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C. A. Lensing et al.
Thermadyne Posts Big Sales Gain

Thermadyne Holdings Corp., St. Louis, Mo., reported its financial results for the first half of 2004, including a 20.6% jump in U.S. net sales compared to the first half of 2003. The parent company of Victor, Tweco/Arcair, Thermal Dynamics, Thermal Arc, Stoody, GenSet, and Cigweld reported a worldwide net sales increase of 18.1%, due to strong sales growth in Latin America and Australia, which was partially offset by declining sales in Europe and Canada.

"The increase in domestic sales was driven by a stronger industrial economy in the U.S. and market share gains," the company stated.

Kotecki Elected Vice President of IIW

AWS vice president Damian J. Kotecki has been elected vice president of the International Institute of Welding (IIW), the consortium of welding societies from 46 countries. Kotecki, technical director for stainless and high-alloy product development at The Lincoln Electric Co., writes the "Stainless Q&A" column in the "Welding Journal."

"I hope to help guide the IIW as it evolves into a more important vehicle for technology transfer and international relations for the welding community," said Kotecki. "In my additional role as vice president of American Welding Society, I expect to strengthen the relationship between IIW and AWS."

OSHA Adds Protocol to Respiratory Equipment Standard

The Occupational Safety and Health Administration (OSHA) added a new fit-testing protocol in August to its Respiratory Protection Standard. The revision adds three quantitative fit-testing exercises to help employees select the right respirator for minimal leakage. The first test exercise involves measuring leakage while standing normally, facing forward, breathing normally for 30 seconds, then holding one’s breath for 10 seconds. The second exercise is the same, while bending over at the waist. The third test requires shaking the head back and forth vigorously while shouting for 3 seconds, then holding breath for 10 seconds. After the three exercises, sampling is repeated for two redonnings of the respirator.

Steel Imports Surged in First Half

The American Iron and Steel Institute’s (AISI) analysis of Census Bureau data found that steel imports jumped 30% in the first half of 2004 compared to 2003. June’s imports were the highest for any month since February 2002. The AISI called on the government to monitor steel imports more vigilantly to protect domestic producers.

The Precision Metalforming Association (PMA), however, praised the increase in steel supplies, stating that "steel consumers in the U.S. desperately need access to competitively priced steel." The PMA pointed out that prices of rolled steel sheets are $100 to $200 more per ton in the United States than elsewhere in the world, and that imports of these products are actually down 10% and 49% from import levels of 2001 and 2002, respectively, before tariffs were implemented.

Jackson Products Increases Earnings, Gets Better Borrowing Rates

Less than six months after restructuring, Jackson Products, Inc., St. Louis, Mo., announced that its investment bankers had cut the rates on its loans, saving it $2 million a year in interest. The lenders made the move based on performance of the safety equipment manufacturer in the first half of this year, the company said. Jackson Products reported an increase in sales and earnings of 41.1% and 14.6%, respectively, for the first half of 2004, compared to the first half of 2003.

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A Shared Passion Brings Results

Over the past three years, I have had the honor to lead a remarkable organization, a dynamic organization in constant movement that has proven to be successful, through its rapid growth and many accomplishments. The organization is the AWS Welding Equipment Manufacturers Committee (WEMCO).

WEMCO owes its success to the contributions of many outstanding individuals: those from the American Welding Society who have worked long and hard to provide the great benefits we all enjoy, the volunteers from the WEMCO sub-committees who are the backbone of the organization and who keep it focused on issues important to our members, and the members themselves who continually encourage us and push for added value for this incredible organization.

Great organizations, large and small, grow and prosper because of the intense passion shared by their members. WEMCO is that kind of organization. Its members are committed. Just eight years old, WEMCO now consists of more than 100 member companies, all of which are focused on making themselves better and more competitive in a global economy and that are committed to improving the health of the welding industry worldwide.

