued on page 240

VersaPower™

Compact, Lightweight, Induction Heating Power Supply

Radyne now offers its new lightweight, solid-state, bench-top power supply for various induction heating applications. Ideal for brazing, joining, annealing, shrink fitting, heat treating and lab applications, the VersaPower is only 20 inches long by 12 inches wide and 12 inches high, weighing only 55 pounds.

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The VersaPower compliments Radyne's other bench-top power units available in 1, 3, 5, and 7.5 kW, 450 kHz tube-type units and 2.5, 5, 7.5, 10 and 15 kW, 50-200 kHz solid-state types.

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SEE US AT AWS SHOW BOOTH 1074

Circle No. 116 on Reader Info-Card

New Literature

— continued from page 238

Also highlighted are a vast array of tools, applications and procedures used worldwide. The book proposes a detailed and uniform standard for deburring and edge finishing. The book is available to SME members for $152; $160 for nonmembers.

Society of Manufacturing Engineers
One SME Dr., P.O. Box 930, Dearborn, MI 48121-0980

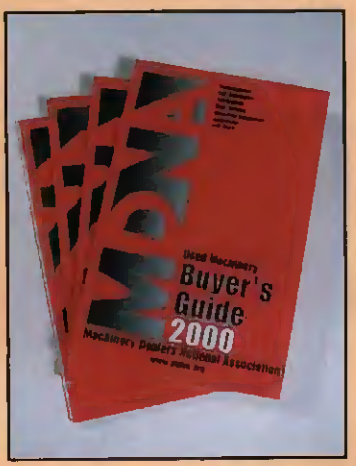
Workholding and Jig and Fixture Components Catalog on CD-ROM

Information on more than 100,000 workholding and jig and fixture components is now available on CD-ROM. The compact disc contains photographs, drawings, dimensions and full technical specifications from the company's product catalog. Separate sections detail tooling components and clamps, jig and fixture bases, chuck jaws, modular fixturing, toggle clamps, drill bushings and workholding. A price list is included on the disc.

Carr Lane Mfg. Co. 227
4200 Carr Lane Ct., St. Louis, MO 63119

Buyer's Guide Lists Used Machinery

The 2000 *Used Machinery Buyer's Guide* is a comprehensive, easy-to-reference directory that offers metalworking machinery users outlets to buy and

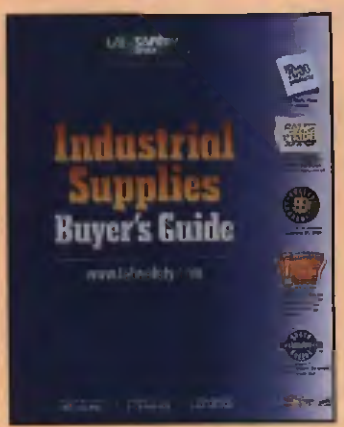


sell quality and used machinery. It also offers liquidation sources to keep machinery users profitable. The guide lists alphabetically and geographically nearly 500 firms and references by specialty machinery categories.

Machinery Dealers National Association 228
315 S. Patrick St., Alexandria, VA 22314

Industrial Supplies Guide Available

This 2000-page buyer's guide offers a large selection of industrial and safety supplies. The catalog includes more than



200 pages of new products including hand tools, first aid, material handling, pneumatics/hydraulics, plasticware/glassware, storage systems and more. Catalog prices are guaranteed through December 31.

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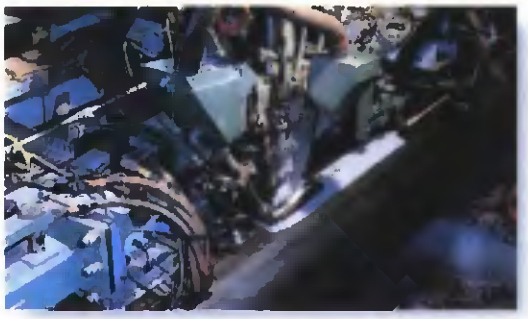

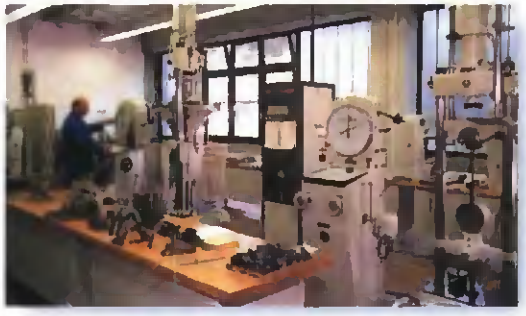

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BY TIM HESTON, Assistant Editor

Pipefitters' Automatic Tube Welding Classes Meet the High Demands of Silicon Valley

Although much of the actual silicon wafer manufacturing has, in fact, moved out of Silicon Valley to Asia, the industry is still the most intense in America. High-purity tubing for nitrogen and ultra-clean water is a vital part of manufacturing, which means welders trained and certified for gas tungsten arc automatic orbital tube welding are in high demand. Intel, Cisco, AMD, Xerox, 3COM and other high-tech companies are continually looking for trained, certified help.

Fig. 1 — The Pipe Trades Training Center in San Jose, Calif., has 100,000 sq ft of indoor training space.

"Orbital welding in this area has for years been a large portion of our work," said Bob Elkins, apprenticeship field coordinator and UA authorized testing representative for Local 393 Pipefitters, Steamfitters and Refrigeration Fitters Union in San Jose, Calif. "Here in Silicon Valley, the demand for high-purity piping is very high."

With such high demand, the union offers something extra for its members: a $19-million, 100,000-sq-ft Pipe Trades Training Center — Fig. 1. Each member of the local working in the pipe trades gives a dollar an hour out of his hourly wage — not from dues — for this center. People have come from as far away as Israel, China and Russia for tours.

The local, which has about 2000 members, certifies to ASME *Boiler and Pressure Vessel Code*, Section 9, which requires an update to certification every six months, either by proving actual welding experience or retesting altogether. Elkins said all local contractors pay for retesting annually. "It's something they think is necessary, which makes sense," he said. Technology changes quickly in the computer industry.

And orbital welding machines used in the industry must change with it. Along with analog orbital tube welding machines, the training center has computerized machines with automatic programming — Fig. 2. After selecting tube thickness, diameter, type of material such as 316L and other factors from pull-down menus; setting the purge rates; and installing the proper tungsten, "all you have to do is push a button," Elkins said, and a high-quality weld, good enough to meet the stringent demands in Silicon Valley, is produced, with no concavity or excess reinforcement.

Like much of the other equipment in the training center, some orbital welding machines are donated from manufacturers. "Companies realize our members are the people they want using their machines," Elkins said. "It makes them look better, and it makes us look better if we know what's out there in the field."

What's out there is making the welder's job easier. Using traditional analog machines, with the setup, programming, the practice weld, refining the weld and testing again, "you can sometimes spend a couple hours just on one tube size," Elkins said. "With today's machines, the setup is faster, the programming is already installed and the first practice weld is so close to perfect there is not much time spent refining the weld."

Fig. 2 — Setting up orbital tube welding heads, which are connected to a computerized control.

The training center has several automatic tube welding machines, three of which are digital machines: two Model 207s from Arc Machines, Inc. (AMI), and one M100 from Swagelok.

Though orbital welding is growing more and more digital, the center still has training for analog machines, a requirement for certification. Welders practice after work and come in on Saturdays for testing, all on their own time.

At the beginning of test day, a welder (usually a journeyman) is given a couple of test coupons, with the ends prepped and ready to go. The welder's identification number is stamped on the tube. Welders then start with a ¼-in.-diameter tube with 0.035-in. wall thickness, then go up to a ½-in. diameter and 0.049-in. wall thickness, a 3-in. diameter with 0.065-in. wall thickness, then finally a 3½-in. diameter with 0.120-in. wall thickness. A third-party witness (contractor) is present. Then, an independent contractor performs X-ray testing to ASME, Section 5.

If a welder passes the test, he's certified from ¼-in. OD and up in tube sizes *and* wall thicknesses up to 0.240 in.

"Right now, everybody who wants to work is working," Elkins said. "And, because of our training and demand for high-purity tubing in Silicon Valley, we have some of the most highly skilled, educated craftsmen in the country." ◆

Stainless Q & A

BY DAMIAN J. KOTECKI

Q: After making a large and rather complicated weldment of 304L stainless steel, the weldment has to be machined to very tight tolerances. Is it advisable to stress relieve after welding to improve dimensional stability during machining, and, if so, at what temperature?

A: Postweld heat treatment (PWHT) is commonly applied to large, complex weldments of carbon steel or low-alloy steel to improve dimensional stability during machining. A large, complex weldment can be expected to contain yield point residual stresses somewhere within it. Machining away some metal containing residual stresses causes redistribution of stresses, which often results in the metal moving slightly during machining. A PWHT before machining produces stress relaxation by creep and local yielding because the yield strength of the metal falls with increasing temperature. So, after a properly controlled PWHT, the maximum residual stress should be on the order of the yield strength of the metal at the PWHT temperature, which is a fraction of the room-temperature yield strength. The result is a greatly reduced tendency for the metal to move during welding, and dimensional stability is improved. In principle, PWHT can do the same for austenitic stainless steel weldments.

With carbon steel or low-alloy steel, PWHT is commonly applied at temperatures such as 1150°F (620°C). However, this temperature is dangerous for 304L austenitic stainless steel and similar weldments for two reasons. First, the weld metal, which is normally 308L, typically contains some ferrite for resistance to hot cracking. At temperatures around 1150°F, the ferrite transforms to sigma phase, a brittle intermetallic compound, which embrittles the weld metal. Second, at the same temperature, the 304L base metal experiences chromium carbide precipitation on the grain boundaries, which depletes the chromium in solution in the metal immediately adjacent to the grain boundaries. This makes the metal sensitive to intergranular corrosion. Type 304L stainless is quite immune to sensitization during the very short thermal cycles of welding, but it is not immune to sensitization during the much longer thermal cycle of PWHT at 1150°F.

If the weldment is not yet made, you can improve the situation relative to sigma phase by using relatively low ferrite filler metal. Normal 308L weld metal often contains more than 10 FN. But 308L filler metals of 4 to 9 FN are available, and use of these can reduce the damage from sigma phase to acceptable levels. If the weldment is already made, of course, there is nothing you can do about the ferrite level.

A safer approach is to reduce the PWHT temperature. I'd suggest PWHT at 800 to 900°F (425 to 480°C) for 2 to 4 h. With this PWHT, 304L base metal welded with 308L filler metal should not form any sigma phase, and the extent of chromium carbide precipitation should be minimal. In this temperature range, the yield strength of the 304L base metal and matching 308L filler metal should be about one half of what it is at room temperature, so considerable stress relaxation can occur. There will not be as much stress relief as at 1150°F, but there should be a big improvement in dimensional stability.

Q: I am trying to develop weld procedure qualifications for duplex stainless steel Alloy 2205 (UNS S31803) using SMAW, GMAW and SAW. I am encountering trouble with high ferrite in the weld heat-affected zone (HAZ). The customer's specification is for 70% ferrite maximum in the HAZ, determined by metallographic examination (point counting) on weld cross sections. The first trial weldments often exceeded this limit. What can be done about it?

A: First of all, I should point out metallographic determination of ferrite is not a very precise method. There is a large problem with reproducibility of results. Unfortunately, for HAZ determinations, there is no available alternative.

Alloy 2205 is nominally 22% Cr, 5% Ni, 3% Mo with some nitrogen. (More will be said about the nitrogen later.) As plate or pipe, this steel microstructurally consists of approximately half ferrite and half austenite. However, in the as-cast form, the ferrite is much higher. Duplex stainless steels such as 2205 solidify as 100% ferrite, and austenite forms only during cooling. Hot working and annealing at temperatures in excess of 1900°F (1040°C) promote diffusion of alloying elements, which increases the amount of ferrite that transforms to austenite. However, welding causes the HAZ very close to the weld interface to transform back to 100% ferrite at temperatures just below melting, and rapid cooling associated with welding does not allow time for diffusion to produce extensive austenite. So the HAZ near the weld interface tends to be higher in ferrite content than the remainder of the steel. High-heat-input welding can slow the cooling rate to a certain extent and allow for more diffusion and formation of austenite, but the tendency for high ferrite in the HAZ along the weld interface remains. This high ferrite tends to reduce the ductility, toughness and corrosion resistance of the weldment.

This situation would also affect the weld metal, but filler metal designers long ago figured out increased nickel (typically 9%) in the filler metal would produce an as-welded deposit of higher austenite content. The increased nickel is the norm today in filler metals for duplex stainless steels such as ER2209 wire, which would normally be chosen for 2205 base metal.

Increased nickel in the filler metal does not help the situation in the HAZ. It is therefore necessary to modify the base metal composition slightly. This is where nitrogen comes into the picture. Nitrogen is a very small atom as compared to iron, chromium, nickel and molybdenum, so it can diffuse much more rapidly than these other elements. And nitrogen is a powerful promoter of austenite. A little extra nitrogen can have a dramatic effect on the ferrite content in a weld HAZ. Some years ago, it was common to attach UNS S31803 to Alloy 220S, with a specified nitrogen range of 0.08 to 0.20%. The problem with this was that base metals in the lower half of this nitrogen range tended to have high ferrite in the HAZ. The composition range of UNS S31803 has not been changed, but the alloy is no longer designated as Alloy 220S. Instead, ASTM A240 and similar specifications redefined Alloy 2205 as UNS S32205, with a required nitrogen range of 0.14 to 0.20%. There were minor adjustments in some other alloy elements as well. It is no longer correct to refer to UNS S31803 as Alloy 2205.

— continued on page 247

Jackson Products Names Officers

Jackson Products, Inc. (JPI), St. Louis, Mo., promoted **Christopher T. Paule** to president and chief operating officer. Paule has served the company as vice president and chief financial officer for the past six years.

Robert H. Elkin will continue to serve as chairman and chief executive officer, providing strategic corporate direction with a focus on acquisition efforts.

Mark Kolmer has been named vice president of finance. Kolmer, who most recently served as controller, joined the company in 1996 as controller for the Flex-O-Lite and Services and Materials businesses.

Jim Van Dusen was named vice president of international. In this position,

Van Dusen

he will oversee the company's growth in European business as well as coordinate efforts to identify and pursue international market opportunities outside of Europe. Van Dusen joined JPI in 1996, most recently serving as director of international sales and managing director of Lansec GmbH.

Postle Announces Appointments

Postle Industries, Inc., Cleveland, Ohio, has announced staff appointments.

Tom Christ is to serve as East Coast district sales manager. He comes to the company with 30 years' experience in the areas of hardfacing, repair and thermal spray.

Appointed to represent Postle Industries' line of products are, in California, Arizona, Nevada and Utah, **Ed Phelan** and **Steve Phelan** of Shamrock Sales; from Gordon Sales in the Northwest, which includes Washington, Oregon, Idaho and Montana, **Lowell Gordon**, **Sjon Delmore** and **Dave Schranze**; in New Mexico, Colorado, Wyoming, Kansas and Nebraska, **Jim Van Coevern**, **Dave Boepple** and **Mike Winter**; and in the Southeast — North and South Carolina, Georgia, Florida and Alabama — **Gary Gorman**.

National-Standard Names Managers

National-Standard, Niles, Mich., recently promoted **Larry Thomas** to national sales manager for welding prod-

Thomas

ucts. In his new position, Thomas will have overall responsibility for providing sales service to customers for the company's line of welding filler metals and unique wire packages. Thomas, with 23 years of experience in the welding industry, was previously national distributor manager. Prior to joining National-Standard, Thomas held key sales management positions with several large welding supply distributors.

Ted Turner joined the company as district sales manager for welding products. He will be responsible for sales of

Turner

the company's full line of carbon steel and stainless steel welding wire products throughout Texas, Oklahoma, Arkansas and Louisiana. Prior to joining the company, Turner was a regional manager for Natweld/Hi-Alloy in Houston, Tex. He has 26 years of sales experience in the welding industry.

Graham Adderley was named district sales manager for the Welding Products Group. He will be responsible for sales

Adderley

of the company's line of carbon steel and stainless steel welding wire products throughout western Canada and the northwestern United States. Prior to joining the company, Adderley was a regional manager for Bohler Thyssen Welding. He has more than 12 years of experience in welding product sales, and has completed several courses and seminars related to the industry.

Coherent Names Managers

Coherent, Inc., Semiconductor Group (CSG), Santa Clara, Calif., has named **Tony Hoult** applications manager. His responsibilities include promoting new applications for CSG high-power diode lasers and systems, as well as spearheading the CSG applications laboratory. Most recently, Hoult served as a senior research fellow at the Warwick Manufacturing Group's industrial laser facility at the University of Warwick, U.K. There, he completed research programs in the laser machining of composites and high-power lasers in rapid prototyping. He also acquired his Ph.D. on the solid-state laser beam welding of aluminum. Previously, Hoult was a development engineer for Lumonics Ltd., Rugby, and senior materials engineer for Lucas Aerospace, U.K.

Joining the company as marketing communications manager is **Sandra Garcia**. She will oversee the planning and development of the company's marketing communications, advertising and promotional programs. A graduate of the University of Arizona, Garcia previously served as vice president in charge of managing industrial recruitment, trade

shows, Web site development and marketing collateral and advertising campaigns for the instrumentation, electronics, environmental technology, optics, plastics, metal fabrication and mining industries for the Greater Tucson Economic Council.

Thermadyne Announces Appointments

Thermadyne Industries, Inc., St. Louis, Mo., recently announced the appointment of **Mike O'Connell** to the position of executive vice president for its

O'Connell

Thermal Arc and Stoody business units. O'Connell, a longtime Thermadyne employee with sales and marketing management experience with several of the company's business units, will assume full sales, marketing and operations responsibilities for the business units while retaining certain national account and corporate marketing duties. His most recent responsibilities with the company included National Accounts, Thermadyne Canada Operations and corporate marketing.

Jim Delaney, executive vice president for Latin American Operations, will assume responsibility for Thermadyne Canada and Thermadyne International Customer Service Operations in Oakville, Ontario.

Wall Colmonoy Announces Appointments

Wall Colmonoy, Madison Heights, Mich., has named **Jean-Francois Boëllmann** general manager of the Argenteuil, France, operation; **Demetrio Jaramillo** was promoted to international sales and customer service manager; and **Victor Taylor** has joined the company as technical sales representative.

Boëllmann brings more than 25 years of experience in sales, production and research and development to his new position. He qualified as an engineer at the École Violet in 1972. In his new position, Boëllmann will spearhead the business development of the Argenteuil, France, operation.

Jaramillo previously served the company as international sales manager. In addition to handling all export sales in Latin America, Asia and the Middle East, Jaramillo will oversee all domestic sales of products and the customer service department. He joined the company in 1995 as export sales administrator.

Jaramillo

Taylor

Taylor, with more than 13 years of experience in the welding industry, is responsible for maintaining and expanding sales of hard-surfacing alloys and brazing filler metals in Canada. Prior to joining the company, Taylor served as welding supervisor at Dofasco, Inc. He received his welding engineering technician diploma from Conestoga College.

TRUMPF Names Manager

TRUMPF Inc., Farmington, Conn., has named **David W. Partain** to the position of manager of training. He will also be responsible for developing educational

Partain

programs for customers of the company's fabricating equipment. Before joining the company, Partain was director of employee development for the Metropolitan Atlanta Rapid Transit Authority. Partain, a retired U.S. Air Force lieutenant colonel, completed his last duty assignment at the Pentagon, where he was responsible for training and professional development for U.S. government defense personnel all over the world.

ESAB Announces Staff Appointments

ESAB Welding and Cutting Products, Hanover, Pa., announced the appointment of **John Schleicher** to quality assurance manager, welding and cutting operations for the Filler Metals Division.

Jerry Mathison was promoted to sales application engineer.

ESAB Welding and Cutting Products in Florence, S.C., has announced the following appointments.

Don Racey has been named director of quality and continuous improvement.

Jonathan Greene has been promoted to product administrator for equipment consumables.

Mark Shepherd has been promoted to director of information technology.

Mark Elender was appointed vice president of domestic sales, with six U.S. sales regions reporting to him.

Doug Jones was named vice president of marketing for filler metals and standard equipment products.

Dale Wodzinski was named vice president of strategic accounts.

Stan Ferree, currently vice president technical for filler metal products, will assume additional responsibilities for all field technical support activities.

Dave Meyer was promoted to product manager for the submerged arc product line. ♦

Stainless Q&A

— *continued from page 245*

I expect your procedure qualification is being run on older Alloy 2205, perhaps remnants from a previous project, which was originally produced under the UNS S31803 composition limits. The solution to your problem very likely is to use current Alloy 2205 (UNS S32205) for your procedure qualification. The required higher nitrogen should produce lower ferrite in the HAZ. ♦

DAMIAN J. KOTECKI is Technical Director for Stainless and High-Alloy Product Development for The Lincoln Electric Co., Cleveland, Ohio. He is a member of the AWS A5D Subcommittee on Stainless Steel Filler Metals; AWS D1 Structural Welding Committee, Subcommittee on Stainless Steel Welding; and a member and past chair of the Welding Research Council Subcommittee on Welding Stainless Steels and Nickel Base Alloys. Questions may be sent to Mr. Kotecki c/o Welding Journal, 550 N.W. LeJeune Rd., Miami, FL 33126.

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WELDING RESEARCH

SUPPLEMENT TO THE *WELDING JOURNAL*, APRIL 2000
Sponsored by the American Welding Society and the Welding Research Council

The Welding of Structural Steels without Preheat

A program was initiated to evaluate whether current guidelines for preheat should apply to low hardenability steels

BY A. J. KINSEY

ABSTRACT. As a result of recent steel making trends toward low hardenability thermomechanically controlled processed (TMCP) steels and the development of lower hydrogen-potential welding consumables, the possibility of welding even thick-section structural steels without preheat is becoming more feasible. Current British guidelines for very low-hydrogen-potential consumables that deposit less than 5 mL H_2/100 g deposited weld metal (Scale D consumables according to BS 5135) are largely based on cracking data obtained mostly on high-carbon equivalent steels. A program was therefore conducted at TWI to assess the validity of the current guidelines when applied to low hardenability steels.

In general, good agreement was observed between the HAZ cracking behavior and that predicted by the TWI nomograms. Steels of low-carbon equivalent were successfully welded using the shielded metal arc welding (SMAW) and flux cored arc welding (FCAW) processes without the application of preheat using low-hydrogen, Scale D consumables. In most cases, the present TWI nomograms correctly predicted cracking behavior, although the deleterious effect of low sulfur on cracking tendency was noted when welding some steels. The use of very low-hydrogen consumables is to be encouraged since, in conjunction with low-carbon equivalent steels, they can reduce the requirement for preheat to avoid HAZ hydrogen cracking and, therefore, reduce fabrication costs. The TWI nomograms provide a good basis for the derivation of procedures for such consumables.

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Introduction

A comprehensive scheme for predicting statistically based, safe welding procedures for structural steels was first published in 1970 (Ref. 1). Industry is now familiar with the nomograms that were developed from this work and are presented in BS 5135: 1984 (Ref. 2). Such nomograms enable the prediction of suitable safe welding conditions for the avoidance of heat-affected-zone (HAZ) cracking in carbon and C-Mn steels. Based on practical experience, these nomograms have been updated and modified since their first introduction in 1972 (Ref. 3), notably by the introduction of a revised second edition of the TWI publication *Welding Steels without Hydrogen Cracking* (Ref. 4) and the proposed pr EN 1011-2 (Ref. 5). Currently, four hydrogen levels are recognized in BS 5135: 1984 (*viz* Scale A through D). To conform to scale D, which represents the lowest weld metal hydrogen content, the hydrogen potential of a given consumable must be less than 5 mL H_2/100 g deposited weld metal. More recently, however, a fifth Scale E level (<3 mL H_2/100 g deposited weld metal) has been proposed for pr EN 1011-2 (Ref. 5). With the emergence of low hardenability thermomechanically controlled processed (TMCP) steels, and the development of lower hydrogen-potential welding consumables, the possibility of welding even thick joints without preheat has arisen. This would obviously lead to a favorable reduction in fabrication costs in a wide variety of situations and industries.

KEY WORDS

Preheat
TMCP
Low Hardenability
Low Hydrogen
SMAW
FCAW
Nomograms
Diffusible Hydrogen

However, at present, few controlled thermal severity (CTS) test cracking data exist at hydrogen levels below the Scale D limit (5 mL hydrogen/100 g deposited weld metal). Indeed, most of the previous tests were performed on older, high-carbon equivalent steels (Ref. 1) and a need exists to extend the data to lower carbon equivalent steels. Therefore, the principal aim of this work was to define quantitative limits on material composition, hydrogen level and weld thermal cycle that would enable preheat above normal ambient to be avoided without inducing HAZ hydrogen cracking.

In addition, some concern has been raised over the necessity to apply preheat to "dry the plate" and eliminate any adverse effects of water that may be present. Practically, moisture of this nature usu-

Table 1 — Compositions of Steel Plates Used for CTS Testing

Plate Identity	Grade of Steel Plate	Element wt-% C	S	P	Si	Mn	Ni	Cr	Mo	V	Cu	Nb	Ti	Al
18433	50	0.18	0.037	0.018	0.45	1.57	0.04	0.02	0.010	0.002	0.060	0.047	<0.002	0.045
18789	50D	0.19	<0.002	0.021	0.28	1.38	0.01	0.02	<0.005	<0.002	0.005	0.024	<0.002	0.047
18704	55	0.05	<0.002	0.012	0.27	1.39	0.80	0.01	<0.005	<0.002	0.940	0.015	0.011	0.021
18457	50E	0.17	0.015	0.010	0.26	1.17	0.01	0.01	0.005	<0.002	0.010	0.063	0.002	0.030
18485	50E	0.08	0.006	0.014	0.40	1.39	0.22	0.06	0.010	0.060	0.230	0.018	0.009	0.030
18859	50D	0.10	0.003	0.015	0.30	1.35	0.005	0.01	0.005	0.002	0.005	0.002	0.005	0.040
18885	50E	0.06	0.004	0.011	0.26	1.28	0.51	0.01	0.005	0.002	0.005	0.021	0.017	0.038

Plate Identity	Grade of Steel Plate	Element wt-% B	Sn	Co	As	Ca	Pb	Zr	O	N	CE_{IIW}
18433	50	<0.0003	0.005	0.01	—	—	—	—	0.0035	0.0076	0.45
18789	50D	—	—	—	—	—	—	—	0.0004	0.0041	0.43
18704	55	<0.0003	0.010	<0.005	<0.005	<0.0003	<0.002	<0.005	0.0020	0.0074	0.40
18457	50E	<0.0003	<0.005	<0.005	0.023	<0.0003	<0.005	<0.005	0.0024	0.0066	0.37
18485	50E	0.0005	<0.005	0.010	<0.005	<0.0003	<0.005	<0.005	0.0009	0.0091	0.37
18859	50D	<0.0003	<0.005	<0.005	<0.005	<0.0003	<0.005	<0.005	0.00086	0.0028	0.33
18885	50E	<0.0003	<0.005	0.010	<0.005	0.0034	<0.005	<0.005	0.0049	0.0047	0.31

Table 2 — Deposited Weld Metal Diffusable Hydrogen Levels for CTS Test Weld Consumables

Consumable Type/ Specification	Drying Conditions Temperature, °C	Time, (h)	Welding Conditions Current, A	Voltage, V	Diffusible Hydrogen Content mL/100 Deposited Metal Final (21 day)	TWI Analysis No.
Medium alloy highly basic flux cored wire AWS E80T5-G/Argoshield 20 gas (18 L/min) flow rate, 20-mm electrode extension	As-received		364	23.2	1.7	H93/6
Moisture-resistant basic coated low-hydrogen (vacuum packed) BS639 E51155B AWS 5.1 E7018-1	As-received		169	21.6	3.3	H92/23
Basic coated low-hydrogen BS639 1986 E51548 (120 2 6H) AWS 5.1-81 E7018	350	2	162	21.2	4.4	H92/22
Basic coated BS639 1986 E51548 (120 2 6H) AWS 5.1-81 E7018	350	2	162	20.7	3.9	H92/21

ally forms as condensation when a cold plate is brought into a warmer fabrication shop. Therefore, the effects of moisture contamination on the propensity for hydrogen cracking was also briefly assessed using a variety of methods to simulate this phenomenon.

The above objectives were met by generating controlled thermal severity (CTS) test data on a range of steels, using consumables with hydrogen levels that conformed to the Scale D level. Tests were performed at ambient temperature both with and without the application of a contaminant such as water.

Experimental Details

Materials and Consumables

In all, seven steels were studied that were representative of old and new steels, and a brief description of each is provided below in order of carbon equivalent.

1) 0.31 CE_{IIW}, 0.06%C, TMCP steel (Grade 50E), TWI identity No.1B885.

2) 0.33 CE_{IIW}, 0.10%C, TMCP steel (Grade 50D), TWI identity No.1B859.

3) 0.37 CE_{IIW}, 0.17%C, microalloyed, normalized C-Mn-Nb steel (Grade 50E), TWI identity No.1B457.

4) 0.37 CE_{IIW}, 0.08%C, microalloyed, normalized, C-Mn-Ni-Cu-Nb-V-Ti, Ca-treated steel (Grade 50E), TWI identity No.1B485.

5) 0.40 CE_{IIW}, 0.05%C, controlled rolled and aged steel (Grade 55), TWI identity No.1B704.

6) 0.43 CE_{IIW}, 0.19%C, low sulfur C-Mn steel, low oxygen content, Al-treated (Grade 50D), TWI identity No.1B789.

7) 0.45 CE_{IIW}, 0.18%C, high sulfur C-Mn steel (Grade 50), TWI identity No.1B433.

Most of the steels were obtained while the now superseded BS 4360 standard was in existence and have been assigned a grade covered by that standard. The steels designated Grade 50 would have had a minimum yield strength typically of around 350 N/mm^2 (~50 ksi), while the Grade 55 would have had a minimum yield strength of around 450 N/mm^2 (~65 ksi). Grades 50D and 50E would be equivalent to Grades S355J2G3 and S355N in BS EN 10025:1993 and BS EN 10113:1993, respectively, while Grade 55 would be similar to S460N.

All CTS tests were conducted using 50-mm (~2-in.) thick plate. The oxygen and nitrogen contents of the steels were determined by inert gas fusion; all other elements were determined using a direct reading optical spectrometer on remelted samples. Grades and compositions are given in Table 1.

Three shielded metal arc (SMAW) electrodes and one flux cored wire (FCAW) were chosen. Details of the consumables, the drying conditions and diffusible weld metal hydrogen levels are given in Table 2. Procedures given in BS 6693: Parts 3 and 5 were followed to determine the deposited weld metal hy-

drogen levels (Refs. 6, 7). Hydrogen was collected at room temperature over mercury. All four consumables conformed to Scale D hydrogen level as defined in BS 5135: 1984.

Welding

All consumables were used in the same condition as employed for the hydrogen analyses. Shielded metal arc welds were produced using an automatic welding system as described by Pedder and Watkinson (Ref. 8). All welds were produced using 4-mm (5/32-in.) diameter electrodes. Welding current and voltage were held essentially constant, and the travel speed was adjusted so that a range of arc energies could be investigated for each plate/consumable combination. For SMAW, 21–24 V and 160–170 A were used such that arc energies of between 0.8 and 1.45 kJ/mm (approximately 20 and 37 kJ/in., respectively) were obtained.

Flux cored arc welds were deposited automatically by fixing the welding gun to an automatic traverse machine usually used for submerged arc welding (SAW). A wire diameter of 1.6 mm (1/16-in.) was used throughout. Approximately 23 V and 320–375 A were employed such that the arc energy was varied between 0.6 and 1.5 kJ/mm (approximately 15 and 38 kJ/in., respectively).

Controlled Thermal Severity Testing

The self-restrained controlled thermal severity (CTS) test block assembly used during this program is described in BS 7363: 1990 (Ref. 9) and is shown in Fig. 1. Single-pass welds were deposited in the flat position across the full width of the block in accordance with BS 7363: 1990 (Ref. 9). In total, six faces were examined metallographically for cracking from each test weld. A Vickers hardness survey of the coarse-grained HAZ was carried out on one face taken from each weld using an indenting load of 5 kg. The face showing maximum cracking was chosen for cracked welds, while a face taken from the midlength was used for uncracked welds.

Controlled Thermal Severity Testing with Moisture Contamination

The procedure outlined above was also performed on test blocks whose surfaces were covered in moisture to simulate condensation as may occur when cold plate is brought into a warmer fabrication shop and no preheat is used. Three methods were employed in order to introduce water onto a clean, degreased test block. First, test blocks were placed in a cold refrigerator at 13°C or 6°C (55°F or 43°F) in order to induce the formation of dew on the test block surface when brought into the laboratory. Second, blocks were placed in a freezer at –2°C (–19°F), which resulted in frost formation on the test block. Finally, blocks were placed in a humidity cabinet at approximately 30°C (86°F) and 87% relative humidity. This induced water droplet formation after approximately 45

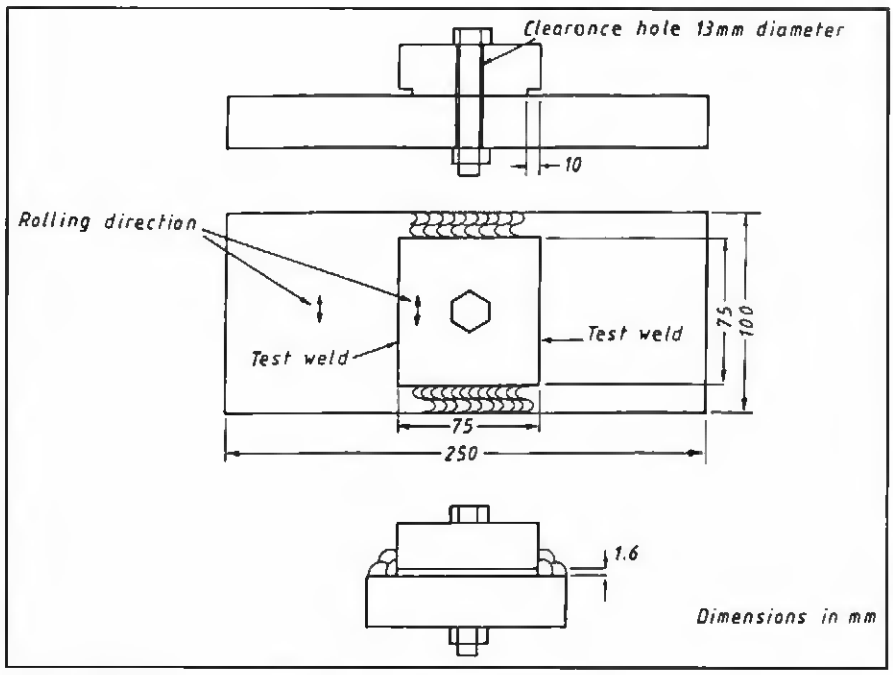

Fig. 1 — Controlled thermal severity (CTS) test block configuration.

Table 3 — Deposited Weld Metal Diffusible Hydrogen Level for Consumable Used for CTS Test Welds with Humidity-Cabinet-Induced Moisture

	Drying Conditions		Welding Conditions		Diffusible Hydrogen Content, mL/100g[a]
Consumable Type/ Specification	Temperature, °C	Time, (h)	Current, A	Voltage, V	Deposited Metal
Basic coated BS639 1986 E5154B (120 2 6 H) AWS 5.1-81 E7018	350	2	165	21.8	5.2, 5.1, 4.3 / 4.9

(a) individual values / mean

Table 4 — CTS Test Weld Data for Plate 1B885 (50-mm thickness, 150-mm combined thickness, $0.31CE_{IIW}$)

		Welding Parameters		Weld Cooling Characteristics				
Weld No.	Diffusible H_2 mL/100 g Deposited Weld Metal	Travel Speed, mm/min	Arc Energy, kJ/mm	$\Delta t_{800-500}$, s	HAZ Hardness HV5[a]	Mean Weld Metal Hardness HV5	HAZ Cracking/No Cracking, C/NC	Proportion of Faces Cracked from a Total of Six
W45	4.4	267	0.83	3.6	239–223 / 233	263	NC	0
W47	4.4	253	0.89	3.2	245–218 / 235	261	NC	0

(a) Presented as max.–min. / average

Table 5 — CTS Test Weld Data for Plate 1B859 (50-mm thickness, 150-mm combined thickness, $0.33CE_{IIW}$)

Weld No.	Diffusible H_2 mL/100 g Deposited Weld Metal	Welding Parameters: Travel Speed, mm/min	Welding Parameters: Arc Energy, kJ/mm	Weld Cooling Characteristics: $\Delta t_{800-500}$, s	HAZ Hardness HV5[a]	Mean Weld Metal Hardness HV5	HAZ Cracking/No Cracking, C/NC	Proportion of Faces Cracked from a Total of Six
W44	4.4	267	0.85	3.1	317–252 / 295	253	NC	0
W46	4.4	240	0.93	--	336 280 / 305	265	NC	0

(a) Presented as max.–min. / average

Table 6 — CTS Test Weld Data for Plate 1B485 (50-mm thickness, 150-mm combined thickness, $0.37CE_{IIW}$)

Weld No.	Diffusible H_2 mL/100 g Deposited Weld Metal	Welding Parameters: Travel Speed, mm/min	Welding Parameters: Arc Energy, kJ/mm	Weld Cooling Characteristics: $\Delta t_{800-500}$, s	HAZ Hardness HV5[a]	Mean Weld Metal Hardness HV5	HAZ Cracking/No Cracking, C/NC	Proportion of Faces Cracked from a Total of Six
W57	4.4	282	0.78	—	362–345 / 350	280	NC	0
W56	4.4	259	0.93	—	367–313 / 347	283	NC	0
W60	1.7	513	0.8	—	362–310 / 340	269	NC	0
W61	1.7	559	0.87	—	358–325 / 340	261	NC	0

(a) Presented as max.–min. / average

Table 7 — CTS Test Weld Data for Plate 1B457 (50-mm thickness, 150-mm combined thickness, $0.37CE_{IIW}$)

Weld No.	Diffusible H_2 mL/100 g Deposited Weld Metal	Welding Parameters: Travel Speed, mm/min	Welding Parameters: Arc Energy, kJ/mm	Weld Cooling Characteristics: $\Delta t_{800-500}$, s	HAZ Hardness HV5[a]	Mean Weld Metal Hardness HV5	HAZ Cracking/No Cracking, C/NC	Proportion of Faces Cracked from a Total of Six
W54	4.4	253	0.9	—	396–325 / 360	291	NC	0
W55	4.4	259	0.9	2.8	376–353 / 364	287	C	4
W63	4.4	246	0.96	2.7	418–349 / 373	291	C	1
W71	4.4	206	1.1	—	391–310 / 369	292	NC	0
W73	4.4	178	1.23	3.3	391–349 / 373	282	C	2
W72	4.4	165	1.32	4.4	412–358 / 385	277	NC	0
W58	1.7	513	0.8	2	396–349 / 370	283	NC	0
W59	1.7	513	0.87	—	401–296 / 350	298	NC	0

(a) Presented as max.–min / average

min of exposure. All test welds were made immediately after the block was removed from the freezer, refrigerator, or humidity cabinet. Two shielded metal arc consumables were used that produced weld metal hydrogen levels of 3.9 mL or 4.4 mL/100 g deposited weld metal when welding was performed under normal, dry conditions (Table 2). A measure of the actual deposited weld metal hydrogen with humidity-cabinet-induced surface moisture was made for the 3.9 mL/100 g deposited weld metal consumable. This was compared to the result obtained under normal, essentially dry, conditions. Two steels were evaluated using this technique, corresponding to 0.45 and 0.33 carbon equivalents.

Results

Hydrogen Levels

The hydrogen levels determined for each consumable are shown in Table 2. All are observed to be within the Scale D level (<5 mL H_2/100 g deposited metal) in BS 5135: 1984.

The diffusible hydrogen present in the weld metal deposited on test blocks covered with humidity-cabinet-induced surface moisture was observed to be 4.9 mL H_2/100 g deposited metal (Table 3). This represents an increase of 1 mL H_2/100 g deposited weld metal in comparison with the previous result obtained under nominally dry conditions. Further assessment and data generation would be required to establish if this is a "real" difference. However, the value of 4.9 mL H_2/100 g still conforms to the Scale D level stipulated in BS 5135: 1984.

CTS Test Data

All CTS test weld results (without moisture contamination) are presented in Tables 4–10 for each individual steel composition. The HAZ cracking behavior is presented in Figs. 2–5. The predicted arc energy for the avoidance of hydrogen cracking, as defined by TWI nomograms for 50-mm (2-in.) thick steel/no preheat/Scale D hydrogen is also shown. (Note that the term "arc energy" describes the energy supplied by the arc, while the term "heat input" refers to the heat input into the steel being welded. The difference between the two terms is accounted for by the "arc efficiency" of the welding process. The arc efficiency of SMAW and FCAW is 80% for the purposes of the TWI scheme). The maximum HAZ hardness is recorded adjacent to each crack/no crack data point.

Cracking was seen to occur in steel 1B789 at a marginally higher arc energy

than that predicted as being safe by the TWI nomogram for a carbon equivalent of 0.43 (Figs. 2 and 5). Steel 1B704 (0.40 CE_{IIW}) showed a single cracked weld at an arc energy assumed to be safe, according to the TWI predictive scheme (Fig. 3), while steel 1B457 produced cracking in three test welds at conditions also predicted to be safe by the nomogram — Fig. 5. However, the other steels behaved in accordance with the TWI predictive scheme. Indeed, for steels 1B885, 1B859 and 1B485, which corresponded to carbon equivalents of 0.31, 0.33 and 0.37, respectively, no HAZ cracking could be produced, even when the lowest practicable arc energies (~0.8 kJ/mm) were employed.

In three steels for which a crack threshold could be established, the critical HAZ hardness at which cracking occurred (defined as the lowest value of maximum hardness in a cracked sample, HV_{crit}) was observed to vary between 376 and 437 HV5 and generally appeared to decrease with lower CE_{IIW} — Fig. 6. However, for steel 1B704 where a single cracked weld was observed, this cracking occurred at a maximum HAZ hardness of 296 HV5.

CTS Test Data with Moisture Contamination

All CTS test weld results with moisture contamination are presented in Tables 11 and 12 for each steel composition examined. The cracking behavior is presented graphically in Fig. 7. The highest arc energy at which cracking was observed under dry conditions is also plotted.

For the steel of lowest carbon equivalent, 0.33 (1B859), no HAZ cracking was observed, even when consumables with a potential hydrogen level of 4.4 mL H_2/100 g (when used in nominally dry conditions) were employed to weld a block covered with frost. The combination of frost, no preheat and use of the highest Scale D consumable (4.4 mL H_2/100 g) constitutes the worst case examined, but cracking was not induced for the lowest practicable arc energy.

The lowest uncracked result for the CTS tests performed on steel 1B433 of 0.43 CE_{IIW} was observed to be at 1.46 kJ/mm. This is ~0.2 kJ/mm higher than that observed for the same steel/consumable combination when welding was performed without contamination and does not represent a significant effect of surface moisture.

Metallographic Observations of Transverse CTS Test Specimens

CTS welds made by the SMAW and FCAW processes showed similar flat or convex bead surface profiles. However, the root geometries for both processes were often different as shown in Fig. 8A and B. The flux cored wire welds invariably showed an acute angle between the weld metal and top plate in the root region of the vertical leg of the CTS test block. This was always an obtuse angle in shielded metal arc welds. When heat-affected-zone cracking was observed, it was always in the vertical leg of the fillet weld and initiated at the root region in the grain-coarsened HAZ.

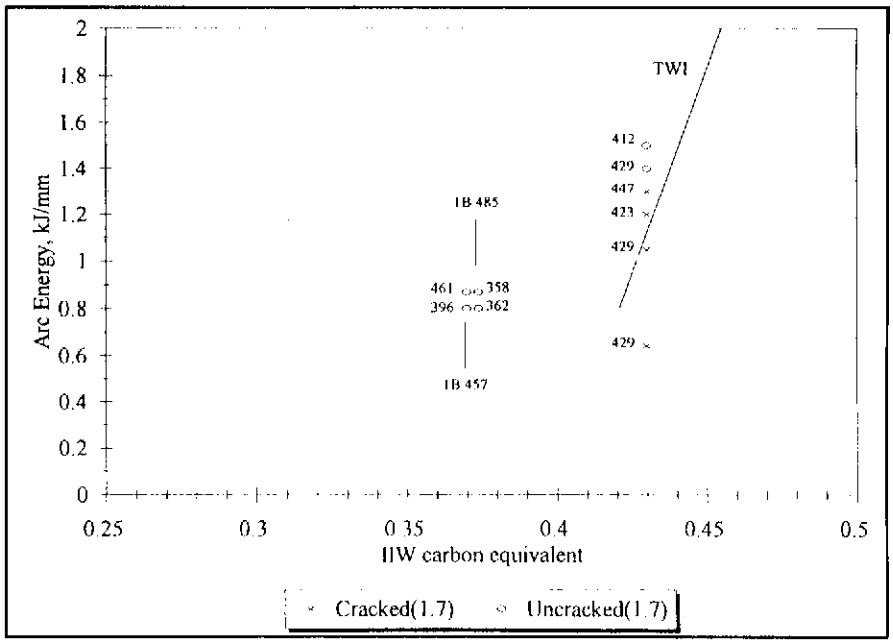

Fig. 2 — Controlled thermal severity test cracking data (150 mm combined thickness, no preheat, FCAW, 1.7 mL H_2/100 g).

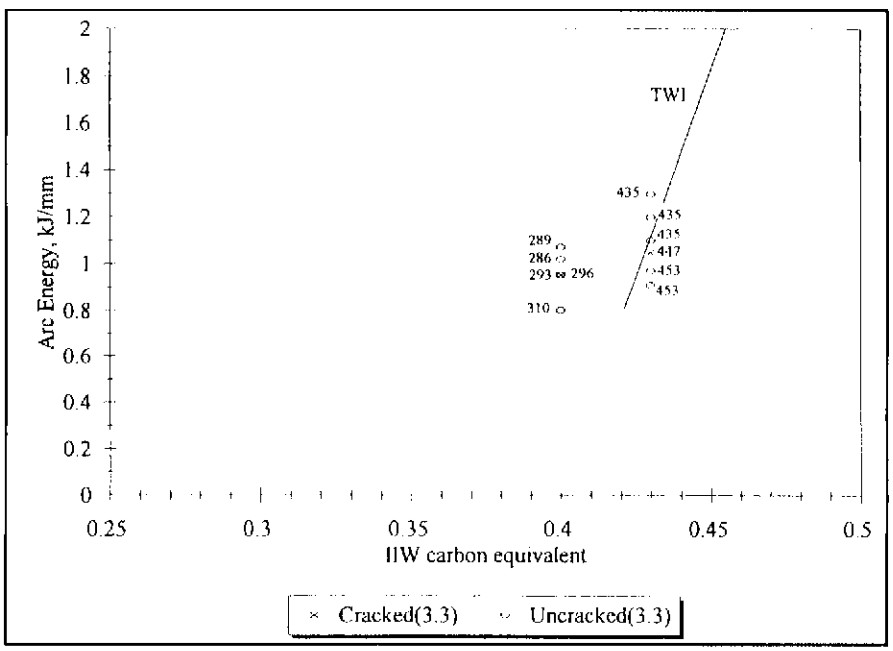

Fig. 3 — Controlled thermal severity test cracking data (150 mm combined thickness, no preheat, SMAW, 3.3 mL H_2/100 g).

Discussion

Comparison of CTS Test Results with TWI Predictive Scheme

The CTS results presented in the plots shown in Figs. 2–5 indicated that, in general, good agreement was observed between the HAZ cracking behavior and that predicted by the TWI nomograms. For the Scale D hydrogen level and a combined thickness of 150 mm, the

Table 8 — CTS Test Weld Data for Plate 18704 (50-mm thickness, 150-mm combined thickness, 0.40CE_{IIW})

Weld No.	Diffusible H_2 mL/100 g Deposited Weld Metal	Welding Parameters: Travel Speed, mm/min	Welding Parameters: Arc Energy, kJ/mm	Weld Cooling Characteristics: $Dt_{800-500}$, s	HAZ Hardness HV5[a]	Mean Weld Metal Hardness HV5	HAZ Cracking/No Cracking, C/NC	Proportion of Faces Cracked from a Total of Six
W53	4.4	255	0.89	—	303–252 280	283	NC	0
W52	4.4	246	0.93	—	303–260 285	265	NC	0
W41	3.9	—	0.9	3.0	299–234 268	258	NC	0
W40	3.9	—	1.0	3.2	280–244 263	266	NC	0
W37	3.9	475	1.01	—	296–262 280	268	NC	0
W30	3.3	260	0.8	2.8	310–262 291	286	NC	0
W28	3.3	234	0.95	3	296–274 288	297	C	4
W26	3.3	223	0.95	—	293–249 268	269	NC	0
W24	3.3	203	1.02	—	286–257 269	257	NC	0
W32	3.3	187	1.07	—	289–241 271	286	NC	0

(a) Presented as max.–min. average

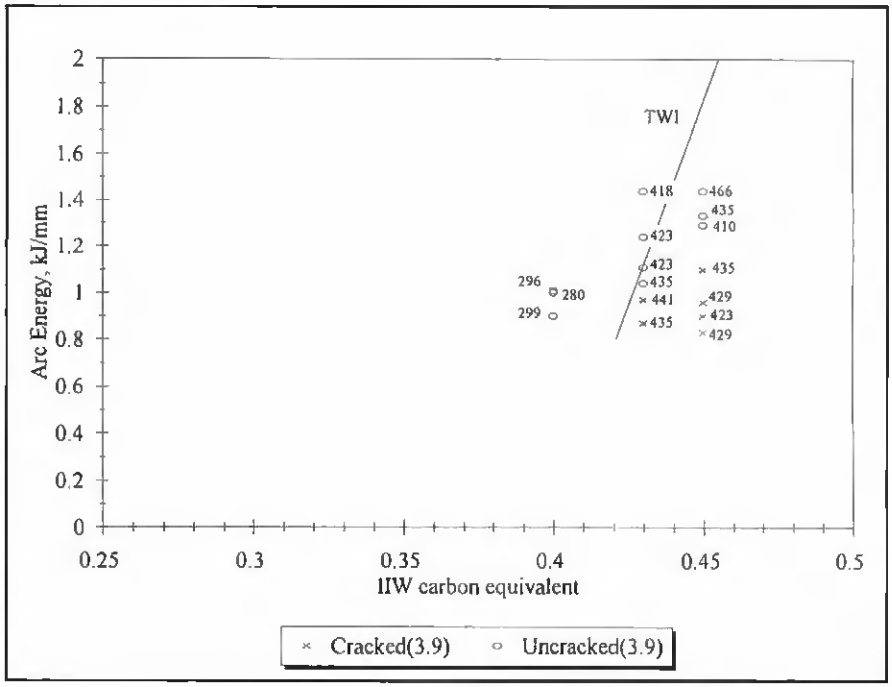

Fig. 4 — Controlled thermal severity test cracking data (150 mm combined thickness, no preheat, SMAW, 3.9 mL H_2/100 g).

scheme predicts HAZ cracking can be avoided without preheat at low arc energies (~0.8 kJ/mm) with steels whose carbon equivalent is less than approximately 0.42. For the majority of situations examined experimentally, this was indeed the case. However, three steels exhibited behavior that required further consideration, and these will be treated individually below.

First, the low-sulfur steel 1B789 (0.43CE_{IIW}, 0.19%C) showed cracking at marginally higher arc energies than predicted when welding was performed with consumables that gave 1.7 mL H_2/100 g deposited weld metal and 4.4 mL H_2/100 g deposited weld metal (Fig. 2 and 5, respectively). However, it should be noted that the cracked result of highest arc energy was only ~0.25 kJ/mm above the TWI "safe" prediction line. To put this in perspective, BS 7363 states that crack/no crack boundaries should preferably be quoted to within 0.3 kJ/mm. Thus, it is questionable whether the behavior of this steel is adequately described by the scheme or not. However, this steel does have a very low sulfur content (<0.002%), and the possible adverse effect of this on the risk of HAZ hydrogen cracking (Ref. 10) has not been taken into account in initially plotting the results in Figs. 2–5. If allowance for a low sulfur effect is taken into account by increasing the carbon equivalent value (Ref. 4 suggests it may be necessary to increase this by 0.03), then the behavior is adequately described.

Another steel that showed apparently anomalous cracking behavior was 1B704 (0.40 CE_{IIW}). Again, this may be considered as a low-sulfur steel for the prediction of weld procedures to avoid HAZ cracking, thus effectively making this a 0.43 CE_{IIW} steel. One incidence of cracking was observed at 0.95 kJ/mm arc energy when welding was performed with the 3.3 mL H_2/100 g deposited weld metal, hydrogen-potential shielded metal arc consumables — Fig. 3. This result is therefore in accordance with the TWI scheme. In addition to the effect of low-sulfur content, however, the high weight percent of nickel and copper (0.80 and 0.94 wt-%, respectively) is also noted in the composition, and this may also have contributed to cracking behavior. Indeed, a steel of this composition was reported by Pargeter and Hart to produce HAZ cracking under conditions not expected based on the TWI nomograms (Ref. 11); it may be that such levels of nickel and copper are not adequately described by the CE_{IIW}.

Finally, the other steel in which HAZ cracking was observed under apparently safe welding conditions was 1B457 (0.37 CE_{IIW}, 0.17 wt-% carbon) — Fig. 5. Notably, cracking was observed only when welding was performed with the consumables that showed the highest hydrogen potential (4.4 mL H_2/100 g deposited weld metal), which still conformed to Scale D. Also, the maximum HAZ hardnesses observed with this steel were significantly higher than those of similar carbon equivalent steels used in this

work. From consideration of the maximum hardness values obtained for a given cooling rate, it would appear that the hardenability of this steel is close to or beyond the upper hound of behavior originally introduced by Bailey (Ref. 3) into the nomogram scheme. Why this should be is not clear from the chemical analysis of the steel, hut it should be noted that this steel has an untypically high niobium level for today's structural steels, and the steel also has higher carbon and lower manganese levels than are typical of many of today's structural steels. The increased hardenability associated with niobium-containing steels is accounted for in certain other carbon equivalent formulas used to assesss a given steel's weldability (Refs. 12–14).

To summarize, the present CTS test work for combined thicknesses up to 150 mm has confirmed that, in general, steels with a low-carbon equivalent can indeed be welded successfully in line with TWI guidelines without the application of preheat when low-hydrogen consumables (<5 mL H_2/100 g deposited weld metal) are used. The data obtained in this work consolidate the limited CTS data previously acquired at TWI for identical plate thicknesses and hydrogen levels without preheat (Ref. 15). No shortcomings in the TWI predictive scheme were highlighted by the previous work, although only two steels were investigated. It would be expected that, as the hydrogen level of the consumable is lowered, the cracking tolerance of hard heat-affected zones would increase, *i.e.*, the critical hardness for cracking would be expected to rise. Comparison of the critical hardnesses measured in the present work with those obtained for test welds deposited with Scale B (~12 mL/100 g) shown in Fig. 9 do indicate that this expected trend has been observed (Ref. 16).

Table 9 — CTS Test Weld Data for Plate 1B789 (50-mm thickness, 150-mm combined thickness, 0.43CE_{IIW})

Weld No.	Diffusible H_2 mL/100 g Deposited Weld Metal	Welding Parameters: Travel Speed, mm/min	Welding Parameters: Arc Energy, kJ/mm	Weld Cooling Characteristics: $\Delta t_{800-500}$ s	HAZ Hardness HV5 [a]	Mean Weld Metal Hardness HV5	HAZ Cracking/No Cracking, C/NC	Proportion of Faces Cracked from a Total of Six
W12	4.4	187	1.13	—	429–401 / 416	277	NC	0
W18	4.4	180	1.22	4.4	435–367 / 413	275	C	4
W19	4.4	167	1.3	5.2	423–391 / 412	261	NC	0
W14	4.4	173	1.32	—	418–376 / 402	258	C	2
W21	4.4	156	1.4	4.8	435–401 / 419	258	NC	0
W16	4.4	156	1.45	—	404–353 / 388	255	NC	0
W17	3.9	246	0.87	2.8	435–407 / 419	283	C	5
W15	3.9	234	0.97	—	441–388 / 406	257	C	6
W11	3.9	213	1.04	—	435–423 / 429	281	NC	0
W13	3.9	187	1.11	—	423–396 / 414	281	NC	0
W22	3.9	167	1.24	5	423–274 / 356	263	NC	0
W20	3.9	156	1.44	—	418–268 / 353	236	NC	0
W27	3.3	234	0.91	2.8	453–412 / 431	325	NC	0
W25	3.3	223	0.97		453–362 / 404	280	NC	0
W23	3.3	195	1.05	—	447–386 / 416	313	C	4
W33	3.3	187	1.1	—	435–310 / 378	286	NC	0
W31	3.3	173	1.2	4	435–371 / 398	275	NC	0
W29	3.3	167	1.3	—	435–407 / 421	277	NC	0
W36	1.7	675	0.64	—	429–295 / 349	338	C	6
W35	1.7	491	1.05	—	429–274 / 381	303	C	6
W38	1.7		1.2	4	423–286 / 371	287	C	5
W39	1.7	No data	1.3	4	447–310 / 368	280	C	4
W43	1.7	350	1.4	—	429–353 / 389	264	NC	0
W42	1.7	323	1.5	—	412–317 / 370	289	NC	0

(a) Presented as max.–min. / average

Comparison of SMAW and FCAW Processes

Steel 1B789 produced similar crack/no-crack boundary conditions of ~1.3 kJ/mm for both the flux cored arc welds at 1.7 mL H_2/100 g and the shielded metal arc welds at 4.4 mL H_2/100 g, while some reduction in critical arc energy might reasonably have been expected. As was noticed earlier, the root profiles of the test fillet welds were different for both processes. The acute angle observed between the weld metal and top plate of flux cored arc welds represents an increased local stress concentration in comparison to the same region for shielded metal arc welds — Fig. 8. This may be an explanation for the absence of an improvement in the cracking risk of the lower hydrogen flux cored arc welds relative to the shielded metal arc welds referred to above. Thus, until more data have been generated, these results suggest that some caution should be exercised when developing weld procedures for this process.

CTS Test Results with Moisture Contamination

Turning now to the CTS test welds that were deposited with moisture contamination, the results are plotted in Fig. 7. Testing performed on the 1B433 (0.45 CE_{IIW}) steel showed the presence of water contamination prior to welding only shifted the crack/no-crack threshold from 1.3 kJ/mm to roughly 1.5 kJ/mm for welds deposited using Scale D consumables without preheat. This shift is within the 0.3 kJ/mm tolerance limit for threshold arc energy as defined in BS 7363:

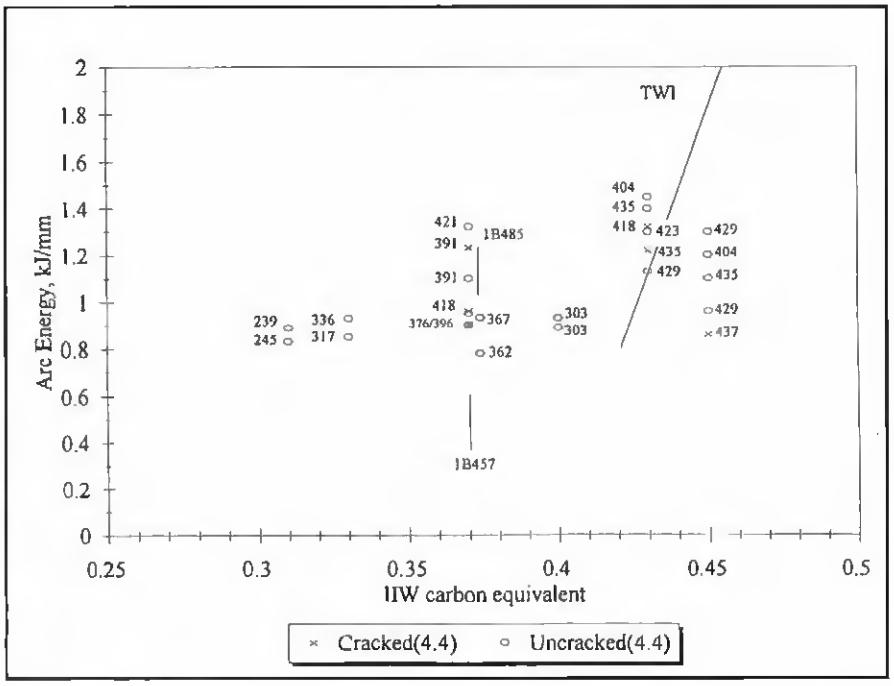

Fig. 5 — Controlled thermal severity test cracking data (150 mm combined thickness, no preheat, SMAW, 4.4 mL H_2/100 g).

Table 10 — CTS Test Weld Data for Plate 18433 (50-mm thickness, 150-mm combined thickness, 0.45CE_{IIW})

Weld No.	Diffusible H_2 mL/100 g Deposited Weld Metal	Welding Parameters: Travel Speed, mm/min	Welding Parameters: Arc Energy, kJ/mm	Weld Cooling Characteristics: $\Delta t_{800-500}$, s	HAZ Hardness HV5[a]	Mean Weld Metal Hardness HV5	HAZ Cracking/No Cracking, C/NC	Proportion of Faces Cracked from a Total of Six
W1	4.4	260	0.86	—	437–387 / 422 (HV10)	302 (HV10)	C	1
W7	4.4	234	0.96	—	429–401 / 419	291	NC	0
W5	4.4	195	1.1	4	435–407 / 423	321	NC	0
W3	4.4	180	1.2	4.8	404–371 / 392	270	NC	0
W9	4.4	167	1.3	—	429–407 / 416	271	NC	0
W2	3.9	260	0.83	3.3	429–389 / 409	295	C	5
W10	3.9	246	0.9	—	423–386 / 411	283	C	5
W8	3.9	234	0.96	—	429–412 / 422	281	C	3
W6	3.9	195	1.1	4	435–412 / 422	284	C	4
W4	3.9	161	1.29	—	410–376 / 388	256	NC	0
W64	3.9	166	1.33	—	435–407 / 423	265	NC	0
W65	3.9	150	1.44	4	466–407 / 429	263	NC	0

(a) Presented as $\frac{\text{max.–min.}}{\text{average}}$

1990. In this context it should be noted that the appreciable quantity of surface water only led to an increase of ~1 mL H_2/100 g in deposited weld metal diffusible hydrogen giving 4.9 mL H_2/100 g, still just meeting Scale D. Further indications of a minimal effect of surface moisture were demonstrated by the uncracked results obtained in steel 1B859 (0.33 CE), which was successfully welded with 0.9 kJ/mm arc energy. Observation of the welding operation revealed that most surface moisture was evaporated by heat from the arc before deposition of weld metal. This could account for the small increase in diffusible weld metal hydrogen observed despite the apparently appreciable surface coverage of water. While it is clearly not good general practice to weld on joint preparations contaminated by moisture or even frost, these results indicate that the concern to use preheat to "dry the plate," even when preheat is not needed for cooling rate control to avoid cracking, may have been unduly highlighted.

Overall Status and Practical Implications

The results obtained in the present work have highlighted the benefits of employing low-hydrogen consumables in order to carry out the welding of structural C-Mn steels without preheat. In addition to using a low-hydrogen potential wire/electrode, the benefit of low-carbon equivalent steels has also been substantiated if welding is to be successfully performed without preheat. The guidelines presented in the TWI nomograms would thus appear to be a good starting point for generating safe welding procedures without preheat that avoid HAZ cracking. The present results have also served to remind that low sulfur levels may increase the risk of HAZ hydrogen cracking and that due consideration of this possibility should be given when devising welding procedures.

The present study has been aimed at validating guidelines for the avoidance of HAZ hydrogen cracking at low hydrogen levels, but due consideration must also be given to avoiding weld metal hydrogen cracking. Certainly for welding C-Mn steels, general experience is that welding procedures devised to avoid HAZ cracking will also avoid weld metal hydrogen cracking, although standards such as BS 5135 (Ref. 2) and pr EN 1011 (Ref. 5) give guidance as to when these general rules may not apply. If very low-hydrogen-level (<5 mL H_2/100 g) consumables are being used to avoid the need for preheat to prevent HAZ hydrogen cracking, this will obviously benefit the avoidance of weld metal hydrogen cracking. Indeed,

Pargeter's data indicate that for C-Mn steel weld metals, the weld metal cracking risk at Scale D (<5 mL H_2/100 g) hydrogen level is low such that preheat is not needed (Ref. 17). For the welding of high-strength steels with alloyed weld metal, however, this is less likely to be the case unless hydrogen levels much less than 5 mL/100 g — perhaps of the order of the proposed Scale E (<3 mL H_2/100 g) — are used (Ref. 5). However, there are currently few data for higher strength steels for a firmer statement to be made.

Summary and Conclusions

A series of CTS tests has been performed on seven C-Mn steels with carbon equivalents 0.31–0.45 CE_{IIW}. Shielded metal arc welds and flux cored arc welds were deposited onto 50-mm-thick plates using consumables that conformed to the Scale D hydrogen level. An assessment of the HAZ cracking behavior has been made and compared to previous relevant data, in particular to predictive nomograms developed at TWI. In addition, further CTS testing was performed using identical materials with test blocks that were covered with various degrees of moisture. The following conclusions were derived from the work:

1) Heat-affected-zone hydrogen cracking can be avoided in some steels with a low carbon equivalent when welded at combined thicknesses of up to 150 mm (6 in.) without preheat using very low-hydrogen consumables, *i.e.*, giving <5 mL H_2/100 g deposited weld.

2) The HAZ cracking behavior at very low consumable hydrogen levels (<5 mL H_2/100 g) of a range of old and modern C-Mn steels was found to be generally satisfactorily described by the TWI predictive scheme, although recognition of the adverse effects of low sulfur level needed to be taken into account.

3) The presence of surface moisture on CTS test blocks just before welding was found to have little or no effect on the risk of HAZ cracking, in agreement with little or no effect on measured weld hydrogen level. However, this does not negate the need to follow general good practice in respect of cleanliness and freedom from moisture on weld preparations.

4) Limited tests with a very low (1.7 mL H_2/100 g) hydrogen flux cored arc weld showed no reduction in the risk of cracking compared to tests made with an SMAW consumable giving 4.4 mL H_2/100 g. This may be due to a more severe root stress concentration observed in the flux cored arc welds. Further testing is needed to establish if the behavior of flux cored arc welds is significantly different than that of shielded metal arc welds.

Table 11 — CTS Test Data for Plate 1B859 (50-mm thickness, 150-mm combined thickness, $0.33CE_{IIW}$) Welded with Moisture Contamination Using Consumables That Gave 4.4 mL/100 g under Dry Conditions

		Welding Parameters		Weld Cooling Characteristics				
Weld No.	Nature of Moisture Contamination	Travel Speed, mm/min	Arc Energy, kJ/mm	$\Delta t_{800-500}$, s	HAZ Hardness HV5	Mean Weld Metal Hardness HV5	HAZ Cracking/No Cracking, C/NC	Proportion of Faces Cracked from a Total of Six
W48	Dew (13°C)	240	0.9	—	313-289/304	257	NC	0
W49	Dew (13°C)	240	0.93	—	329–285/304	263	NC	0
W50	Dew (6°C)	234	0.9	—	321–282/304	262	NC	0
W51	Frost (–1°C)	240	0.94	2.9	332–265/313	271	NC	0

* Presented as max.–min./average

Table 12 — CTS Test Data for Plate 1B433 (50-mm thickness, 150-mm combined thickness, $0.45CE_{IIW}$) Welded with Moisture Contamination Using Consumables That Gave 3.9 mL/100 g under Dry Conditions

		Welding Parameters		Weld Cooling Characteristics				
Weld No.	Nature of Moisture Contamination	Travel Speed, mm/min	Arc Energy, kJ/mm	$\Delta t_{800-500}$, s	HAZ Hardness HV5	Mean Weld Metal Hardness HV5	HAZ Cracking/No Cracking, C/NC	Proportion of Faces Cracked from a Total of Six
W68	Water droplets	192	1.16	—	450–381/420	262	C	2
W67	Water droplets	180	1.25	—	447–371/429	270	C	4
W69	Water droplets	152	1.46	—	429–401/420	273	NC	0
W66	Water droplets	133	1.61	—	429–407/415	256	NC	0

* Presented as max.–min./average

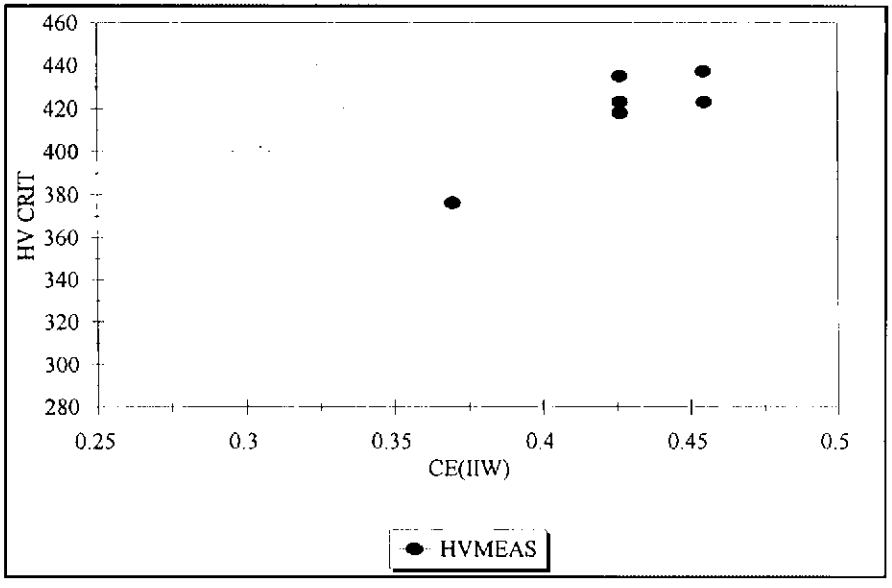

Fig. 6 — Critical hardness to cause cracking from CTS test without preheat.

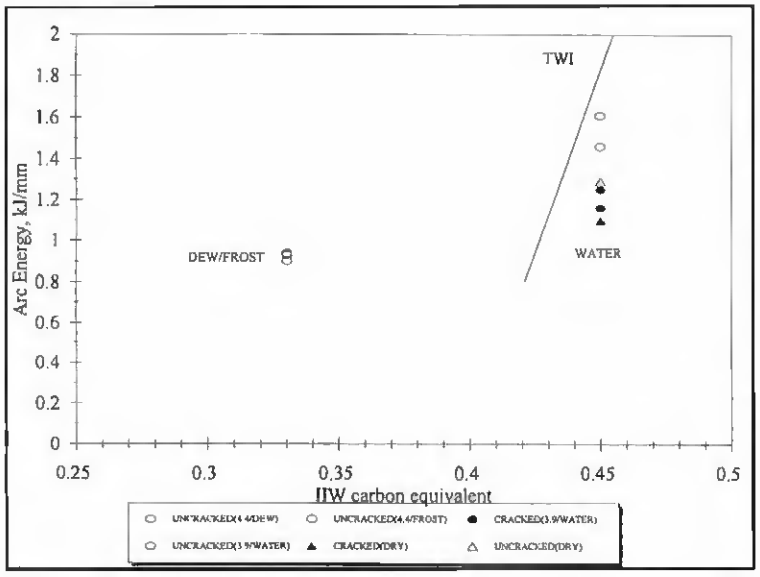

Fig. 7 — Controlled thermal severity test cracking data with moisture contamination (150 mm combined thickness, no preheat, SMAW, Scale D).

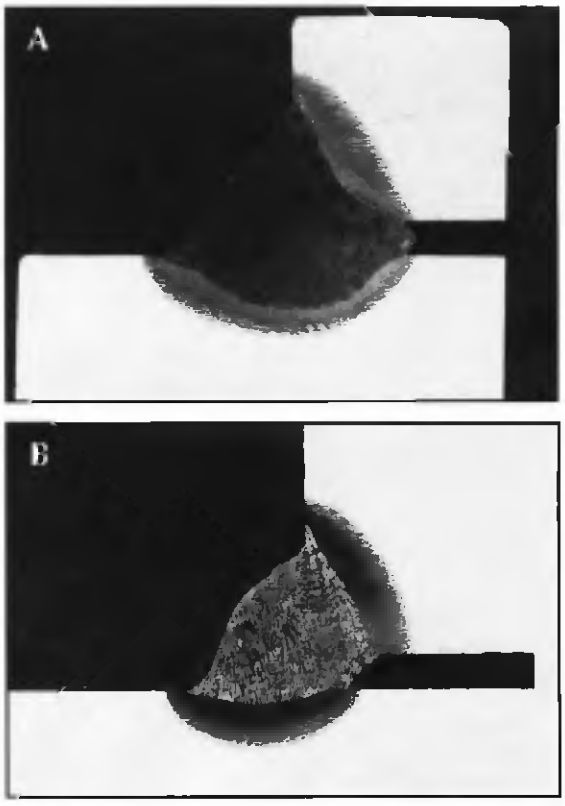

Fig. 8 — Macrographs showing cross sections of CTS welds. A — FCAW, 1.2 kJ/mm arc energy; B — SMAW, 1.2 kJ/mm arc energy.

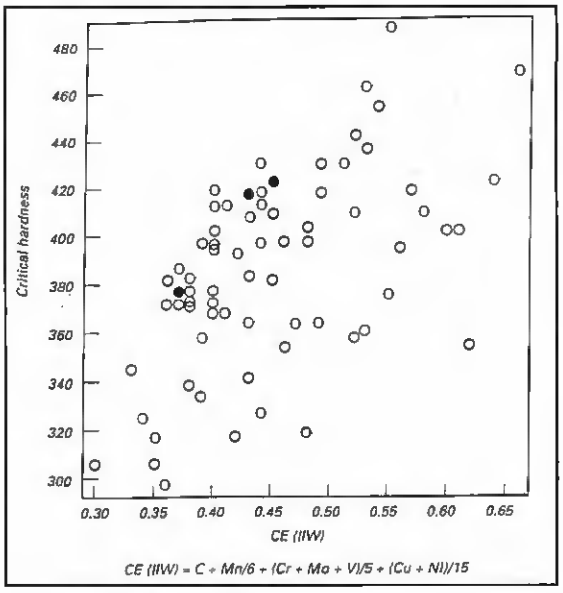

Fig. 9 — Critical hardness vs. CE_{IIW} for CTS test data at Scale B hydrogen level. Filled circles represent data from present work.

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Image-Based Penetration Monitoring of CO_2 Laser Beam Welding

Characteristics of the weld pool and plasma plume as viewed through a dual-camera system indicate degrees of weld joint penetration

BY R. K. HOLBERT, R. W. RICHARDSON, D. F. FARSON AND C. E. ALBRIGHT

ABSTRACT. A dual-camera video system was developed to provide real-time information about the penetration modes of CO_2 laser beam welding for process quality monitoring and control. An experiment was designed to vary the penetration modes during welding by continuously changing the focal point position at different power levels and travel speeds. A study of the video images of the weld pool/keyhole region identified three types of weld pools: flat, depressed and keyhole. Images of the plasma plume revealed that a wispy, diverging fantail-shaped plume corresponded to the steady-state, flat and weakly depressed weld pools. As the power density and weld penetration depth increased, the diverging fantail plume changed to a concentrated columnar shape. A keyhole cavity was initiated when the diameter of the base of the columnar plume at the coupling spot (beam/material interaction site) and the calculated beam spot size were identical. Video images of the events during transition into and out of the keyhole mode from two vantage points were studied to identify features indicative of the presence of a keyhole. Keyhole welds were associated with a very intense columnar plume, elevated weld pool rim and several other visual cues. The unique perspective produced by the dual-camera video system could provide the basis for an in-process penetration control strategy and add to understanding of the physical processes that affect laser welding penetration mode and pool/plume dynamics during CO_2 laser welding.

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Introduction

An important feature of continuous-wave, carbon dioxide (CO_2) laser welding is the ability to vary power density on the material surface over wide ranges by varying beam focus and power. Focusing the beam to a very small, high-power-density spot leads to the formation of a vapor cavity and a deep, narrow "keyhole-mode" weld. The high travel speeds and low thermal distortion associated with this welding mode give keyhole laser welding important advantages over other welding processes in certain applications. On the other hand, shallow conduction-mode laser welds generated at lower power densities are advantageous for surfacing applications where minimal penetration is usually desired.

The welding mode and the weld penetration depth in either mode are determined primarily by power density at the material surface, travel speed, base material properties and gas shielding. Since a number of these process inputs are susceptible to variation, process monitoring and feedback control to ensure proper welding penetration would be beneficial. In-process measurement of the laser welding mode (whether keyhole or conduction) and penetration depth is currently not possible, but it is vital for successful monitoring and control implementation. These measurements are difficult because of the small size of the laser weld, the harsh environment (smoke, spatter, high temperatures, etc.) and the practical need to make measurements from the topside of the work. Thus, developments in welding mode and penetration depth measurement are critical to the improvement and increased application of in-process laser weld monitoring and control capability. In this investigation, real-time images of the weld pool, keyhole and plume are analyzed to determine what weld mode and penetration information can be extracted from them.

KEY WORDS

Keyhole Mode
CO_2 Laser
Camera System
Monitoring
Conduction Mode
Weld Penetration

Laser Weld Penetration Monitoring

Techniques that provide direct in-process measurements of laser weld penetration (such as X-ray or ultrasonic sensing) have not been developed to the point that they are generically practical for industrial use. Thus, a popular approach (and the approach taken in this work) is to make measurements of other welding process information that is related to penetration and then infer the state of penetration from these measurements. Past work has been directed at analysis of

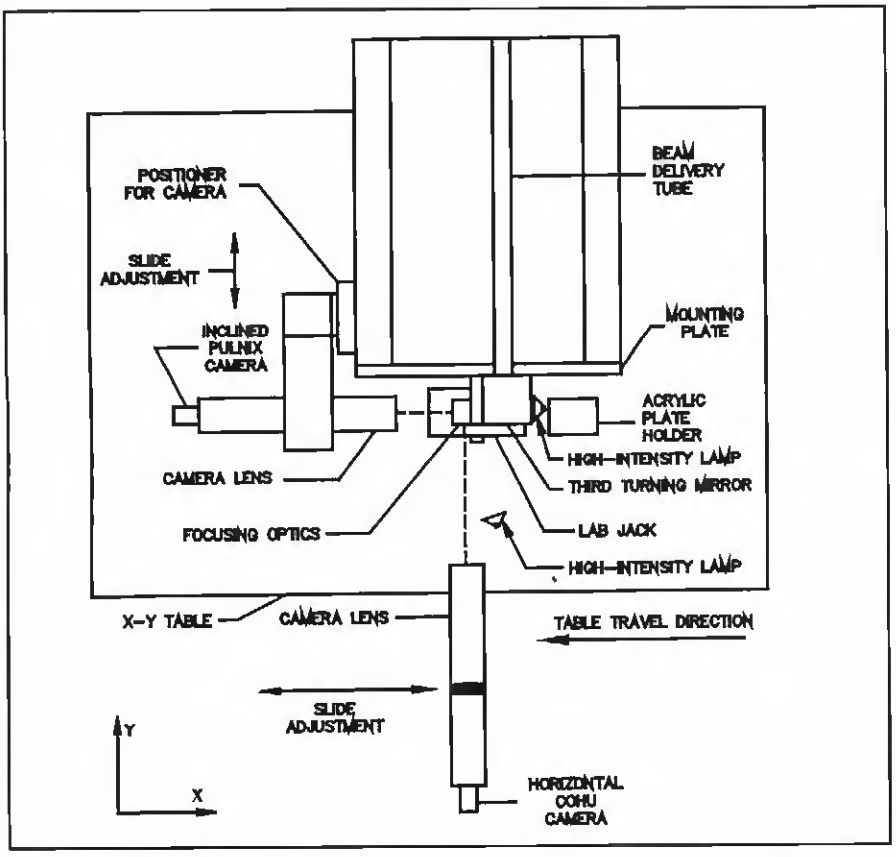


Fig. 1 — Top view of the video imaging equipment.

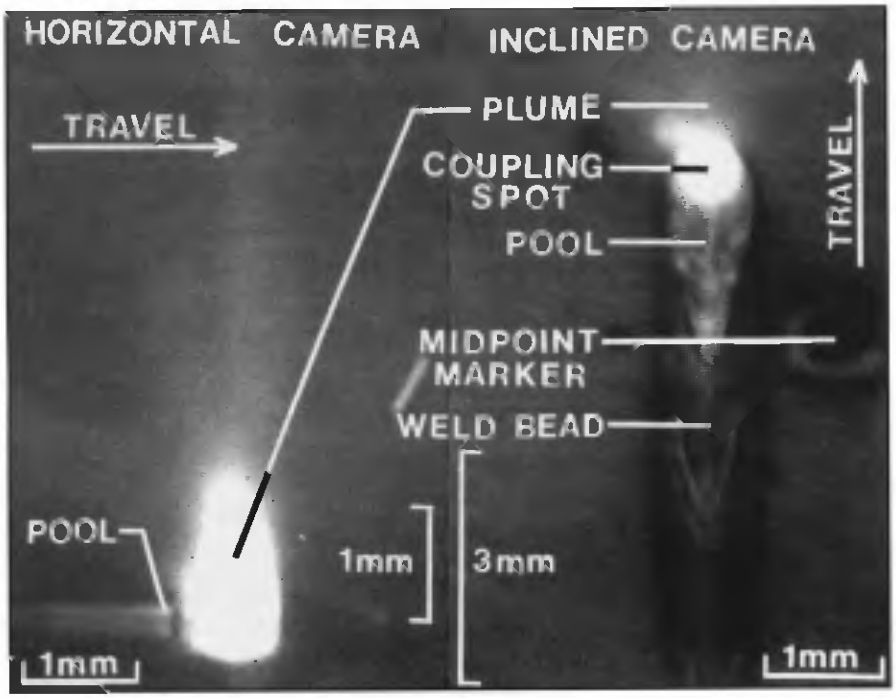


Fig. 2 — Split-screen video image of a 2-kW test weld (7.62 m/min) with the left image supplied by the horizontal camera and the right image supplied by the inclined camera.

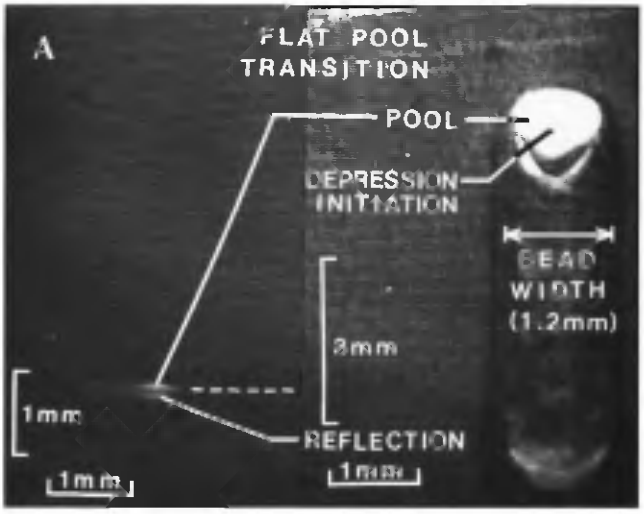
acoustic and optical emissions (Refs 1–3), plasma charge emissions (Refs. 4, 5) and video images of the laser weld pool region. This short review concentrates on the latter since it is most relevant.

Denney and Metzbower (Ref. 6) describe a video system that visually monitors a CO_2 laser welding process. A pulsed, nitrogen laser was synchronized with a charged-coupled-device (CCD) camera to illuminate the weld area for the video images. A narrow-band line filter was used with the camera to allow only the nitrogen laser light (337 nm) to be received by the camera. Elimination of the effect of the plume intensity was not entirely achieved by nitrogen laser light, but the keyhole opening is clearly visible in the recorded images. Voelkel and Mazumder (Ref. 7) report a similar monitoring system that uses a continuous-wave argon laser (488 nm) for illumination. This system was used primarily for surface topography measurements, and the observations were made on shallow penetration laser welds.

Bagger, *et al.* (Ref. 8), describe a video system that was used to determine the penetration characteristics of the CO_2 laser welding of steel in a lap-joint configuration. The system had two CCD cameras providing images of the top and bottom of the weld. The images in their report are clear because an R66 filter (transmitting wavelengths above 660 nm) was used with the topside camera along with a high-intensity lamp for suppressing the intensity of the plume emissions. A green filter was used with the camera mounted backside. Schimon and Mazumder (Ref. 9) used a video system to monitor the interface width of laser lap welds in sheet metal. A CCD camera with external laser illumination was used to obtain measurements of weld bead top width. A number of welds were made over a matrix of power and travel speeds. An empirical relation was fit between the weld top widths and lap-joint interface widths, allowing on-line prediction of interface weld width.

Experimental Apparatus and Procedures

A video system previously developed at The Ohio State University (Ref. 10) was modified to a two-camera system design providing real-time images of the CO_2 laser pool and plasma plume. To investigate the capabilities of this two-camera video system, an experiment was designed to systematically analyze the phenomena occurring during penetration



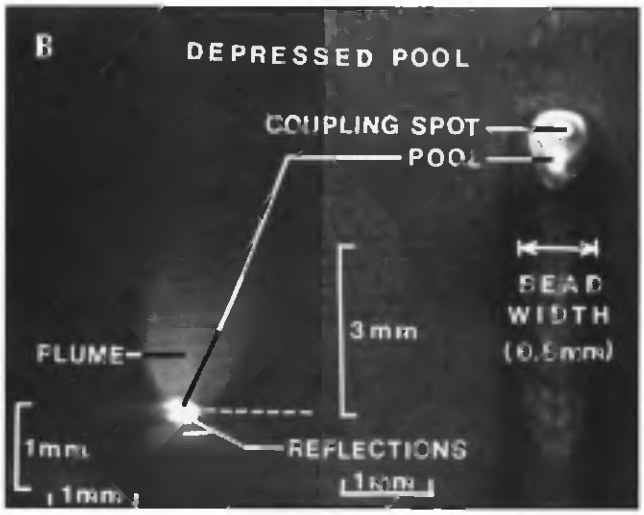


Fig. 3 — Transition from a flat weld pool to a depressed weld pool from a 1.5-kW test weld (2.03 m/min). A — Flat pool image; B — depressed pool image.

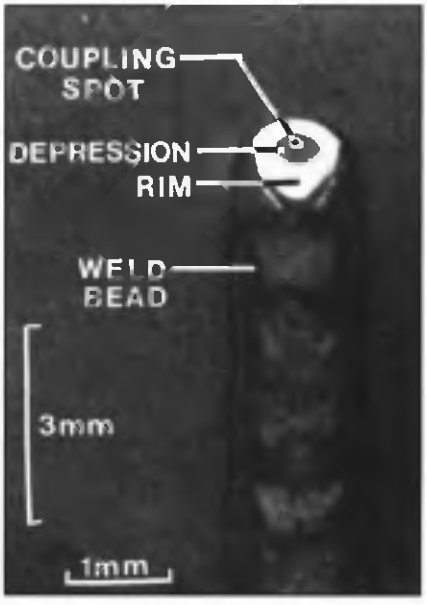


Fig. 4 — Inclined-camera image of a depressed pool from a 1.5-kW test weld (2.03 m/min) showing the coupling spot, the depression and the pool rim.

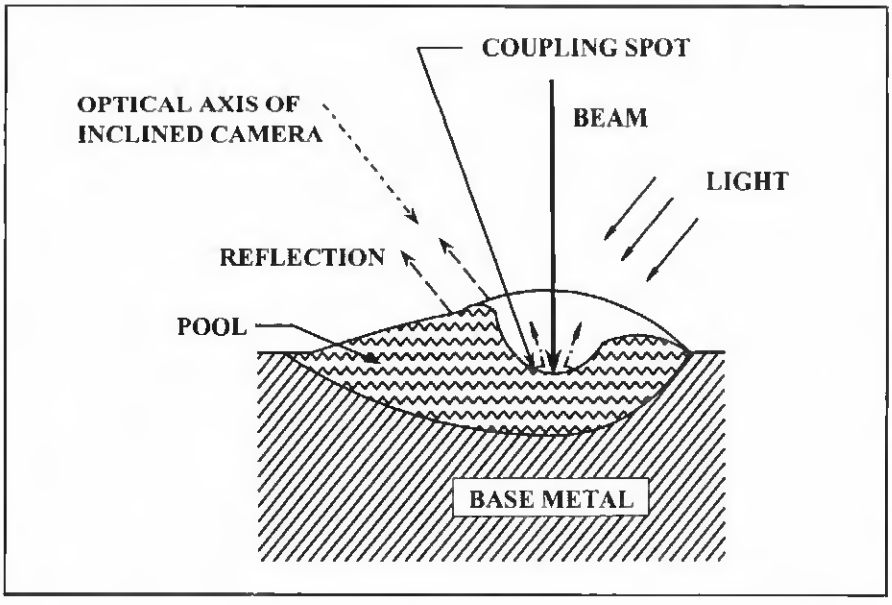


Fig. 5 — Depressed weld pool characteristics.

mode transitions from the video images. Recorded video images captured the dynamic behavior of the plasma and weld pool with power density change and resulting mode transition along the weld.

Video System

The video system recorded images from two camera systems (including CCD cameras, long-distance microscopic lenses and optical filters) and displayed them on a split monitor screen for simultaneous viewing of the weld process from two angles to facilitate analysis. Images from an inclined camera (mounted above and behind the weld at 45 deg to the beam axis in the direction of weld motion, as illustrated in Fig. 1) primarily provided information about pool characteristics, while images from a horizontal camera (mounted transverse to the direction of motion, as illustrated in Fig. 1) contained information about the plasma plume.

Both cameras used long-distance microscopic lenses with an approximate working distance of 305 mm. The camera/lens combination allowed a microscopic observation from a safe distance, protecting the camera and lens from smoke and spatter emitted by the weld. The shutter speed of the inclined camera was $\frac{1}{1000}$ s and that of the horizontal camera was $\frac{1}{2000}$ s. The video frame rate was fixed for both cameras at 30 interlaced frames/s. Quartz projector lamps of 300 W were used to overpower the plasma and thermal emissions so the weld pool could be observed clearly. One lamp was placed above the horizontal camera to illuminate the sample's surface, as shown

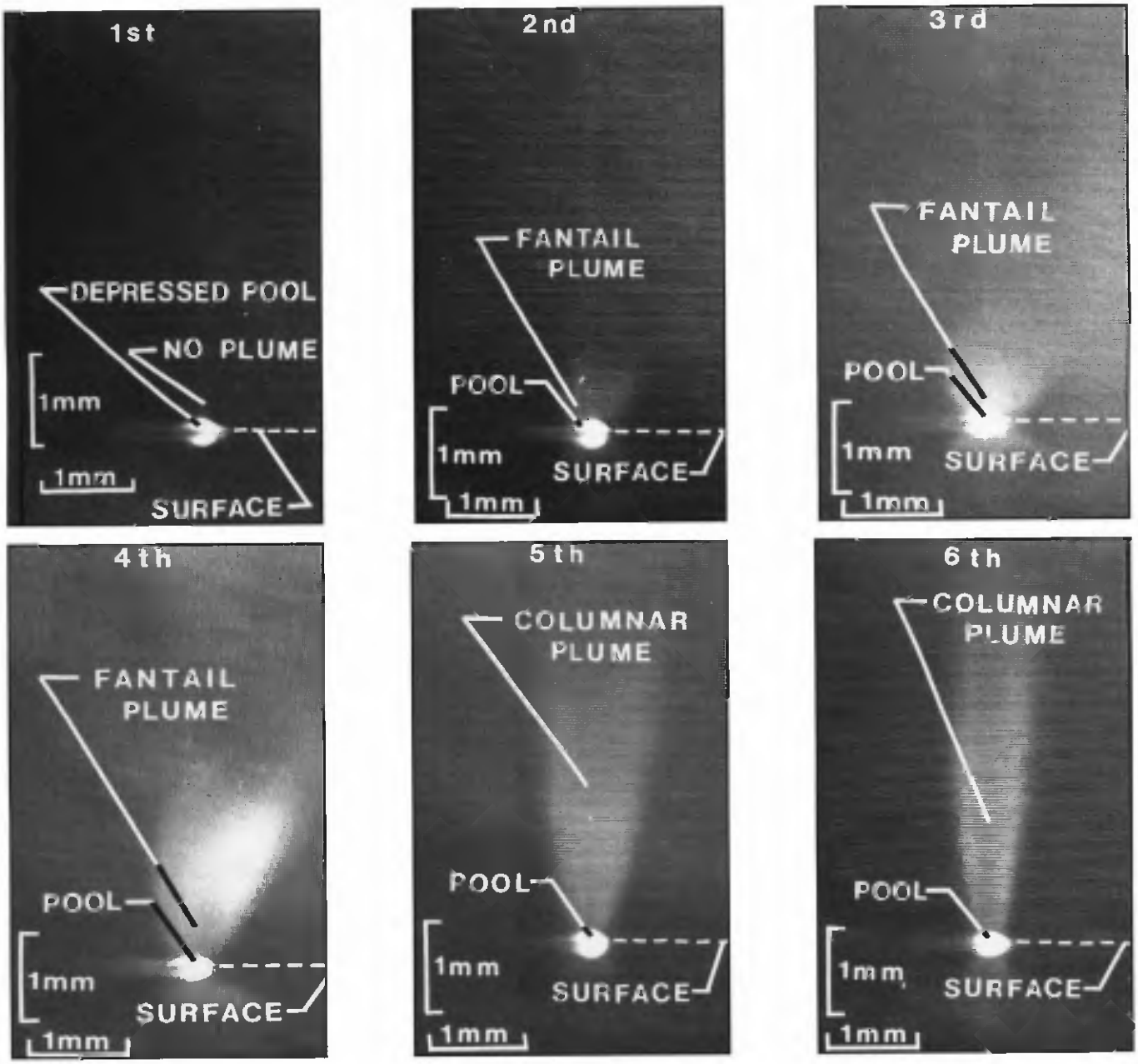


Fig. 6 — Horizontal camera images of plume pattern variations above the depressed pool of a 1.5-kW test weld (2.03 m/min) as the focal point moves closer to the surface.

in Fig. 1. The other lamp was mounted opposite to the inclined camera, also at a 45-deg angle in the weld-axis/beam-axis plane. This lamp provided oblique illumination of the weld area at the angle of maximum specular reflection from the sample surface to the inclined camera to brighten the background area around the intense glow of the plasma and molten metal. The horizontal lamp was less effective for illuminating the background because of its placement, but it did illuminate the weld pool during the tests. A 650-nm (±10 nm) narrow-band pass interference filter was used with the inclined camera. This filter passed the reflected, high-intensity light from the illuminator and blocked much of the keyhole plasma emission that consisted primarily of blue visible light (as determined by the unaided eye). Only a No. 2 neutral density filter was used with the horizontal camera to attenuate the plume light intensity.

The laser apparatus was a 3-kW, CO_2 laser with three programmable axes of motion. The laser equipment included a motorized Z axis that positioned a 150-mm reflective optic for beam focusing relative to the workpiece. Two other rectilinear axes provided part motion under the laser beam. The focal point position could be adjusted during the test weld, and reflective focusing optics minimized the fluctuation of the position caused by thermal distortion of the optic material. Helium shielding gas flowed across the entire top surface of the base material from a plenum incorporated into the weld fixture.

The beam power and travel speed were set prior to each test weld. Type 304 stainless steel sheet samples of thickness 1.5, 3.0 and 6.2 mm were used to obtain both partial and full penetration welds at different power levels. The focusing optics position was varied continuously during each test weld to change the power

density at the sample surface, producing transitions in weld penetration mode. Penetration mode transitions were from shallow, conduction-mode penetration at the weld start to keyhole-mode penetration in the middle, reverting back to conduction-mode near the end of weld. The standoff change magnitude was selected to produce a keyhole weld over roughly one third of the total weld length.

The experimental design was a three-by-five test matrix (three power levels at five travel speeds for each sample thickness), which provided the high and low extremes with some midpoint parameters in the practical envelope of operation, as presented in Table 1. To eliminate any systematic bias in the statistical design of the experiment, test welds were conducted in random order. Each test involved a continuous change of laser beam focus position from above (+) to below (–) the sample's surface. Samples of different thickness were not randomized in the experimental sequence since the change from one thickness to another required a significant amount of setup time.

Focal point position relative to the material surface was measured before each test weld using an acrylic plate beam imprint as described by Arata (Ref. 11).

Results and Discussion

A unique characteristic of the dual-camera video system was its ability to provide observations of the weld pool and plume from two vantage points at approximately the same time. Recorded images capture the changes in the plume and pool during the penetration mode transitions. Figure 2 shows a typical split-screen display of the two-camera image of a laser weld in the keyhole penetration mode.

The left image in Fig. 2 is from the horizontal camera that provided observations of the weld pool and plume transverse to the weld axis. From this viewpoint, the leading edge of the pool in the horizontal-camera image is to the right. The dominant feature in a typical horizontal-camera image is the laser plume, but the molten pool can also be seen protruding above the sample's surface (to the left of the plume). Magnification of these features in the horizontal-camera image was approximately 31:1 of the actual proportions (scale bars are shown to allow estimation of the magnification as-published). The transitions of the plume during the tests are distinct in the horizontal-camera, image but detailed study of the time variation of the plume was precluded by the slowness of the frame rate (30 Hz) relative to plume variation frequencies (which are known to range up to about 15 kHz). The camera used in this investigation "averaged out" the high-frequency plume variations.

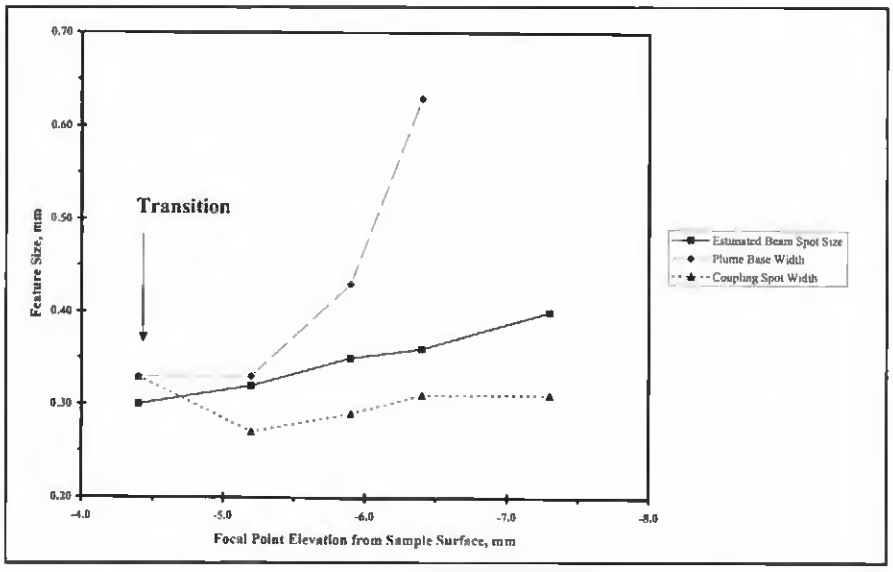


Fig. 7 — Change in the plume base and coupling spot dimensions with increasing beam spot size for a 1.5-kW test weld (2.03 m/min), showing a transition to keyhole mode when the three are roughly equal.

The right image of the video output in Fig. 2 is from the inclined camera with the optical axis at a 45-deg angle from vertical and to the rear of the weld. This camera provides observations of the top of the pool, and the plume is also visible due to the angle of the optical axis. The leading edge of the pool and the direction of travel is toward the top of the inclined-camera image. Some foreshortening of the vertical dimensions of the image results from the angle of inclination; the corrected vertical magnification of the features in the inclined image was approximately 21:1 of the actual dimensions. The magnification of horizontal features in the image was 32:1 of the actual size. A feature that will be termed the "coupling spot" is also labeled in this camera view. In this article, the term coupling spot is used to refer to the highly luminous area where the beam is absorbed by the molten material and its vapor. In keyhole welding mode (which is studied in more detail later), it corresponds to the cavity opening. The coupling spot and the beam spot (intersection of the focused beam and the surface of the workpiece) are also related but are not necessarily identical. Since the plume originates from the coupling spot, the width of the base of the plume and the diameter of the coupling spot should be comparable in the two images. The diameter of the plume base along the X axis in the horizontal-camera image in Fig. 2 is 0.9 mm, which correlates closely with the width of the coupling spot in the inclined-camera image (0.9 mm).

Table 1 — Summary of the Test Parameters Used for the Experimental Welds

Sample Thickness, mm	Beam Power W	Travel Speed m/min	Focal Point Position Relative to the Surface of the Sample
1.5	700	0.25	From
	1100	1.02	+7.6 (above)
	1500	2.03	
		3.81	To
		7.62	–7.6 (below)
3.0	1100	0.25	From
	1500	1.02	+10.2 (above)
	2000	2.03	
		3.81	To
		7.62	–10.2 (below)
6.2	1500	0.25	From
	2000	1.02	+12.7 (above)
	2500	2.03	
		3.81	To
		7,62	–12.7 (below)

Analysis of Conduction-Mode Weld Pool Images

Three distinct weld pool types were identified from the video observations: flat, depressed and keyhole. The first two both fall under the heading of conduction mode welds. These were generated by changes in power density due to the variation of the focal point position during the tests. The smooth, flat pool occurred when the focal point position was

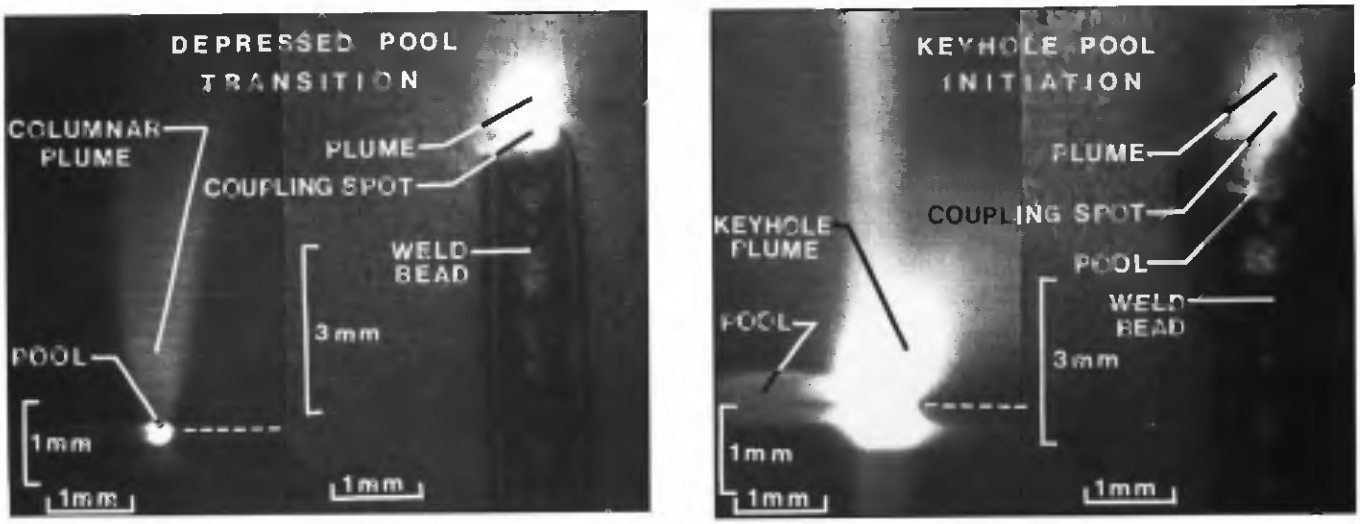


Fig. 8 — The transition from a depressed pool to a keyhole pool for a 1.5-kW test weld (2.03 m/min). A — Depressed pool image; B — keyhole pool image.

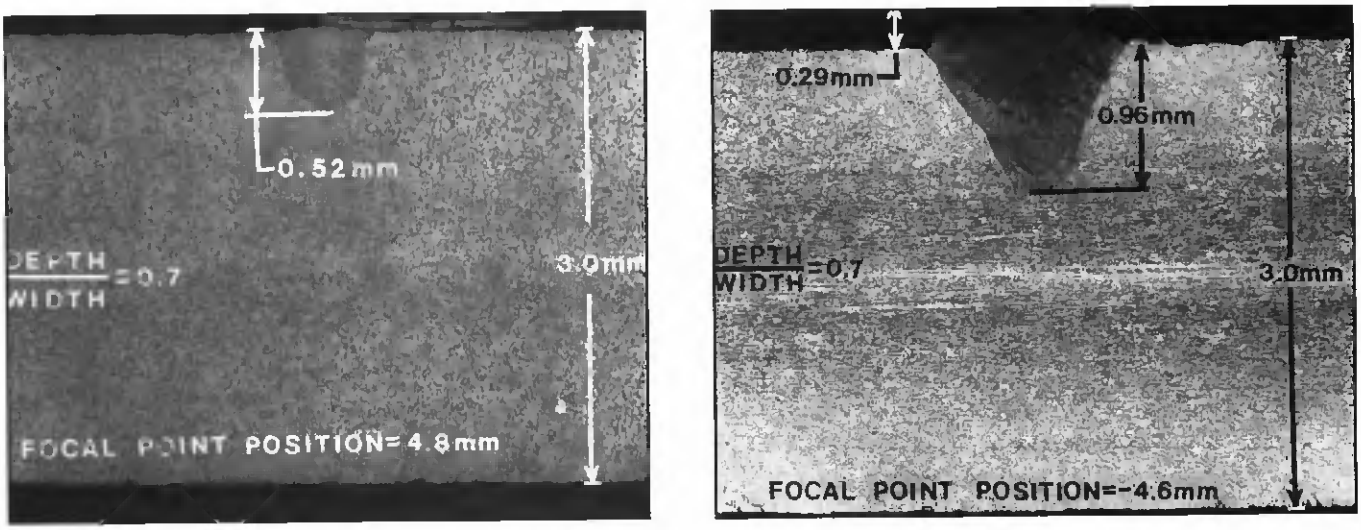


Fig. 9 — Weld cross sections corresponding to plume images shown in Fig. 8. A — Depressed weld; 8 — keyhole weld.

far from the sample's surface, resulting in a low-beam power density. As the focal point approached the sample surface, beam power density increased, creating a gradually deepening depression in the molten pool, which was visible in both camera views. In cases where maximum power density was sufficiently high, an abrupt transition to a keyhole weld with a large, turbulent pool was observed.

Video recordings showed a depressed pool occurred in all of the test welds. Figure 3 shows the transition from a flat pool to a depressed pool in a 1.5-kW test weld. The pool in the top horizontal-camera image of Fig. 3 is flat with an insignificant pool height. A small depression just forming in the molten pool is seen as a faint, dark semicircle in the pool (barely visible in the inclined-camera image of the top photograph). The dark area denotes an inclined surface that reflects light away from the inclined camera. A uniform, specular reflection is characteristic of the remainder of the pool, which is interpreted as a smooth surface. No plume was visible over the flat pools, but as power density increased and the pool surface became depressed, a faint plume appeared and gradually increased in brightness. In most cases, propagation of the columnar plume was not exactly along the beam axis but slightly tilted away from the axis. The weld pool in the bottom horizontal-camera image (after the flat-to-depressed transition) is an elliptical glow 0.2 mm above the sample surface with its reflection below the surface. In the bottom inclined-camera image of Fig. 3, the leading portion of the slender teardrop-shaped depressed pool contains the coupling spot and the depression with a uniformly smooth surface in the aft section of the pool. The bottom horizontal-camera image in Fig. 3 shows a wispy fantail-shaped plume

The transition to a depressed pool was somewhat erratic. The depression in the pool generally formed, disappeared and reformed a number of times before achieving a stable depressed-pool state. A decrease of the weld bead width (from 1.2 to 0.8 mm) occurred with the transition from a flat pool to a depressed pool. Initially, the weakly depressed-pool plume had a fantail shape, which evolved into a columnar shape as the power density increased. Stabilization of the depressed pool generally occurred

when the plume was visibly present.

In the depressed-pool images from both cameras, the features of primary interest are the plume, pool and coupling spot. Observations of the plume could be made from the horizontal and inclined images. The pool was also identifiable in both camera images, but the coupling spot was visible only in the inclined-camera images. The depressed pool appeared to be concave at the CO_2 laser beam/material interaction location. This observation agrees with the conclusions of Voelkel and Mazumder (Ref. 7) based on their video images of conduction-mode welds. Three regions of the depressed pool were identified in the inclined-camera images: the rim, the depression and the coupling spot. Figure 4 shows the coupling spot in the upper portion of the depressed pool surrounded by a dark band and then a very bright outer ring (teardrop shaped) in the inclined-camera image of a 1.5-kW test weld. The bright outer ring is interpreted to be the flat, tranquil upper rim of the pool, projecting above the sample's surface. Where the inclination angle of the depression walls is unfavorable for light reflection into the camera, a dark band can be seen in the pool. A bright nucleus is evident at the center of this dark depression. This bright spot is identified as the coupling spot and is accentuated in the darkness of the depression in the inclined-camera images.

Based on video images of depressed pools, the illustration in Fig. 5 depicts the depressed pool relative to the laser beam, the high-intensity lighting and the optical axis of the inclined camera. The outer portion of the molten pool forms a rim around the shallow depression, which is in the interior of the pool located near the leading edge. Since the coupling spot is at the center of the depression, the depression and coupling spot are apparently centered on the beam axis. This observation agrees with the findings of Voelkel and Mazumder (Ref. 7). Illumination of the rim is by the auxiliary lighting opposite the inclined camera. This light is specularly reflected toward the inclined camera, but the walls of the depression are not at the appropriate angle for reflection. Thus, the depression appears dark in the images with the bright coupling spot in the center. Figure 5 shows the highest location on the rim is on either side of the depression where the Y-Z plane passes through the beam axis. The center of the coupling spot and the lowest point in the depression occur at the intersection of the beam axis and this Y-Z plane. It appears that this location on the rim is composed of the displaced molten metal from the depression in the pool.

Figure 6 shows six successive (but noncontiguous) horizontal-camera images of the plume transformation over the depressed pool for a 1.5-kW test weld with a travel speed of 2.03 m/min. During the time spanned by the six images, the focal point position approached the surface from an elevation of +10 mm (above the surface) in the first image to +4 mm in the last image. There was no plume present in the first image when the pool initially changed from the flat pool to a depressed pool. A slightly crowned appearance of the pool is the only indication the pool was not completely flat.

The focal point position was closer to the surface in the second image, and the increased power density resulted in the formation of a weak, wispy, fantail-shaped plume over the depressed pool. In the third and fourth images, the fantail plume developed into a more distinct vapor cloud and began to increase in height as the spot size became continuously smaller. Finally, the fantail plume concentrated into a columnar shape, as seen in the fifth image. The sixth image shows the weld just before initiation of the keyhole cavity, when the beam waist was 4.0 mm above the material surface. The columnar plume was more slender and slightly taller than in the previous images. No significant change was observed in the diameter of the coupling spot throughout the sequence, even though the beam spot size and the width of the plume base decreased.

During the image sequence shown in Fig. 6, cross section measurements (repeated for two welds with the same parameters) revealed the weld pool penetration increased from 0.38 mm to 0.52 mm. Thus, the plume shape (divergence angle) and height are both observables that could correlate to power density and weld depth in conduction-mode welds. Additional tests are required to quantify the relationship and determine the accuracy of penetration estimates obtained from plume-shape measurements.

Comparing the sizes of the various features in the conduction-mode weld images, a relationship that consistently predicted the transition to or from keyhole-mode welding was noted. Figure 7 summarizes this result. The figure plots the dimensions of three features measured in a sequence of images taken as a weld transitioned from keyhole to depressed mode when the focal position moved from –4.4 to –7.3. Prior to the welding mode transition, the coupling spot diameter, estimated beam spot diameter and plume base diameter were all approximately equal. This relationship is potentially useful in determining when a weld is about to switch in or out of keyhole mode.

Comparison of Keyhole- and Conduction-Mode Weld Images

Image observables that are potentially useful for detecting keyhole weld formation were determined by studying pictures taken just before and after the transition to and from keyhole welding. Figure 8 shows one video image taken just at the instant of the depressed-to-keyhole transition and another a few video frames later. Figure 9 shows weld cross photographs corresponding to the plume images in Fig. 8. A columnar plume is evident in the horizontal-camera image and is representative of the depressed pool prior to the keyhole cavity formation. However, an intense glow denotes a keyhole plume was beginning to develop in the inclined-camera image. The weld cross section in Fig. 9A shows a very deeply depressed conduction mode weld pool. Images at the bottom of Fig. 8 show the keyhole pool and plume as they were beginning to stabilize. An extremely bright, dynamic keyhole-pool plume (in the horizontal-camera image) signified the formation of the keyhole cavity. Also, the pool height increased significantly during the stabilization of the keyhole cavity, appearing as a "rooster-tail" wake behind the coupling spot. This wake is presumably formed by displacement of the molten material from the keyhole cavity. It also causes turbulence in the molten pool resulting in the "ruffled" appearance. The bottom inclined-camera image in Fig. 8 shows that the pool widened dramatically and the pool shape changed from a small teardrop of the depressed pool to a large, uneven elongated ellipse of the keyhole pool. Keyhole initiation also resulted in the increase of the coupling spot dimensions. The corresponding keyhole-mode weld cross section in Fig. 9B confirms the dramatic increases in weld width and depth that were associated with the onset of keyholing.

In summary, both the plume shape and intensity, as well as the measured weld pool height, were clear indications of whether or not the weld was in keyhole mode. Pool width and surface appearance also appeared to be potentially useful for this purpose.

Conclusions

The investigations using the video system and weld images led to the conclusions below.

1) The dual-camera video system developed during this investigation successfully produced simultaneous, high-resolution images from two vantage points. The cameras and optics were located at a sufficient distance from the heat and debris caused by laser material processing that they could be the basis of a practical penetration control system. Other restrictions, such as access to the weld location, might also have to also be accomodated during practical implementation of such a system for a specific application.

2) As observed in the horizontal-camera images, decreasing focus spot size generated a fantail-to-columnar plume shape transition. Just before keyhole initiation, the columnar plume was much more intense and distinct than the original fantail plume of a weakly depressed pool.

3) A potentially useful correlation was noted between nonkeyhole weld pool penetration and the divergence, height and intensity of the plume

4) Dimensions of selected depressed-pool image features were found to be related to the formation and termination of the keyhole cavity. The width of the columnar plume base, coupling spot width and estimated beam spot size, were approximately equal immediately before and just after transition to and from keyhole welding mode.

5) Keyhole welds were differentiated from flat or depressed pools in the images by much brighter plumes with larger variations in size and shape and much larger pool heights as measured in the horizontal view.

Acknowledgments

We express our gratitude to Edison Welding Institute, especially Karl Graff and Dave Edmonds, for allowing us to use their laser system and equipment to conduct this research. We appreciate the contributions of Bob Rivett, John Lippold, Gene White, Jim Hurley, Scot Leonard, Larry Stahr, Tim Freck, Ed Robitz and Dan Gibson on the experimental procedure. The advice of David Whitehouse and Stan Ream concerning the measurements of beam quality are valued.

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Evolution of Titanium Arc Weldment Macro and Microstructures — Modeling and Real Time Mapping of Phases

Rigorous heat transfer modeling and real-time experimental mapping of phases are used to understand HAZ phase transformations and three-dimensional grain structure evolution during welding

BY Z. YANG, J. W. ELMER, J. WONG AND T. DEBROY

ABSTRACT. Macro and microstructural features in gas tungsten arc (GTA) welded titanium were modeled for the first time based on a combination of transport phenomena and phase transformation theory. A transient, three-dimensional, turbulent heat transfer and fluid flow model was developed to calculate the temperature and velocity fields, thermal cycles, and the shape and size of the fusion zone. The kinetics of the $\alpha \rightarrow \beta$ allotropic transformation during continuous heating and the corresponding $(\alpha+\beta)/\beta$ phase boundary were calculated using a modified Johnson-Mehl-Avrami (JMA) equation and the calculated thermal cycles. The modeling results were compared with the real-time phase mapping data obtained using a unique spatially resolved X-ray diffraction technique with synchrotron radiation. The real-time evolution of grain structure within the entire weld heat-affected zone (HAZ) was modeled in three dimensions using a Monte Carlo technique.

The following are the major findings. First, the rates of heat transfer and fluid flow in the titanium weld pool during gas tungsten arc welding (GTAW) are significantly enhanced by turbulence, and previous calculations of laminar fluid flow and heat transfer in arc-melted pools need to be re-examined. The fusion zone geometry, and the $\alpha/(\alpha+\beta)$ and $(\alpha+\beta)/\beta$ phase boundaries in the HAZ could be satisfactorily predicted. Second, comparison of real-time $\alpha \rightarrow \beta$ transformation kinetics with the rates computed assuming various alternative reaction mechanisms indicates the transition was most likely controlled by the transport of Ti atoms across the α/β interface. Third, comparison of the experimental data with the simulated results indicates the real-time evolution of the grain structure around the weld pool could be simulated by the Monte Carlo technique. Finally, the insight developed in this research could not have been achieved without concomitant modeling and experiments.

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Introduction

The integrity and performance of the weldment depends on both its macro and microstructures. During fusion welding, the interaction of the heat source and the material leads to rapid heating, melting and vigorous circulation of the molten metal in the weld pool. In the weld pool, the heat transfer and fluid flow affect temperature fields and thermal cycles, which, in turn, affect the macro and microstructures of the weld metal. In the solid region around the weld pool, the thermal cycles may lead to solid state phase transformations and changes in the grain structure through annealing, recrystallization and grain growth. The kinetics of the phase transformations and the grain growth vary across the weldment and are functions of both the heating and cooling rates and the maximum temperatures attained during the thermal cycles. These welding-induced spatial variations of microstructures significantly affect the weldment properties such as strength, ductility, toughness and corrosion resistance. Thus, control of the macro and microstructure is important in achieving structurally sound and reliable welds during arc welding.

Knowledge of the thermal cycles in the fusion zone (FZ) and HAZ is a prerequisite for understanding microstructural evolution in the weldment. Accurate measurements of temperature profiles in the FZ and HAZ are difficult, and noncontact techniques for the measurement of surface temperatures are still evolving. Mathematical modeling provides a recourse to overcome the difficulties encountered in temperature measurements. In recent years, modeling of fluid flow and heat transfer in the weld pool have provided detailed insight about the welding processes that could not have otherwise been obtained (Refs. 1–16). Significant progress has been made to understand the development of weld pool shape and size (Refs. 1–6), cooling rate (Ref. 7) and the concentration of volatile alloying elements from the weld pool (Refs. 8, 9). However, ef-

KEY WORDS

GTAW
Titanium
3-D Model
Heat Transfer
Fluid Flow
Phase Mapping
X-ray Diffraction
Grain Growth
Monte Carlo

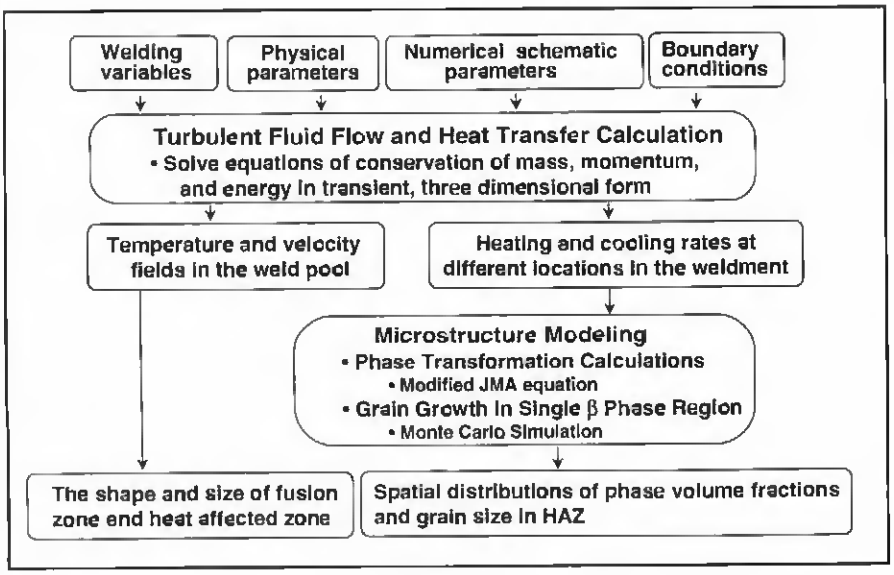

Fig. — 1 Flow chart.

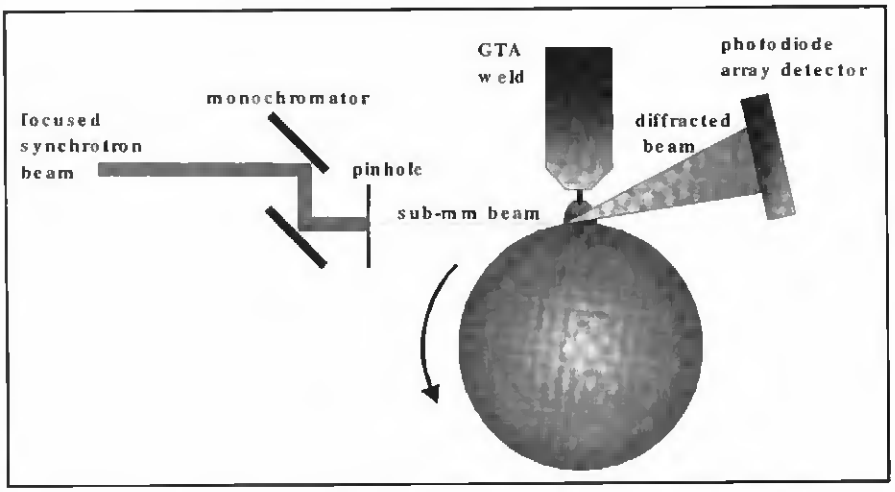

Fig. 2 — Experimental setup.

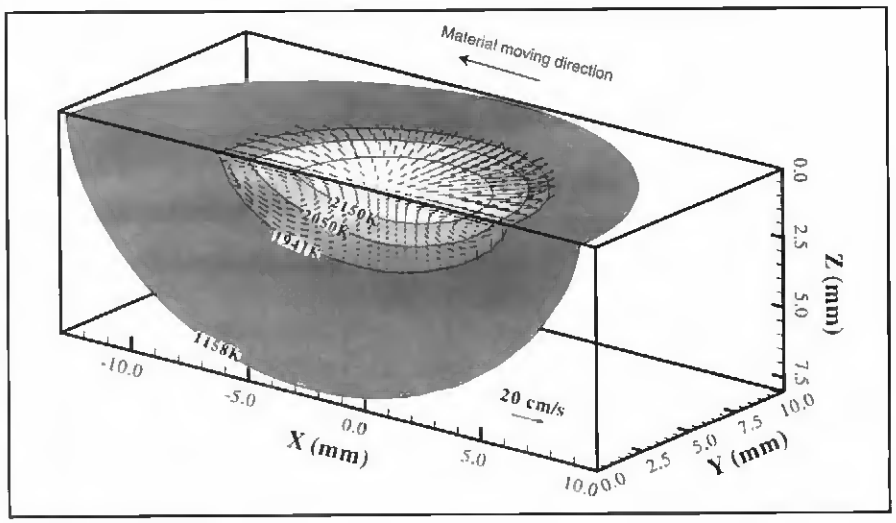

Fig. 3 — Calculated temperature and velocity fields in three dimensions. Welding conditions: GTA, 100 A, 19 V, 1.1 mm/s welding speed.

forts to quantitatively model the development of weldment microstructures (Refs. 10–12), inclusion characteristics (Ref. 13) and concentrations of dissolved gases in the weld metal (Refs. 14–16) starting from transport phenomena are just beginning.

Accurate calculation of the geometry and the thermal cycles in the weldment requires a well-tested numerical thermofluid model. In the past decade, several numerical thermofluid models (Refs. 1–5) have been established to study heat transfer and fluid flow in arc welding processes in which laminar flow was assumed in the weld pool. However, recent experimental observations (Ref. 17) and theoretical calculations (Refs. 18, 19) in GTA welding have indicated that, in many cases, the fluid flow in the weld pool is turbulent in nature. Previous results from two-dimensional (2-D) calculations strongly suggested that accurate predictions of flow patterns and weld pool geometries will only be possible if the effects of turbulence are modeled accurately (Refs. 18, 19). In the present study, a well-tested, three-dimensional, turbulent heat transfer and fluid flow model (Ref. 12) was used to calculate the temperature field, geometry of the FZ and the thermal cycles in the titanium weldment during GTA welding.

During welding commercially pure titanium, a series of phase transformations take place in both the FZ and the HAZ. The microstructural history of the FZ is $\alpha \rightarrow \beta \rightarrow$liquid$\rightarrow \beta \rightarrow \alpha$, while that of the HAZ is $\alpha \rightarrow \beta \rightarrow \alpha$ (Ref. 20), where α is the hexagonal close-packed form of titanium and β is the body-centered-cubic form of titanium. In the present research, both real-time-based experiments and mathematical modeling were used to study the microstructural evolution in the HAZ of titanium weldment. An experimental method (Refs. 20–23) for observing phase transformation behavior during welding using spatially resolved X-ray diffraction (SRXRD) with synchrotron radiation was used to study the phase transformations in real time during the welding of commercially pure titanium. Also, the extents of the phase transitions at various locations were computed by the combination of the calculated thermal cycles and phase transition kinetics.

As a first effort to model the phase transitions in titanium, only the $\alpha \rightarrow \beta$ transition during heating was considered in the present paper because of the uniqueness of the kinetic data that can be obtained from the SRXRD technique. These kinetic data are very difficult to obtain by traditional methods because the microstructures that form during heating are subsequently altered by the transfor-

mations that take place during cooling. Under the present welding conditions, it is believed the α→β transformation in titanium takes place by classical nucleation and growth process rather than martensitic transformation (Ref. 20). Thus, a modified Johnson-Mehl-Avrami (JMA) equation (Ref. 24) was used to calculate the kinetics of the α→β transformation during continuous heating. The degree of the α→β transition and consequently the change of phase concentration at various locations can be calculated by incorporating the calculated thermal cycles into the modified JMA equation. The quantitatively calculated phase distribution combined with the real-time experimental results can help us identify the possible mechanism of the α→β transition during welding.

In addition to the spatial distribution of phases, another important microstructural feature in the HAZ is the significant grain-size gradient. In the past decade, the Monte Carlo (MC) technique has been widely used to simulate the evolution of grain structure under isothermal conditions (Refs. 25–27). Compared with the analytical method (Ref. 30), the Monte Carlo simulation of grain growth can provide not only grain growth kinetics but also detailed information on temporal grain morphology evolution. More recently, the Monte Carlo technique has been used to simulate grain growth in the HAZ of welds (Refs. 28, 29) The simulation of grain growth in the HAZ by the MC technique is more realistic than by the classical analytical equation, because the temperature gradient near the weld interface is steep and the atomic mobility can vary across a single grain. This phenomenon cannot be taken into account by the classical analytical equation; however, it can be effectively simu-

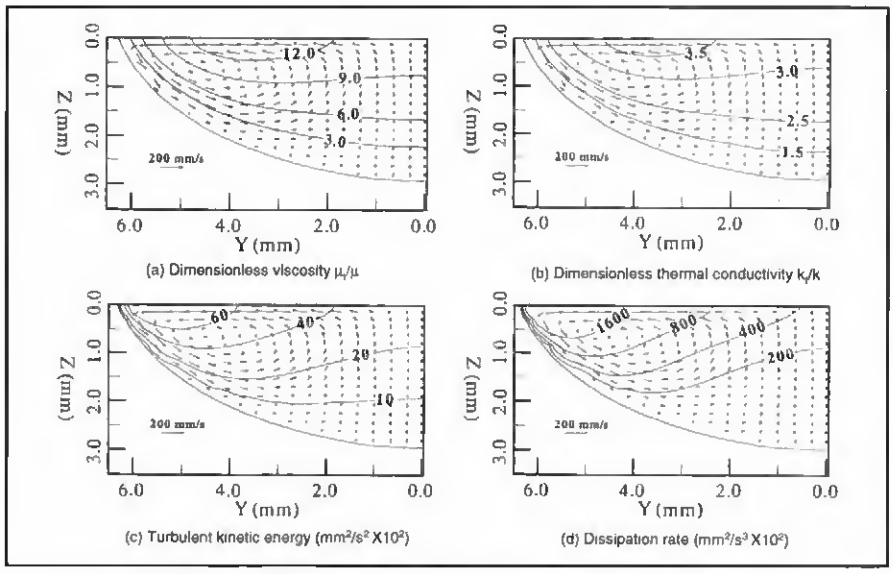

Fig. 4 — Spatial distribution of turbulent variables.

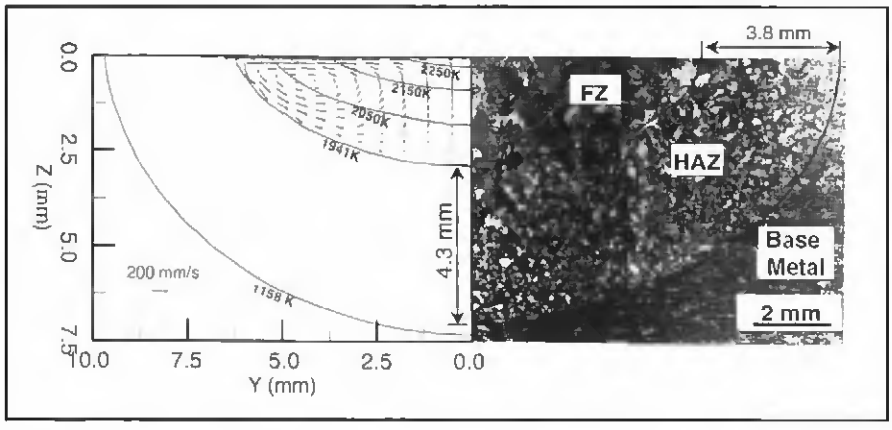

Fig. 5 — Comparison of the calculated (at location x = 0) and experimental geometries of the FZ and HAZ. The width of the HAZ varies with location. The width of the HAZ on the top surface is less than that at the bottom of the HAZ.

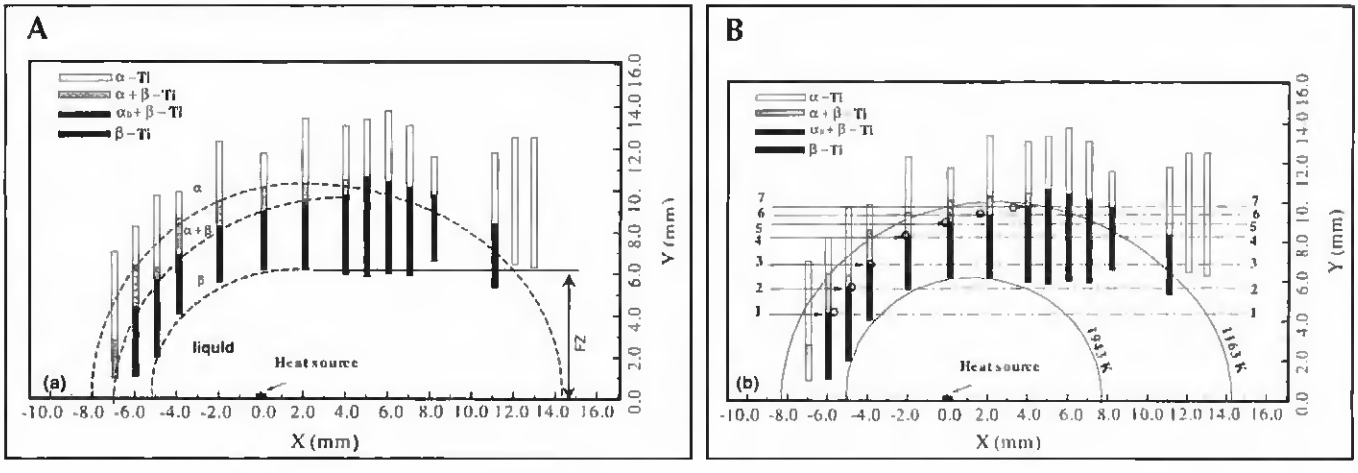

Fig. 6 — A — Real-time phase distribution map from SRXRD data; B — calculated phase transition isotherms on the phase distribution map. Distances from weld centerline: 1, 4.2 mm; 2, 5.8 mm; 3, 6.6 mm; 4, 8.2 mm; 5, 8.8 mm; 6, 9.2 mm; 7, 9.6 mm.

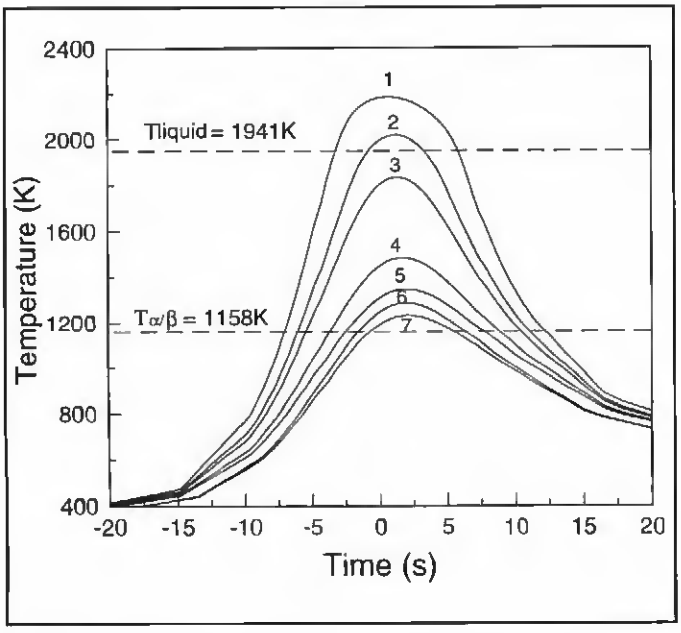

Fig. 7 — Calculated thermal cycles at different locations. Distances from welding centerline: 1, 4.2 mm; 2, 5.8 mm; 3, 6.6 mm; 4, 8.2 mm; 5, 8.8 mm; 6, 9.2 mm; 7, 9.6 mm.

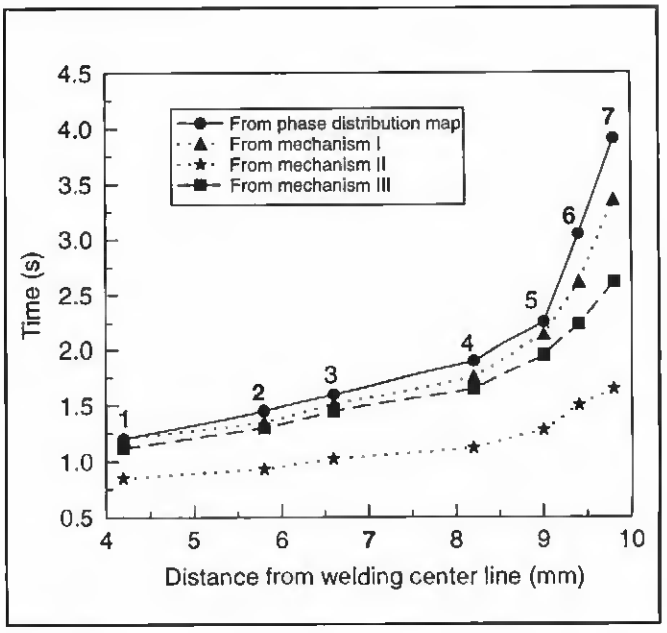

Fig. 8 — Comparison of the times needed for α→β transformation from JMA equation and from phase distribution map. Different mechanisms assumed for the application of JMA equations are given in Table 2. Distances from weld centerline: 1, 4.2 mm; 2, 5.8 mm; 3, 6.6 mm; 4, 8.2 mm; 5, 8.8 mm; 6, 9.2 mm; 7, 9.6 mm.

lated by the MC technique, in which the grains are subdivided into many discrete small units and each unit can have its own atomic mobility depending on the local temperature.

Previous simulations of the grain growth in the HAZ were limited to two-dimensional calculations. Considering the significant local thermal and topological environment change in the HAZ, simulation of grain growth in two dimensions is not sufficient for grain growth occurring in real welds that are three dimensional. Furthermore, the width of the HAZ usually varies with the location in the actual weldment. This temperature dependence of spatial dimension variation was ignored in the previous two-dimensional simulations. For more realistic simulation, the purpose of the present investigation is to develop a three-dimensional (3-D) MC model in which the whole region of the HAZ around the weld pool is considered. By incorporating the calculated thermal history data at each site into the three-dimensional MC model, the simulated grain growth kinetics at each site will thus be strictly based on the corresponding thermal history — Fig. 1. Therefore, the detailed thermal and grain topological environment at each site in the actual weldment can be taken into account. Furthermore, a simulated 3-D real-time map of grain structure distribution around the weld pool can be established by relating the grain growth extents at various locations with their temperature-time histories, as well as grain topological environments. This simulated 3-D real-time grain distribution map can provide detailed insight in understanding the grain growth phenomena under the steep temperature gradient and transient thermal cycles that could not be obtained otherwise.

The work reported here is the first attempt to systematically model the complex welding phenomena involving heat transfer and fluid flow, phase transition and grain growth. The ability to predict both the geometry of the weld pool and important microstructural features indicates significant promise for understanding both macro and microstructures of titanium welds from the combination of the fundamental principles from both transport phenomena and phase transformation theory.

Experimental Procedures

Welding

Grade 2 commercially pure titanium bar of 10.2 cm diameter was welded by gas tungsten arc (GTA) welding. The composition of the as-received bar was (in wt-%): 0.14% Fe, 0.17% O, 0.03% Al, 0.02% Cr, 0.08% C, 0.001% H, 0.014% N, 0.02% Ni, 0.005% V and 0.004% Si. Gas tungsten arc welds were made at a constant power of 1.9 kW (100 A, 19 V), and extra high-purity helium (99.999%) was used as both the welding and shielding gas. The titanium bar was rotated at a constant speed of 0.20 rpm below the fixed electrode, which corresponds to a surface welding speed of 1.1 mm/s. Additional details about the welding procedure are reported in Refs. 20–23.

Spatially Resolved X-Ray Diffraction

A schematic diagram of the SRXRD experimental setup is shown in Fig. 2. The SRXRD experiments were performed on the 31-pole wiggler beam line (Ref. 31), at Stanford Synchrotron Radiation Laboratory (SSRL) with Stanford Positron-Electron Accumulation Ring (SPEAR) operating at an electron energy of 3.0 GeV and an injection current of ~100 mA. The focused monochromatic synchrotron beam (8.5 keV) was passed through a 180-μm tungsten pinhole to render a 200-μm beam on the sample at an incident angle of ~25 deg. Additional details about the synchrotron beam are available in the literature (Refs. 20–23). The welding assembly was integrally mounted to a translation stage driven by a stepper motor with 10-μm precision and placed inside the environmental chamber to prevent oxidation of the titanium during welding. Spatial mapping of the phases in the HAZ was performed using the translation stage to manipulate the weld (welding torch and workpiece) with respect to the fixed X-ray beam in order to probe discrete regions around the weld. Movements perpendicular to

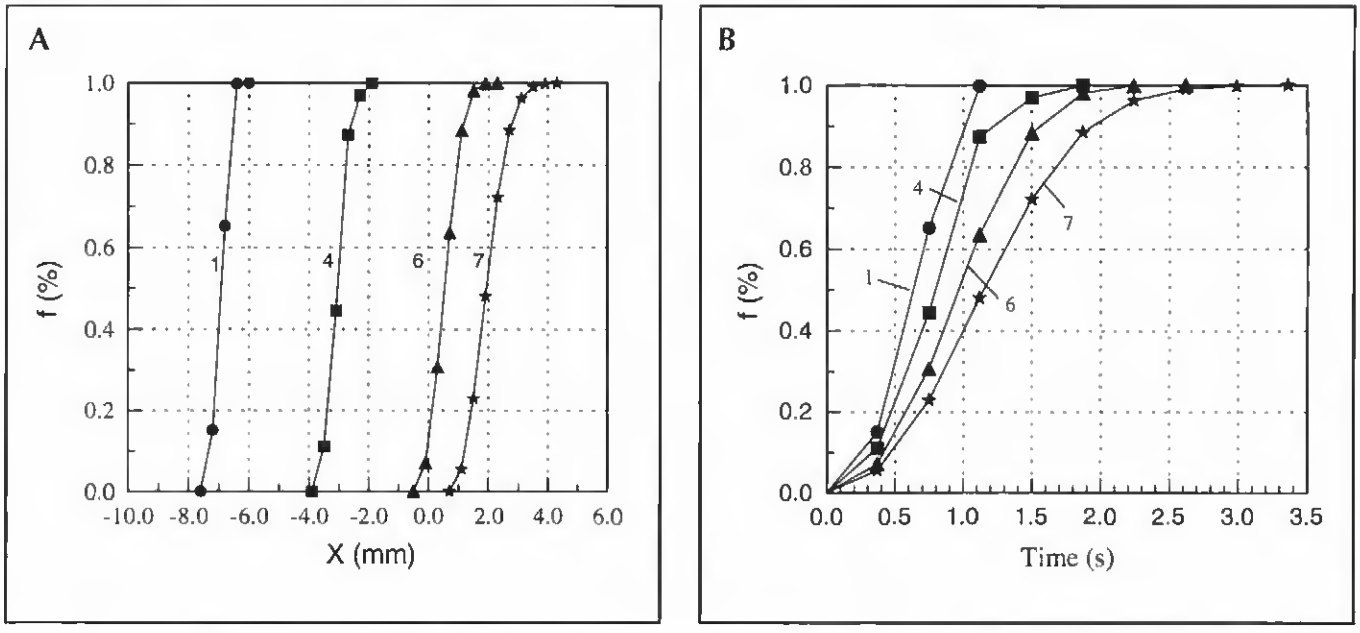

Fig. 9 — A — Calculated β phase transformation along temperature-time profiles given in Fig. 7; B — calculated times needed for α→β transformation at different lines.

the centerline of the weld were controlled by a computer and were achieved by direct translation of the workpiece with respect to the X-ray probe. A typical SRXRD run consisted of gathering 40 diffraction patterns at 200 μm apart along a predetermined path to span a range of 8 mm through the HAZ.

SRXRD data were taken during welding by positioning the beam at a fixed location with respect to the welding electrode and collecting data for 6 s per diffraction scan while the bar rotated under the torch at a constant speed. Up to 40 scans were taken during one revolution of the weld around the cylinder by incrementally jogging the weld in 200-μm steps to new locations at 6-s intervals. In this way a series of X-ray diffraction patterns was collected for a given weld along a direction perpendicular to and away from its centerline, and thus spanning an 8-mm range through the HAZ. Results of the sequential linear X-ray diffraction measurements made perpendicular to the welding direction were combined to construct a phase transformation map around the liquid weld pool.

Material Characterization

Optical metallography was performed on postweld samples using conventional polishing and etching techniques. Etching was performed in a chemical bath of 15 parts lactic acid, 5 parts nitric acid and 1 part hydrofluoric acid. To quantitatively describe the grain size gradient in the HAZ, the mean grain sizes at various distances from the weld interface were measured using lineal intercept method (Ref. 32) by placing test lines parallel to the weld interface. Because of significant grain size gradient in the HAZ, different magnifications in the range of 20X to 100X were used depending on the locations from the weld interface to ensure accurate grain size measurements.

Mathematical Modeling

Calculation of Heat Transfer and Fluid Flow

Governing Equations

The heat transfer and fluid flow were calculated by numerical solution of the equations of conservation of mass, momentum and energy in three-dimensional form. In this work, the transient problem was transformed into a steady-state problem by solving in a coordinate system, which moves with the heat source (Ref. 5). In the moving coordinate system, the velocity and enthalpy fields are independent of time. As a consequence, the time required for computation is reduced significantly. The velocity transformation used and the transformed continuity, momentum and energy equations can be expressed as follows:

$$V' = V + V_s \tag{1}$$

$$\nabla \cdot V = 0 \tag{2}$$

$$\rho \nabla \cdot (VV) = -\nabla P + \mu_{eff} \nabla \cdot (\nabla V) + (S_v - \rho \nabla \cdot (V_s V)) \tag{3}$$

$$\rho \nabla \cdot (Vh) = \nabla \cdot \left(\frac{K_{eff}}{C_p} \nabla h \right) + S_l + S_h - \rho \nabla \cdot (V_s h) \tag{4}$$

where V', V and V_s are the net velocity at any point, the convective component of the liquid metal velocity and the welding velocity, respectively ρ is the density; P is the effective pressure; C_p is the specific heat; S_V is the source term that takes into account the combined effect of buoyancy force, Marangoni stress and electromagnetic force; h is the enthalpy; S_h is the source term that takes into account the heat input from the welding source and the convective and radiative heat loss; S_l is the source term that accounts for latent heat of melting and convective transport of latent heat; μ_{eff} is the effective viscosity; and k_{eff} is the effective thermal conductivity.

An important component in the present heat transfer and fluid flow model is the incorporation of K - ε model to calculate the turbulent fluid flow and heat transfer in the weld pool under the present welding conditions. A detailed description of the K - ε model is given by Launder and Spalding (Ref. 33). Only the salient features of the model are presented here. The effects of turbulence on the fluid flow and heat transfer were included through the use of effective viscosity and thermal conductivity. The effective viscosity and thermal conductivity can be expressed as

$$\mu_{eff} = \mu_l + \mu \tag{5}$$

$$k_{eff} = k_l + k \tag{6}$$

Table 1 — Data Used for the Calculation of Velocity and Temperature Fields

Physical Property	Value
Liquidus temperature (K)	1941.0
Solidus temperature (K)	1941.0
Density of liquid metal (kg/m^3)	4400.0
Viscosity of liquid (kg/m.s.)	6.0×10^{-3}[a]
Thermal conductivity of solid (J/m-s-K)	28.0
Thermal conductivity of liquid (J/m-s-K)	28.0[a]
Specific heat of solid (J/kg-K)	700.0
Specific heat of liquid (J/kg-K)	700.0[a]
Latent heat of melting (J/kg)	292.6×10^3
Temperature coefficient of surface tension (N/m-K)	-0.26×10^{-3}

[a] Estimated due to no values available for these data in the literature.

where μ_t and k_t are the turbulent values, and μ and k are the molecular values. Unlike the molecular viscosity and thermal conductivity, which are physical properties, the turbulent viscosity and thermal conductivity are the properties of both the fluid and the flow system. The turbulent viscosity was calculated by

$$\mu_t = \frac{C_\eta \rho K^2}{\varepsilon} \tag{7}$$

where C_η is an empirical constant, K is the turbulent kinetic energy and ε is the dissipation rate of turbulent kinetic energy. The value of turbulent viscosity can be determined through solution of the equations of conservation of K and ε as following:

$$\rho \frac{DK}{Dt} = \frac{1}{\sigma_k}\left\{\frac{\partial}{\partial x}\left[\mu_t \frac{\partial K}{\partial x}\right] + \frac{\partial}{\partial y}\left[\mu_t \frac{\partial K}{\partial y}\right] + \frac{\partial}{\partial z}\left[\mu_t \frac{\partial K}{\partial z}\right]\right\} + \mu_t G_k - \varepsilon \tag{8}$$

$$\rho \frac{D\varepsilon}{Dt} = \frac{1}{\sigma_\varepsilon}\left\{\frac{\partial}{\partial x}\left[\mu_t \frac{\partial \varepsilon}{\partial x}\right] + \frac{\partial}{\partial y}\left[\mu_t \frac{\partial \varepsilon}{\partial y}\right] + \frac{\partial}{\partial z}\left[\mu_t \frac{\partial \varepsilon}{\partial z}\right]\right\} + \frac{\varepsilon}{K}\left(C_1 G_k - C_2 \rho \varepsilon\right) \tag{9}$$

where σ_k, σ_ε, C_1 and C_2 are empirical constants and $\mu_t G_k$ is the turbulent counterpart to the viscous dissipation (Ref. 33). The turbulent thermal conductivity is related to the turbulent viscosity by the turbulent Prandtl number (Refs. 18, 33). $Pr_t = C_p \mu_t / k_t = 0.9$. Thus, the spatial distribution of viscosity and thermal conductivity of the liquid metal could be calculated from the turbulence model.

Boundary Conditions

The calculations were carried out in a Cartesian coordinate system, and only half of the workpiece was considered since the weld pool is symmetrical. Lin and Eagar (Ref. 51) calculated the maximum depth of weld pool surface depression to be 1.3 mm at 300 A during GTA welding. They pointed out that at low currents the surface of GTA weld pools is essentially flat. Since the experiments reported in this paper were conducted at 100 A, the surface of the weld pool was essentially flat. Along the vertical plane of symmetry (y = 0 plane), the boundary conditions for the velocity components were defined as

$$\frac{dV_x}{dy} = 0 \tag{10.1}$$

$$V_y = 0 \tag{10.2}$$

$$\frac{dV_z}{dy} = 0 \tag{10.3}$$

where V_x, V_y and V_z are the components of the convective velocity V in the x, y and z directions. The z component of the velocity, V_z, was defined to be zero at the top surface. The x and y components of the velocity vector on the top surface (z = 0 plane) were determined by the Marangoni stress and were defined as

$$-\mu_{eff}\frac{dV_x}{dz} = f_l \frac{d\gamma}{dT}\frac{dT}{dx} \tag{11.1}$$

$$-\mu_{eff}\frac{dV_y}{dz} = f_l \frac{d\gamma}{dT}\frac{dT}{dy} \tag{11.2}$$

where $d\gamma/dT$ is the temperature coefficient of surface tension and f_l is the liquid fraction, which is assumed to vary linearly with temperature in the mushy zone. The velocity in the solid region was set to be zero.

On the top surface (z = 0 plane), the heat exchange between the heat source and the surface of the sample and the radiative and convective heat loss to the surrounding were prescribed as

$$J_h(\xi, y, z)_{z=0} = \frac{q\eta}{2\pi r_b^2} e^{\left[\frac{-\left(\xi^2+y^2\right)}{2r_b^2}\right]} - \varepsilon_1 \sigma\left(T(\xi, y, z)_{z=0}^4 - T_g^4\right) - h_c\left(T(\xi, y, z)_{z=0} - T_g\right) \tag{12}$$

where q is the power input, η is the welding process efficiency, r_b is the arc radius, $T(\xi, y, z)_{z=0}$ is the local weld pool surface temperature, T_g is ambient temperature, ε_1 is the emissivity, σ is the Stefan-Boltzmann constant and h_c is the heat transfer coefficient. At the plane of symmetry (y = 0 plane), the gradient of the enthalpy was defined as

$$\frac{dh}{dy} = 0 \tag{13}$$

At other surfaces of the system, the enthalpy was prescribed by setting the temperature as the ambient temperature.

The boundary conditions for K and ε at the vertical symmetry plane (y = 0 plane) were defined as $\partial K/\partial y = 0$ and $\partial \varepsilon/\partial y = 0$, and at the top surface (z = 0 plane): $\partial K/\partial z = 0$ and $\partial \varepsilon/\partial z = 0$. At the solid-liquid interface, the values of K and ε were taken to be zero.

Solution Procedure

The governing equations were represented by a set of finite difference equations and solved iteratively on a line by line basis utilizing a tri-diagonal matrix algorithm. The details of the procedure are described elsewhere (Ref. 34). The dimensions of the solution domain were 32.0 (length) x 6.3 (width) x 5.1 (thickness) cm^3. A 56 x 30 x 25 grid system was used in the calculations. Spatially nonuniform grids were used for maximum resolution of variables. Finer grid spacing was used near the heat source. The minimum grid spacing was 0.005 cm directly below the weld pool surface. The data used for the calculation of the fluid flow and heat transfer are presented in Table 1.

Calculation of Thermal Cycle

After the solution of the transformed momentum and energy equations, a steady-state temperature field can be obtained. At any given locations (x, y, z), the temperature variation with time can be expressed as

$$T(x, y, z, t_2) = \frac{Ts(\xi_2, y, z) - Ts(\xi_1, y, z)}{\xi_2 - \xi_1} V_s(t_2 - t_1) + T(x, y, z, t_1) \tag{14}$$

where $Ts(\xi_2, y, z)$ and $Ts(\xi_1, y, z)$ are the steady-state temperatures at coordinates (ξ_2, y, z) and (ξ_1, y, z), respectively, $\xi_2 - \xi_1$ is the distance traveled by the arc in time $(t_2 - t_1)$, V_s is the welding speed and $T(x,y,z,t_2)$ and $T(x,y,z,t_1)$ are the temperatures at times t_1 and t_2, respectively.

Phase Transformation Calculation

Possible Mechanisms

The α-β phase transformation in titanium can occur by martensitic (Ref. 35), massive (Refs. 35–38) or classical nucleation and growth (Refs. 35, 38) mecha-

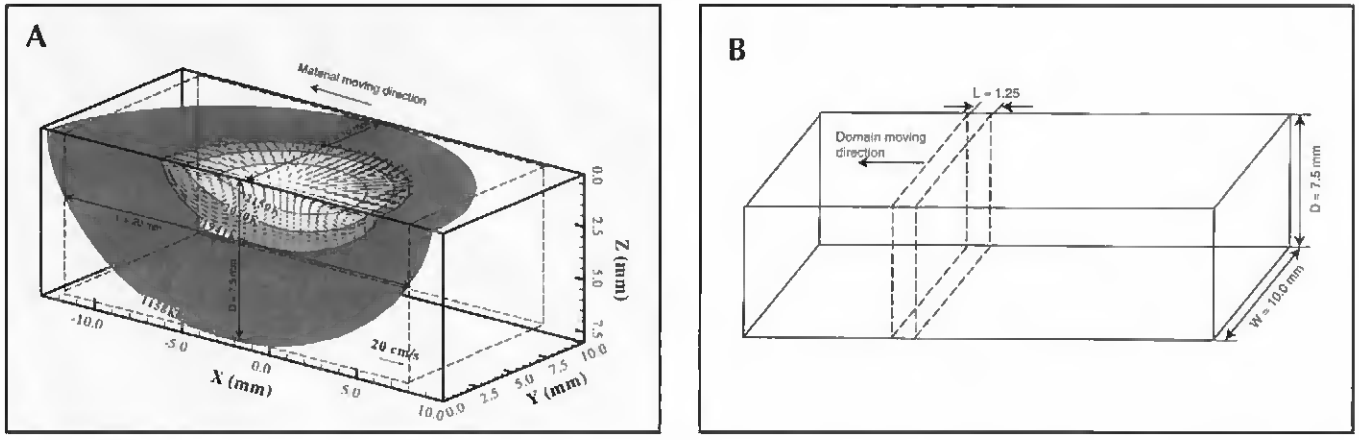

Fig. 10 — A — Domain selected for simulation of grain structure evolution in the HAZ. The length (L), width (W) and depth (D) of the selected domain are 20, 10 and 8 mm, respectively. The corresponding grid system used for the MC model is 400 x 200 x 160. B — Domain selected for simulation of grain structure evolution in the HAZ. The selected domain is assumed to move from the location where grain growth begins to the location where grain growth ends. The length (L), width (W) and depth (D) of the selected domain are 1.25, 10 and 7.5 mm, respectively. The corresponding grid system used for the MC model is 50 x 400 x 300.

nisms. These mechanisms compete with one another, and the mechanism that is ultimately responsible for the phase transformation depends on the purity of the titanium, its microstructure and the thermal processing conditions. The martensitic phase transformation occurs only at high rates and has been reported to take place at cooling rates in excess of 3000 K/s (Ref. 35). This cooling rate far exceeds those encountered in conventional arc welds and precludes this mechanism. Massive transformations in titanium have been reported to occur at cooling rates similar to those of martensitic transformations (Ref. 35), but also at cooling rates well within the realm of arc welds (Ref. 38). Conventional nucleation and growth phase transformations with long-range solute partitioning occur only at low cooling rates and are generally believed to occur with much slower kinetics than massive transformations (Refs. 36, 37).

In a previous investigation, SRXRD was used as an *in-situ* experimental technique to map the phases that exist around an arc weld in commercially pure titanium (Ref. 20). This phase map contains direct evidence of the $\alpha \rightarrow \beta$ transformation kinetics in the form of spatial displacements of the product phase with respect to the thermodynamic transformation isotherm. Results of this study showed the $\alpha \rightarrow \beta$ transformation during heating took place with slower kinetics than the $\beta \rightarrow \alpha$ transformation during cooling. From the SRXRD measurements, the $\beta \rightarrow \alpha$ transformation was estimated to occur with an interface velocity of 100 μm/s (Ref. 20), which is consistent with measured interface velocities of massive transformation in dilute titanium alloys (Ref. 36). Since massive $\beta \rightarrow \alpha$ transformations during cooling of titanium and titanium alloys have been well documented by other investigators (Refs. 35–38), this mechanism was assumed to be responsible for the $\beta \rightarrow \alpha$ transformation during cooling in titanium arc welds. The $\alpha \rightarrow \beta$ transformation, on the other hand, was estimated by the SRXRD measurements to occur at rates more consistent with long-range diffusional growth (Ref. 20), but a thorough investigation of this mechanism was not performed. Since the $\alpha \rightarrow \beta$ transformation has not been documented nearly as well as the $\beta \rightarrow \alpha$ transformation in the available literature, the transformation kinetics need to be studied in more detail. Here, we utilize isotherms calculated from the turbulent fluid flow and heat transfer model as input to a modified JMA kinetic model to study the possible rate-controlling steps for the $\alpha \rightarrow \beta$ phase transformation.

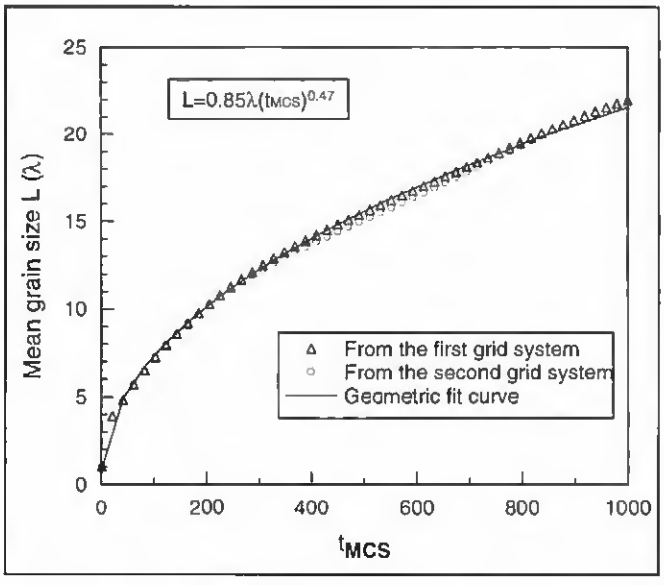

Fig. 11 — Simulated grain growth kinetics from the MC model. Both of the mean grain size L and Monte Carlo simulation time t_{MCS} are dimensionless quantities in this figure.

The principal impurities in the Grade 2 titanium are O (0.17 wt-%) and Fe (0.14 wt-%). In the previous study, the presence of Fe-rich bcc/omega phase particles distributed throughout the grains was observed in the starting titanium microstructure (Ref. 20). These pre-existing particles appear to provide growth sites for the $\alpha \rightarrow \beta$ transformation and also tie up much of the Fe impurities. Therefore, it is likely the $\alpha \rightarrow \beta$ transformation during arc welding takes place by a growth dominated mechanism whereby nucleation of the β phase is not necessary. Since the $\alpha \rightarrow \beta$ transformation could be controlled either by diffusion of titanium or oxygen atoms across the α/β interface, or oxygen atoms long-range diffusion, each of these possible scenarios will be modeled to determine which

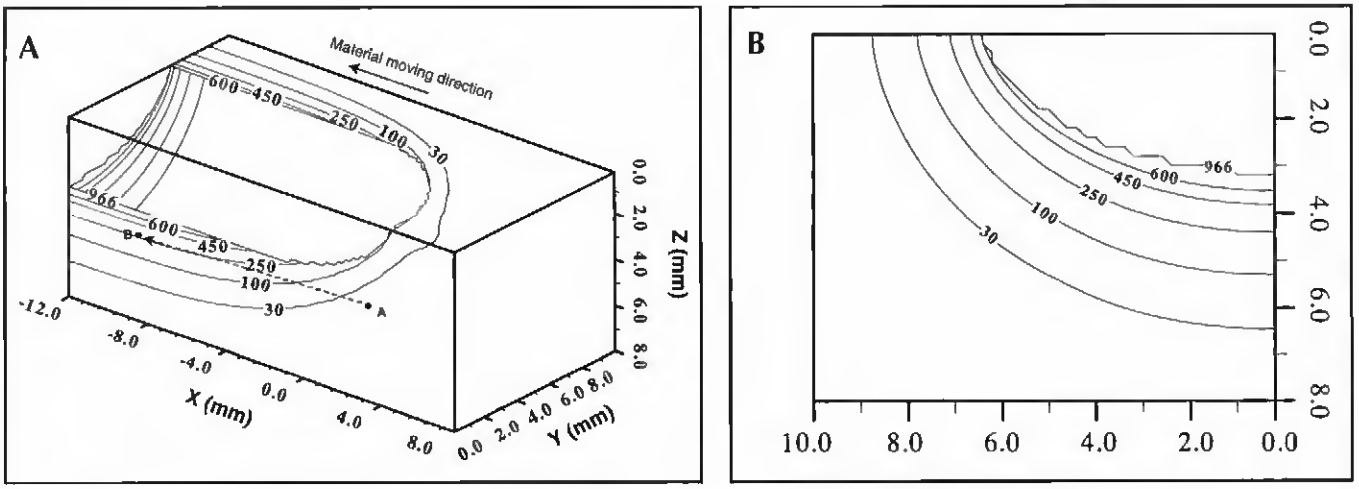

Fig. 12 — A — Monte Carlo simulation time t_{MCS} spatial distribution in the domain (20 x 10 x 8 mm³); B — Monte Carlo simulation time t_{MCS} spatial distribution in the cross section of the domain (x = –12 mm).

Table 2 — Kinetic Data Used for the Calculation of the α ⇻ β Phase Transformation for Different Proposed Mechanisms

Scenarios	Assumed mechanisms	n	K_0	ΔG (k)/mol
I	Titanium short-range diffusion (interface controlled)	3.0	2.18×10^6	152.7 (Ref. 44)
II	Oxygen short-range diffusion (interface controlled)	3.0	2.18×10^6	138.2 (Ref.49)
III	Oxygen long-range diffusion	1.5	2.18×10^6	138.2 (Ref. 49)

is the most likely to control the α→β transformation rate. The three different scenarios can be summarized as 1) an interface controlled mechanism with titanium short-range diffusion (across the α/β interface), 2) an interface-controlled mechanism with oxygen short-range diffusion (across the α/β interface) and 3) a long-range solute partitioning mechanism with oxygen diffusion.

Application of JMA Equation

The JMA equation is suitable for describing the kinetics of reactions controlled by the nucleation and growth mechanism (Refs. 39, 40). Therefore, this equation is applicable to describe the α→β transition in titanium for all the mechanisms assumed in the above three scenarios. The JMA equation under isothermal conditions can be expressed as (Ref. 24)

$$f=1-\exp\{-[k(T)(t-t_0)]^n\} \qquad (15)$$

where n is a numerical exponent whose value is determined by the nucleation mode and the dimensions of the growing particles (Ref. 41). It is a constant independent of temperature, provided there is no change in the nucleation mechanism. On the other hand, k(T) depends on both the nucleation and growth rates and is therefore highly sensitive to temperature

$$k(T)=k_0\times\exp\left(-\frac{\Delta G(T)}{k_B T}\right) \qquad (16)$$

where ΔG(T) is the total activation energy for nucleation and growth, k_0 is pre-exponential constant and k_B is the Boltzmann constant. Since heterogeneous nucleation is assumed in the JMA equation, the values of k(T), ΔG(T) and k_0 are usually determined by isothermal experiments.

The JMA equation can be modified for the nonisothermal kinetics (Ref. 24). The proposed method used the discretization of the time dependence of the temperature, *i.e.*, approximation of the continuous temperature-time curves by many isothermal steps, each of them obeying the isothermal JMA-kinetics. The detailed procedure to derive the modified JMA equation is available in the literature (Ref. 24). The final expression for the transformed fraction obtained from m subsequent isothermal steps can be expressed as

$$f(t(T))=1-\exp\left\{-\left[\sum_{i=0}^{m-1}k(t_0+i\Delta T)\Delta t\right]^n\right\} \qquad (17)$$

where f(t(T)) stands for the transformed phase fraction under nonisothermal conditions, Δt is the time step, ΔT is the temperature change corresponding to each Δt, T_0 is the initial temperature, k is a temperature-dependent constant and m is the total number of the subsequent isothermal steps.

In order to use Equation 17, the temperature dependence of the transformation rate k(T) and the exponent n have to be specified. The values of k(T) and n are dependent on the transition mechanism assumed. If the transport of Ti atoms across the interface is considered to be the limiting step, then the activation energy of the titanium self-diffusion could be taken as the value of ΔG(T) in Equation 16 to calculate k(T). If the transport of oxygen atoms across the interface is considered to be the limiting step, then the activation energy of the oxygen diffusion in titanium could be taken as the value of ΔG(T). In both cases, it is assumed that the pre-existing Fe-stabilized bcc/omega phase particles (Ref. 20) provide a sufficient density of growth sites so that nucleation of β particles from the α matrix is not required. Under these zero-nucleation-rate conditions, a value of n = 1.5 can be assumed for the JMA nucleation mode exponent for long-range diffusion and n = 3.0 can be assumed for interface-controlled growth (Ref. 41).

The kinetic data used in the JMA model is summarized in Table 2 for three different scenarios. In all three mechanisms, the pre-exponential constant k_0 in Equation 16 took the same value. This value was estimated from the experimental data in the literature (Ref. 35) and was found to be 2.1B x 10^6. For the purpose of this paper, k_0 will be taken to be

a constant for the α→β transformation since the temperature dependence of k_0 is not known for titanium and also it is believed the temperature dependence of k_0 can be considered to be small compared to the exponential term in Equation 16 (Ref. 42).

Grain Growth Prediction by Monte Carlo Simulation

The methodologies of using the MC technique to simulate grain growth have been given in detail in the literature (Refs. 25–29). Only the salient features to apply this technique to simulate grain growth in the HAZ are described here. To apply the MC technique to a real metallurgical phenomena, the conversion of the MC simulation time (t_{MCS}) to real time is necessary. Depending on the nature of the problem, different methods (Ref. 28) have been used to convert t_{MCS} to real time. When the isothermal grain growth data for the given material are insufficient, such as grain growth in pure titanium, the grain boundary migration model (GBM) proposed by Gao, *et al.* (Ref. 28), can be used to establish the relation between t_{MCS} and real time-temperature kinetics. In the GBM model, the grain growth exponent is taken as 0.5. The isothermal grain growth kinetics in beta-titanium are available in the literature and the grain growth exponent was found (Ref. 52) to be approximately 0.5. This value justifies the application of grain boundary migration model to simulate grain growth in commercially pure titanium.

Relation between t_{MCS} and Real-Time-Temperature

Through the MC simulation, an empirical relation between the simulated grain size and the MC simulation time can be obtained as (Ref. 28)

$$L = K_1 \times \lambda \times (t_{MCS})^{n_1} \qquad (18)$$

where L is the dimensionless simulated grain size measured by mean grain intercepts, λ is the discrete grid point spacing in the MC technique, t_{MCS} is MC simulation time or MC simulation iteration steps, and K_1 and n_1 are the model constants, which are obtained by regression analysis of the data generated from MC simulation. It should be noted Equation 18 represents the intrinsic grain growth kinetics of the MC model. The grain growth kinetics so obtained are dependent only on the grid system of the MC model and independent of material properties and temperature-time history. The simulated mean grain size (L) and the MC simulation time (t_{MCS}) in Equation 18 are dimensionless quantities. To simulate grain growth of a specific material under specified thermal conditions, a relation needs to be established between t_{MCS} and the given conditions, such as the material properties and temperature-time history.

Based on the well known parabolic law for isothermal grain growth (Ref. 30) and the assumptions of grain boundary migration made by Porter, *et al.* (Ref. 43),and Gao, *et al.* (Ref. 28), an analytical equation was derived from the first principles to describe the isothermal grain growth kinetics

$$L^2 - L_0^2 = \left\{\frac{4\gamma_b A Z V_m^2}{N_a^2 h_p} \times \exp\left(\frac{\Delta S_a}{R}\right)\right\} \times \exp\left(\frac{-Q}{RT}\right) \times t \qquad (19)$$

where L is the average grain size at time t, L_0 is the initial average grain size, γ_b is the grain boundary energy, A is the accommodation probability, Z is the average number of atoms per unit area at grain boundary, V_m is the atomic molar volume, N_a is Avagadro's number, h_p is Planck's constant, ΔS_a is the activation entropy, Q is the activation energy for grain growth, T is the absolute temperature, R is the gas constant and t is time. In the present investigation, the value of initial grain size (Ref. 20) L_0 is about 25 μm. The data of activation energy Q for grain growth in titanium is not available in the literature. However, the value of activation energy for grain growth usually ranges from ½ to ⅔ of that for bulk diffusion (Ref. 43). Here we take approximately ⅔ of the activation energy of Ti atom bulk diffusion (Ref. 44) (153.0 kJ/mol) as the value of that for grain growth. The grain boundary energy has been assumed to be a constant and independent of temperature (Refs. 25–29). The data of titanium grain boundary energy is not available in the literature, but was estimated to be 0.75 J/m², as indicated by the procedure given in the appendix. The value of V_m can be calculated based on the density and atomic weight of titanium. The activation entropy for grain boundary migration, ΔS_a, can be assumed (Ref. 28) to be equal to the fusion entropy of the material, ΔS_f. The value of ΔS_f for titanium (Ref. 46) is 7.21 J·mol^{-1}·K^{-1}. The data used for the modeling grain growth are listed in Table 3.

Equation 19 can be further extended for grain growth under nonisothermal conditions by differentiating and then integrating it over the continuous thermal cycles. If we assume that γ and ΔS_a are independent of temperature, K_2 in Equation 20, which equals all terms within

Table 3 — Data Used for the Calculation of the β Grain Growth Kinetics

Initial average grain size, L_0	25 μm
Activation energy for grain growth, Q	1.02×10^5 J/mol
Grain boundary energy, γ_b	0.75 J/m²
Accommodation probability, A	1.0
Average number per unit area at grain boundary, Z	2.0×10^{19} atoms/m²
Atomic molar volume, V_m	1.1×10^{-5} m³/mol
Activation entropy, ΔS_a	7.21 J/mol-K
Avagadro's number, N_a	6.02×10^{23} mol^{-1}
Planck's constant, h_p	6.624×10^{-34} J · s

Table 4 — Calculated Peak Temperatures and Overall Times over the α/β Isotherm at the Seven Different Locations

Location No.	1	2	3	4	5	6	7
Distance[a] (mm)	4.2	5.8	6.6	8.2	8.8	9.2	9.6
T_{peak} (K)	2186	2019	1835	1483	1347	1287	1233
t_{total} (s)[a]	20.0	18.1	16.6	13.1	10.6	9.0	7.1

(a) Distance here indicates the distance from the location to the weld centerline; t_{total} here represents the total time above the α/β isotherms.

Table 5 — Comparison of the Calculated and Experimental Times Necessary for the Completion of α ⇆ β Transformation at Different Locations

Location		1	2	3	4	5	6	7
Times from phase distribution map (s)		1.25	1.45	1.60	1.91	2.26	3.05	3.91
Calculated times under different conditions (s)	Mechanism-1	1.20	1.35	1.51	1.75	2.14	2.62	3.36
	Mechanism-2	0.85	0.93	1.02	1.12	1.28	1.50	1.65
	Mechanism-3	1.12	1.30	1.45	1.65	1.95	2.24	2.62

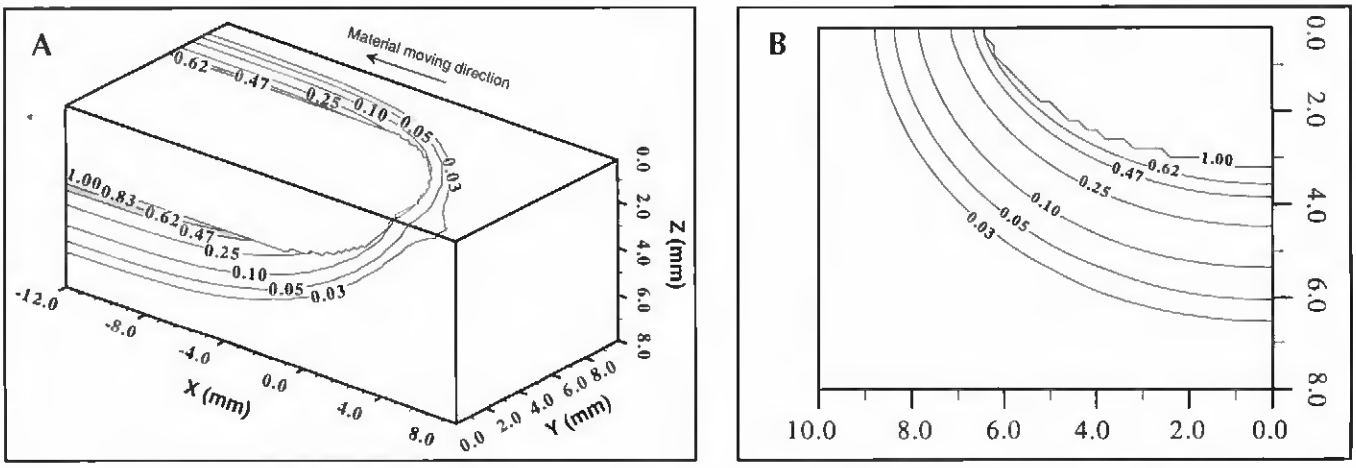

Fig. 13 — A — Site selection probability spatial distribution in the domain (20 x 10 x 8 mm³); B — site selection probability spatial distribution in the cross section of the domain (x = –12 mm).

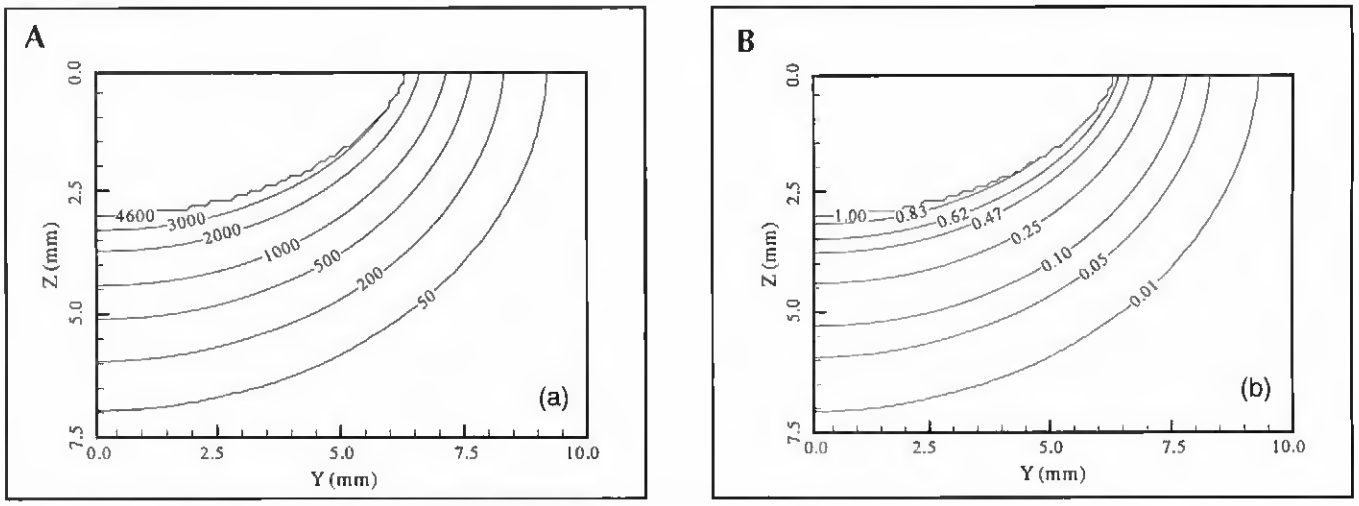

Fig. 14 — Monte Carlo simulation time t_{MCS}; B — site selection probability spatial distribution at the cross section of the second domain (1.25 x 10 x 7.5 mm³).

bracket in Equation 19 as a constant and the grain growth kinetics during continuous heating and cooling, can be expressed as

$$L^2 = L_0^2 + K_2 \sum_{i=1}^{m} \left[\Delta t_i \times \exp\left(-\frac{Q}{RT_i} \right) \right] \quad (20)$$

where Δt_i and T_i are the time step and the corresponding temperature, respectively. Equating the mean grain size from Equation 20 to that from Equation 18, the MC simulation time can be related with the real time and temperature and expressed as

$$(t_{MCS})^{2n_1} = \left(\frac{L_0}{K_1 \lambda} \right)^2 + \frac{K_2}{(K_1 \lambda)^2} \sum_{i=1}^{m} \left[\Delta t_i \times \exp\left(-\frac{Q}{RT_i} \right) \right] \quad (21)$$

Thus, the t_{MCS} necessary to achieve a specific mean grain size during a non-isothermal process can be determined by incorporating the corresponding thermal cycle into Equation 21. Since the thermal cycle in the HAZ varies depending on its location, the corresponding t_{MCS} varies at each site. The higher the temperature or the longer the time period for grain growth at a site, the higher the value of t_{MCS} expected at that site.

Site Selection Probability

The t_{MCS} variation at different locations, calculated from Equation 21, cannot be directly applied in the MC algorithm because the t_{MCS} is a measure of time in the MC algorithm. To solve this problem, a concept of site selection probability is introduced. The site selection probability varies depending on the time-temperature history at any given location. The larger the t_{MCS} at a site, the higher the corresponding site selection probability, p(r)

$$p(r) = \frac{t_{MCS}}{t_{MCS}^{max}} \quad (22)$$

where t_{MCS} is the MC simulation time at any site in the region and t_{MCS}^{max} is the maximum value of the MC simulation time in the computational domain. Both t_{MCS} and t_{MCS}^{max} can be calculated from Equation 21 from the calculated thermal cycles at the corresponding locations. The t_{MCS} variation can thus be transformed into the variation of site selection probability and applied in the MC model. Thus, the spatial variation of thermal cycles is included in the site selection probability.

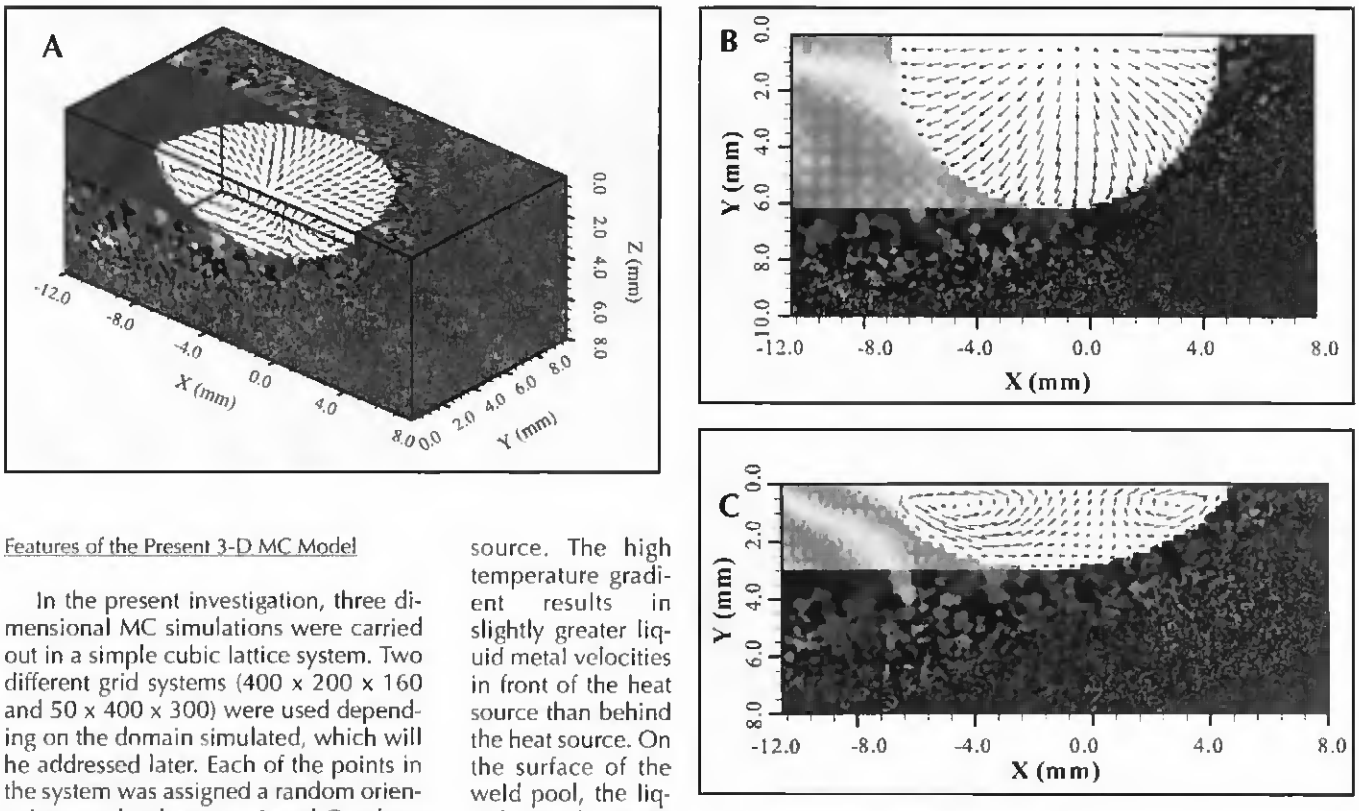

Fig. 15 — A — Real-time mapping grain structure distribution around the weld pool in three dimensions using 400 x 200 x 160 grids (the grid spacing is 50 μm); B — top view of grain structure distribution around the weld pool; C — side view of grain structure distribution around the weld pool.

Features of the Present 3-D MC Model

In the present investigation, three dimensional MC simulations were carried out in a simple cubic lattice system. Two different grid systems (400 x 200 x 160 and 50 x 400 x 300) were used depending on the domain simulated, which will he addressed later. Each of the points in the system was assigned a random orientation number between 1 and Q, where Q was the total number of grain orientations. The value of Q was taken to be 48 in the present simulation, since it is known (Ref. 24) the grain growth exponent becomes almost independent of Q when its value is larger than 30. The local energy was calculated by a shell of 26 grid points (Ref. 26) consisting of the first, second and third nearest neighhors. It should be pointed out that in the present MC model the new attempted orientation was limited to one of the nearest-neighbor orientations rather than all possible orientations in the system. This is because the grain boundary migration only results from the process that atoms close to the grain boundary jump into the nearest grain interior. The soundness of this method has been justified in the literature (Refs. 47–48).

Results and Discussion

Profiles and Geometry

The computed temperature and velocity fields in three dimensions considering turbulent transfer of heat and momentum are shown in Fig. 3. In this figure, the temperature field is indicated by contour lines and the velocity field is represented by the arrows. The general features of the calculated temperature field are consistent with the results reported in the literature (Ref. 2). In front of the heat source, the temperature gradient is greater than that behind the heat source. The high temperature gradient results in slightly greater liquid metal velocities in front of the heat source than behind the heat source. On the surface of the weld pool, the liquid metal moves from the center to the periphery. This is expected for a metal with a very low concentration of surface-active elements (*e.g.*, very low sulfur and low free-oxygen contents), which results in a negative temperature coefficient of surface tension $d\gamma/dT$ (Ref. 50). As the result of the outward fluid flow and heat transfer on the surface, the weld pool is wide and shallow.

The distributions of turbulent viscosity, thermal conductivity, kinetic energy and dissipation rate in the weld pool are shown in Fig. 4. These quantities are determined by the fluid motion in the weld pool. Since the welding current is not high under the present welding conditions, the electromagnetic force is weak and surface tension is the dominant force. Therefore, the circulation of the molten metal is most intense near the surface and the level of turbulence decreases progressively as the fluid approaches the solid surface. It is interesting that the maximum values of these variables do not lie in the middle of the weld pool. This is because the distributions of these variables are determined by the flow system, and the maximum velocity gradient does not occur in the middle in the present flow system. The maximum dimensionless viscosity (μ_t/μ) and thermal conductivity (k_t/k) values were found to be 13.5 and 4.0, respectively. The calculated dimensionless viscosity (μ_t/μ) and thermal conductivity (k_t/k) values and their spatial distribution patterns are comparable with those reported in the literature (Refs. 18, 19). The high values of these ratios indicate the dissipations of heat and momentum in the weld pool are significantly aided by turbulence. In some previous research on the simulation of heat transfer and fluid flow in the weld pool, the viscosity and thermal conductivity values were arbitrarily enhanced by a constant factor (Ref. 6). The rigorously computed turbulent viscosity and thermal conductivity values presented here clearly show these quantities vary strongly depending on the location within the weld pool. Therefore, accurate calculations of temperature and velocity fields must utilize an appropriate turbulence model.

The geometry of the fusion zone can be predicted from the calculated temperature field, shown in Fig. 5. The fusion zone was determined by the liquidus temperature (1941 K). The calculated width and depth of the fusion zone were found to be 12.2 mm and 2.9 mm, respectively. The corresponding experimental data were 12.0 ± 0.2 mm and 2.8 ± 0.2 mm, respectively. Thus, the calcu-

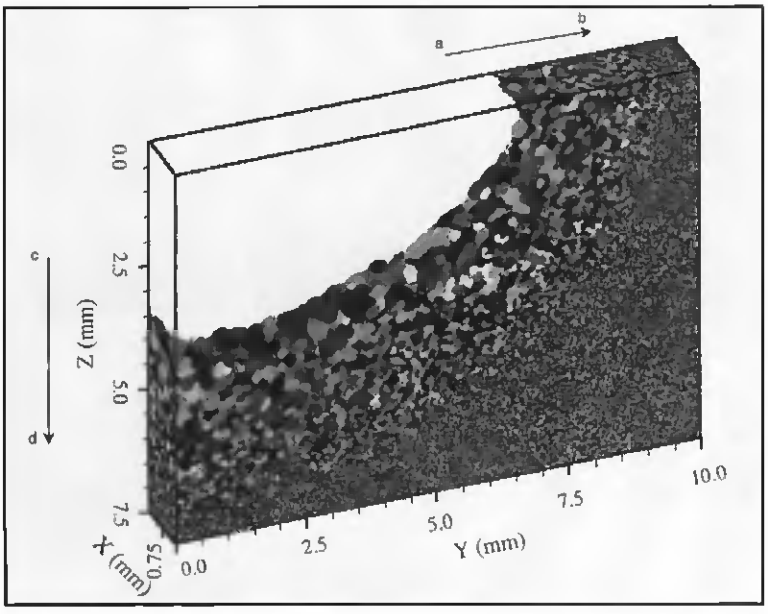

Fig. 16 — Simulated final grain structure of the HAZ using 50 x 400 x 300 grids.

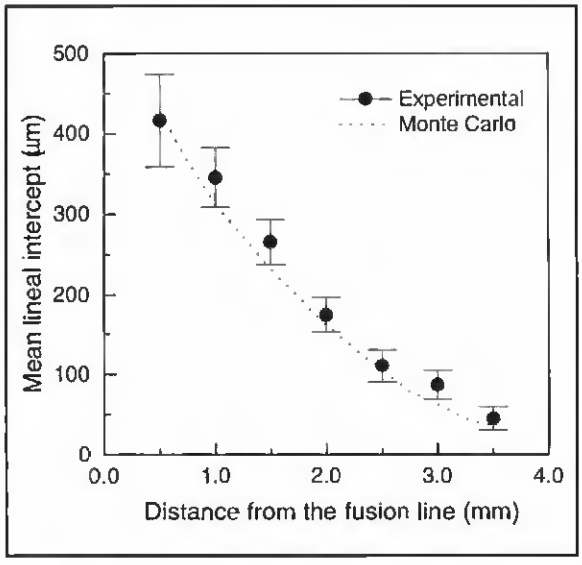

Fig. 17 — Comparison of the calculated and experimental mean grain size at various locations along line ab on the surface of the weldment.

lated dimensions of the FZ agreed well with the corresponding experimental results. Since the starting temperature for the annealing and recrystallization of α-Ti is not known, the geometry of the HAZ cannot be exactly predicted. However, the β-phase-containing region (α-Ti partially or fully transformed to β-Ti) in the HAZ can be predicted. This region exists between the α→β transition isotherm (1158 K) and the liquidus temperature (1941 K). The calculated width of this predicted β-phase-containing region on the top surface was about 3.8 mm, which equals to the corresponding experimentally measured width on the top surface as shown in Fig. 5. From Fig. 5, it can be observed that both the shape and size of this predicted β-phase-containing region are comparable with those of the experimental HAZ.

Spatial Distribution of Phases

Experimental Phase Distribution Map

The spatial distribution map of phases (Ref. 20) as determined from the SRXRD data is shown in Fig. 6A, where the stationary welding electrode is positioned at X = Y = 0, with metal moving from left to right along the X-axis. Five different phase regions were identified in Fig. 6A: α-Ti, (α+β) mixed region, (α_B+β) mixed region, β-Ti and liquid phase. The symbol α_B in the map denotes the back-transformed α-Ti from β-Ti during cooling. The experimental phase boundaries can be approximately determined, as shown by dashed lines in Fig. 6A. It should be noted that the phase distribution map in Fig. 6A is somewhat different from that in the previous paper (Ref. 20) in which the HAZ were subclassified into six regions. To focus on the issues investigated in the present paper, some subclassified regions in a previous investigation (*e.g.*, the annealed and recrystallized zone α_{AR}, and the recrystallized zone undergoing grain growth α_{RG}) are incorporated in the α-Ti region in Fig. 6A.

Calculated Phase Boundaries

The calculated isotherms of α/β (1158 K) and β/liquid (1941 K) phase transitions were imposed on the experimentally determined phase distribution map, as shown in Fig. 6B. It was found the calculated isotherms matched the phase distribution map very well. This means the phase boundaries of α/(α+β) and β/liquid can be satisfactorily predicted by the calculated temperature. The (α+β)/β phase boundary lies at the locations where α–Ti totally transformed to β-Ti, as indicated by the arrows in Fig. 6B. The prediction of the (α+β)/β phase boundary needs the knowledge of both thermal cycles and the kinetics of the transformation, and therefore cannot be predicted by the thermal model alone.

To predict the locations of the (α+β)/β phase boundary, a series of lines parallel to the welding direction were selected, as shown in Fig. 6B. These lines pass through the locations where the (α+β)/β phase boundary has been experimentally determined. As the material approaches the heat source, the α→β transition at different locations begins when the monitoring locations reach the α/β isotherm (1158 K). The extent of α→β phase transformation along these lines was calculated by the combination of the calculated thermal cycles and the modified JMA Equation 17. The calculated thermal cycles experienced by the material moving along these lines are shown in Fig. 7. From this figure, the peak temperatures and the time periods above the α/β isotherm along these lines can be obtained. The further the line is away from the welding centerline, the lower the temperature and the shorter the time period above the α/β transformation temperature. The peak temperatures and the time periods above the α/β isotherm along these lines are given in detail in Table 4.

After knowing the thermal cycles along the lines parallel to the welding direction, the extents of phase transformation along these lines can be calculated by Equation 17. Different transition mechanisms assumed were used to predict the (α+β)/β phase boundary by taking the corresponding values of n and ΔG(T) in Table 2. For each mechanism, the times for the completion of the α→β transformation along these lines were calculated. The calculated reaction times for all of the mechanisms are shown in Table 5. The time for the completion of the α→β transformation along a line parallel to the welding direction can also be obtained experimentally from the phase distribution map. In this way, the time was calculated by dividing the distance — between the α/β isotherm and the experimentally determined location of the (α+β)/β phase boundary along this line — by the welding speed.

To identify the possible mechanism for the α→β transformation, the calculated times for each assumed mechanism were compared with the times determined from the experimental phase distribution map, as shown in Fig. 8. It was found the times from the phase distribution map agreed well with the calculated times from mechanism 1, in which the α→β transition was assumed to be controlled by the transport of Ti atoms across the interface. The calculated times from mechanism 3, in which the transition was assumed to be controlled by oxygen long-range diffusion, are also approximately comparable with the experimentally determined times. Significant discrepancies exist between the experimental determined times and the calculated times from mechanism 2, in which the transition was assumed to be controlled by the transport of oxygen atoms across the interface. Through the comparison of the calculated times with the experimentally determined times, it seems that the α→β transition is most likely controlled by the transport of Ti atoms across the interface.

By adopting the mechanism that the α→β transformation was controlled by the transport of Ti atoms across the interface, the locations of the (α+β)/β phase boundary along the lines parallel to the welding direction were predicted. The transformed volume fractions of a phase along the lines were calculated by Equation 17 and shown in Fig. 9A. Depending on the thermal history experienced, the times for the completion of the α→β transformation along these lines were different. As expected, the further away the line from the welding centerline, the longer the time for the completion of the transformation. This can be more clearly observed by comparing the times needed for the α→β transformation along different lines, as shown in Fig. 9B. After obtaining the reaction times along these lines, the distances between the transformation starting points and the transformation finishing points can be calculated by multiplying the welding speed with the calculated reactions times. The starting points are the intercepts of the calculated α/β isotherm with these lines. Thus, the locations of the (α+β)/β phase boundary along these lines can be determined and shown as the plain circles in Fig. 6B.

Grain Growth in the Single β Region

Domain Selection for MC Simulation

The selection of the domain for MC simulation of grain growth in the HAZ was based on the calculated temperature field from the 3-D heat transfer and fluid flow model. In order to achieve efficient simulation of grain growth, two factors need to be considered in selecting the simulation domain. First, all the essential geometric features of the HAZ should be included in the simulated domain. On the other hand, the domain should be kept as small as possible, because simulation of grain growth in the whole HAZ region requires extensive calculations. Depending on the purpose of the simulation, two domains in the weldment were selected in the present study. The first domain was selected as the dashed block shown in Fig. 10A to simulate real-time grain structure evolution in the HAZ around the weld pool. This domain covers the whole region of the HAZ where β grain growth occurs. The length, width and thickness of the simulation domain were 20 mm, 10 mm and 8 mm, respectively. A 400 x 200 x 160 grid system was used.

The second domain was selected as the thin dashed block shown in Fig.10B to focus on simulation of the final grain structure in the HAZ. The grid system used in this domain was 50 x 400 x 300, which corresponds the actual domain with the volume of 1.25 x 10 x 7.5 mm^3. Thus, the spacing of the grid points, 25 μm, was equal to the initial mean grain size. The initial β-Ti grain size, L_0, was assumed to be equal to the α-Ti grain size after recrystallization (25 μm). The grain size change due to the α→β transformation was not considered. Thus, the starting β-Ti grain size was set to an upper limit, since the grain size of the daughter phase is smaller than that of the parent phase. The selected domain was assumed to move at the same speed and in the same direction as the workpiece, as indicated in Fig. 10B.

Grain Growth Kinetics from MC Simulation under Isothermal Conditions

Before simulation of the grain growth under nonisothermal conditions, the dimensionless grain growth kinetics from the present MC model under isothermal conditions needs to be established. In other words, the values of K_1 and n_1 in Equation 18 need to be determined. Figure 11 shows the simulated isothermal dimensionless grain growth kinetics for the used two grid systems at 1548 K, which is the median of the melting temperature (1941 K) and the α→β transition temperature (1158 K). The data used for calculations are presented in Table 3. It can be observed the simulated grain growth kinetics in the two grid systems are actually the same. This is expected since the numbers of the grids in these two systems are very large and both systems use simple cubic grids. By geometric fitting of the data in Fig. 11, the values of the constants K_1 and n_1 in Equation 18 were determined to be 0.85 and 0.47, respectively.

Distributions of the t_{MCS} and the Probability

After knowing the constants K_1 and n_1 of the present 3-D MC model, the t_{MCS} at each site was calculated from Equation 21 by incorporating the corresponding thermal history into the equation. The distribution of the t_{MCS} in the first domain using the 400 x 200 x 160 grid system is shown in Fig. 12A and B. From these figures, it can be observed that the maximum value of the t_{MCS} lies at the locations nearest to the weld interface. The t_{MCS} near the fusion zone change drastically due to the steep temperature gradient. This phenomenon is more evident at the edge in front of the weld pool. From Fig. 12A, it can also be observed the value of t_{MCS} increases as the temperature or time for grain growth at a location increases. This can be easily understood by tracking a specific point in the domain as shown in Fig.12A. As the material at this location moves from point A to point B, the t_{MCS} at this point will increase. After knowing the t_{MCS} spatial distribution in the domain, the corresponding site selection probability, p(r), distribution can be obtained from

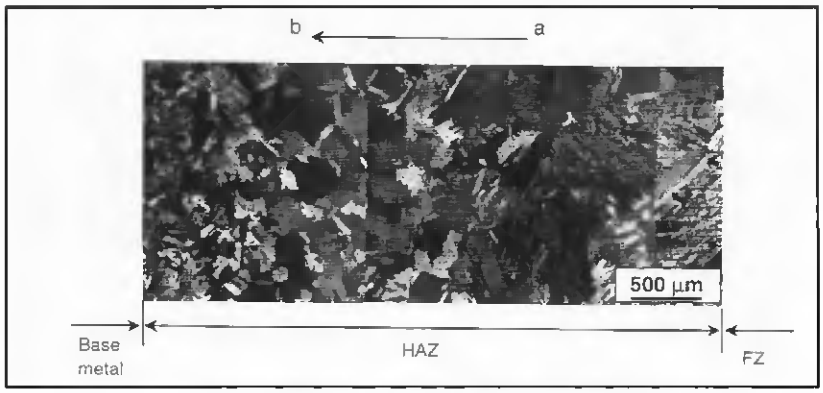

Fig. 18 — Grain size gradient in the HAZ (50X). The direction indicated by line ab is labeled in Fig. 16.

Equation 22, as shown in Fig. 13A and B. The spatial distribution of p(r) is similar to that of t_{MCS}.

Figures 14A and B show the distribution of the t_{MCS} and p(r) in the domain shown in Fig. 10B using the 50 x 400 x 300 grid system. Compared to the values of t_{MCS} in Fig. 14A and Fig. 12A, it can be observed the t_{MCS} in the second grid system is much larger than in the first system. This is because the grid spacing in the second system is only half of that in the first grid system. The finer the grid system, the larger the t_{MCS} needed for achieving the same grain size. After obtaining the p(r) distribution, the temperature time history at each site, as well as the material properties, can be incorporated into the model by considering the spatial site selection probability distribution in the simulation domain.

Simulated Grain Structure in the HAZ

After the introduction of the site selection probability into the MC model, the dynamic grain growth in the HAZ around the weld pool can be simulated. By using the first grid system, a real-time, three-dimensional map of grain structure distribution around the weld pool can be obtained, as shown in Fig. 15A, B, C. From these figures, the detailed grain structure in every location in the whole HAZ around the weld pool can be obtained. The grain structure at any plane in the domain can be viewed by examining any cross section. Furthermore, the real-time grain structure map can provide insight into the thermal and topological effects experienced in the HAZ. In the region in front of the weld pool, the grain growth is not significant and the grain size is fine due to the very short time for grain growth before the material at these locations melts. At the locations where the material does not melt, the mean grain size becomes coarser with time. In the meantime, the width of the HAZ increases with time. These features can be seen clearly in both the top and side views of the simulated grain structure map shown in Fig. 15B and C. The results shown here can provide detailed insight about the grain structure evolution under steep temperature gradient in the HAZ, which cannot be obtained otherwise.

The simulated final grain structure of the HAZ after the welding is completed is shown in Fig. 16. Significant spatial grain size gradient is observed in the simulated HAZ structure. The closer a site to the weld interface, the coarser the grain at that site. This is expected since the grain size change depends on both the temperature and the time period for grain growth. The higher the temperature and the longer the time for grain growth, the larger the final grain size. Furthermore, it can be observed grain growth on the top surface of the HAZ (along line ab) is not as significant as in the vertical direction shown by line cd in Fig. 16. This is because the temperature gradient on the top surface is relatively steeper and the time for grain growth is less than those at the bottom of the HAZ.

Along line ab on the top surface in Fig. 16, the calculated grain size gradient is compared with the experimental results in Fig. 17. It can be observed the calculated and the experimental grain sizes are comparable. The experimental grain size measurement was made after cooling to ambient temperature. Note that the grain size in the postweld microstructure is not the same as predicted in the single β phase region due to β→α transformation occurring during the cooling of the weldment. However, the prior β grain boundary can still be identified from the postweld microstructure, as shown in Fig. 18.

Summary and Conclusions

The research reported here represents the first modeling of macro and microstructural features in GTA titanium weldments based on a combination of both rigorous transport phenomena and phase transformation theory. The modeling results were compared with the real-time phase mapping data in a region surrounding the liquid weld pool obtained using a unique 5RXRD technique with synchrotron radiation. Through the comparison of the calculated and experimental results, the conclusions below can be made.

1) The high-computed values of turbulent viscosity and thermal conductivity indicated the transport of heat and momentum in the weld pool was significantly aided by turbulence. Thus, previous calculations of heat transfer and fluid flow based on the assumption of laminar flow need to be re-examined. The geometry of the fusion zone, the α/(α+β) phase boundary and the β/liquid phase boundary predicted from the comprehensive 3-D turbulent heat transfer and fluid flow model were in good agreement with the experimental results.

2) The mechanism of the α→β transition was examined by the comparison of the calculated reaction times from several possible mechanisms with the experimentally determined reaction times. It was found the α→β transition was most likely controlled by the transport of Ti atoms across the α/β interface. The (α+β)/β phase boundary predicted from the combination of the calculated thermal cycles and the modified JMA equation agreed well with that determined from the experimental phase distribution map.

3) A real-time 3-D map of grain structure distribution around the weld pool was calculated by coupling the 3-D MC model with the calculated thermal cycles from the 3-D heat transfer and fluid flow model. This simulated real-time 3-D grain structure map can provide detailed insight into the dynamic grain structure evolution under steep temperature gradient in the HAZ that cannot be obtained otherwise. The simulated grain size distribution in the HAZ agrees well with the experimental results.

The above agreements between the calculated and experimental results indicate significant promise for understanding both macro and microstructures of titanium welds from the combination of the fundamental principles from both transport phenomena and phase transformation theory. Neither experiments nor modeling alone could have provided the detailed insight about the real-time evolution of macro and microstructures.

Acknowledgments

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Appendix

The grain boundary energies of metals are often found to be roughly ½ of their surface free energies (Ref. 43). The surface free energy of titanium is not available in the literature. However, the surface free energies of metals are related with their melting points. The higher the melting point, the higher the value of surface free energy (Ref. 43). This correlation can be seen in Fig. 19, which is drawn based on the data available in the literature (Ref. 45). By linear fit of the data in Fig. 19, the surface free energy of titanium can be estimated to be about 2.25 J/m^2. If the grain boundary energy of titanium is taken as ½ of this estimated surface free energy, its corresponding value will be 0.75 J/m^2. This estimated grain boundary energy is comparable with those of other metals whose melting points are close to titanium and experimentally measured value are available in the literature. For example, the grain boundary energy (Ref. 45) of γ-Fe is 0.756 J/m^2.

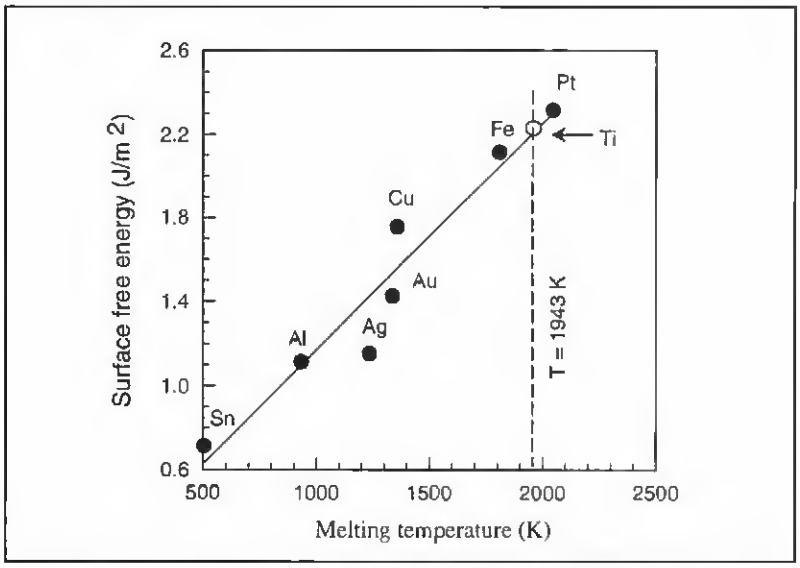

Fig. 19 — Estimation of the surface-free energy of titanium based on the data of other metals available in literature (Ref. 44).

Nomenclature

A	Accommodation probability for the jumping atoms
C_1,C_2,C	Empirical constants in K~ε model
C_p	Specific heat, (J/kg-K)
f	Volume fraction of transformed phase
g	Acceleration of gravity, (m/s^2)
G_K	Cartesian tensor notation in K ~ ε model, (s^{-2})
ΔG(T)	Total activation energy for nucleation and growth, (J/mol)
h	Enthalpy, (J/kg)
h_c	Heat transfer coefficient, (J/m^2-s-K)
h_p	Planck's constant, (J/s)
$J_h(\xi,y,z)_{z=0}$	Heat flux change on top surface, (J/m^2-s)
k	Molecular value of thermal conductivity, (J/m-s-K)
k_B	Boltzmann constant, (J/K)
k_{eff}	Effective thermal conductivity, (J/m-s-K)
k_t	Turbulent thermal conductivity, (J/m-s-K)
k_0	Pre-exponential constant in JMA equation
k(T)	Temperature-dependent kinetic constant in JMA equation
K	Turbulent kinetic energy, (m^2/s^2)
K_1	Grain growth kinetic constant from MC simulation
K_2	Pre-exponential constant for calculation of grain size
L	Average grain size at time t, (μm)
L_0	Initial average grain size, (μm)
n	Kinetic constant in JMA equation
n_1	Grain growth kinetic constant from MC simulation
N_a	Avagadro's number, (mol^{-1})
P	Effective pressure, (N/m^2)
Pr_t	Turbulent Prandtl number
p(r)	Site selection probability in MC simulation
q	Welding power input, (J/s)
Q	Activation energy for grain growth, (J/mol)
r_b	Radius of the arc beam, (m)
R	Gas constant, (J/mol-K)
S_h	Heat source term considering heat input from welding source and heat loss by convection and radiation, (J/s-m^2)
S_l	Heat source term considering latent heat of melting and convective transport of latent heat, (J/s-m^2)
S_v	Momentum source term considering the combined effect of buoyancy force, Marangoni stress and electro magnetic force, (N/m^3)
ΔS_a	Activation entropy for grain growth, (J/mol-K)
t	Time, (s)
t_0	Initial time of phase transformation, (s)
t_{MCS}	MC simulation step or MC simulation time
t_{MCS}^{max}	Maximum MC simulation step in the computation domain
Δt	Time increment, (s)
T	Absolute temperature, (K)
$T_s(\xi,y,z)$	Temperature at coordinate (ξ,y,z) in steady-state temperature field, (K)
$T(\xi,y,z)_{z=0}$	Local weld pool surface temperature, (K)
T(x,y,z,t)	Temperature at coordinate (x,y,z) at time t, (K)
T_g	Ambient temperature, (K)
T_0	Initial temperature of phase transformation, (K)
ΔT	Temperature increment, (K)
V_x,V_y,V_z	Velocity components in the x, y and z directions respectively, (m/s)
V'	Transformed velocity, (m/s)
V	Convective component of the velocity, (m/s)
V_m	Atomic molar volume (m^3/mol)
V_s	Welding velocity, (m/s)
Z	Average number of atoms per unit area at grain boundary, (atoms/m^2)
ε	Dissipation rate of turbulent kinetic energy, (m^2/s^3)
ε_1	Emissivity
γ	Surface tension of liquid metal, (N/m)
γ_b	Grain boundary energy, (N/m^2)
η	Welding process efficiency
λ	Discrete grid point spacing in MC simulation, (μm)
μ	Molecular value of viscosity,(kg/m-s)
μ_{eff}	Effective viscosity, (kg/m-s)
μ_t	Turbulent viscosity, (kg/m-s)
ρ	Density, (kg/m^3)
σ	Stefan-Boltzmann constant, (W/m^2-K^4)
σ_k, σ_e	Empirical constants in K–ε model
ξ_1, ξ_2	Coordinates in x direction at time t_1 and t_2 respectively, (m)

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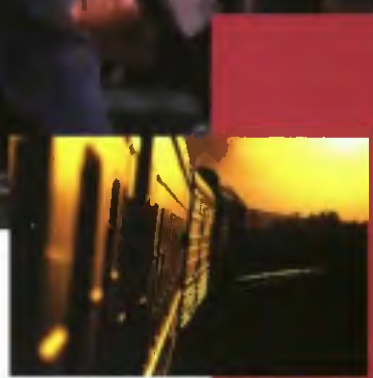

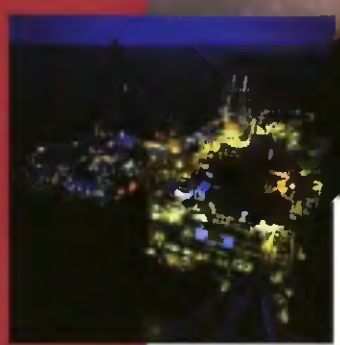

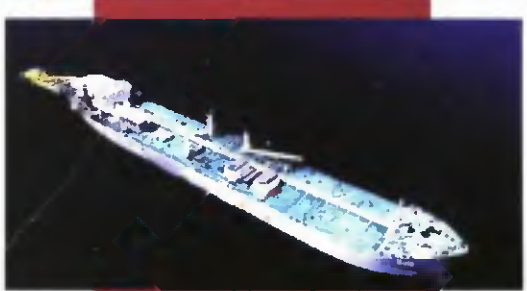

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