The structure of WEMCO has let us tackle issues crucial to the welding industry and to its members. For instance, the AWS Image of Welding Initiative, a high-profile, award-winning effort that includes radio and television spots, highlights welding as a career choice. WEMCO is proud to have a leadership role in this program and will be announcing more exciting components in the near future.

For the past couple of years, WEMCO has worked closely with AWS leadership to develop a strategy that will improve the AWS Welding Show in terms of "added value" for both exhibitors and attendees.

On a global trade level, we are researching possible trade missions to be held annually and many of our members are regular American Pavilion exhibitors in the international arena, exhibiting at shows in Germany, China, Mexico, and numerous other sites worldwide.

The WEMCO annual meetings are first class both in terms of resort sites and program content, and provide unparalleled networking opportunities. Our speakers are of the highest caliber. Topics include an annual review of the domestic and world economy, supply chain management, human resource development, partnering and alliances, electronic commerce, and manufacturing technology.

This is my last year as chairman of WEMCO. I've enjoyed my tenure and as I reflect on our accomplishments, I would like to honor those individuals who have worked for our success:

Served as Chairman
- Rusty Franklin, Sellstrom Manufacturing Co., vice president sales and marketing

Served as Chairman and Vice Chairman
- Phil Winslow, Hypertherm, vice president sales and marketing

Served as Vice Chairman

--- continued on page 15 ---
There Are No Limits

Just Endless Possibilities
Miller Fall Protection Plant Expanding

Bacou-Dalloz has announced a multimillion-dollar expansion of its Franklin, Pa., plant, where it manufactures the Miller Fall Protection brand of safety equipment. An increase of as much as 50,000 sq ft will allow the firm to consolidate its U.S. manufacturing and warehousing operations in one location. Construction is scheduled to begin this year. The company is also upgrading its Canadian manufacturing and distribution facility in Trenton, Ont. Bacou-Dalloz appointed a new CEO, Henri-Dominique Petit, in June.

Doctors Prove They Can Weld Human Tissue

A process developed by the E. O. Paton Institute of Electric Welding in Ukraine has been utilized in clinical trials of 71 medical patients in that country who suffered from lung and other diseases. The process uses low heat from radio-frequency energy to reconnect and bond tissue after incisions, without sutures or staples. The welding process left little or no scarring and reduced postoperative hospital stays, the doctors reported.

Consortium Formed to Validate Welding Process for Heat Exchangers

Delphi Corp. has formed a consortium of welding industry firms to validate a new technology for welding tubes to sheet metal, a technique that could make it less expensive to manufacture heat exchangers. The solid-state process, called deformation resistance welding, has been successfully used by Delphi in auto products. It creates leak-tight joints between tubes and solids, sheet metal, or other tubes by heating and deforming the mating surfaces. Suppliers to the consortium include Unitek Miyachi Corp., AddisonMckee Inc., RoMan Manufacturing Inc., and Taylor-Winfield Corp.

First Textbook on Nanotechnology Published

Three scientists who met while working together at Virginia Tech have created the first college textbook on nanotechnology. The 23-chapter Introduction to Nanoscale Science and Technology combines materials written by about 60 active researchers in the field. The book covers a broad range of topics and is aimed at being accessible to undergraduate readers and anyone with a background in science or engineering.

Group Demands Action on Scrap Steel Prices

Citing high steel prices and domestic shortages, an industry group called the Emergency Scrap Steel Coalition has asked the government to restrict the export of scrap steel. Scrap brokers
blame a spike in steel prices on exports to China's expanding industrial sector. The industry group says other countries have restricted their scrap exports to maintain domestic supplies, and that the United States should follow suit.

**EPA May Require Cooling Retrofits at More than 500 Power Plants**

A new ruling by the Environmental Protection Agency may require major retrofits in the cooling water intake structures at 543 major U.S. power plants. The rule requires plants to minimize their impact on aquatic life, and could lead some plants to implement closed-cycle cooling systems. Another phase of the rule, to be released later this year, will address the water intake structures of refineries and paper companies.

**Lincoln Sets Sales Records**

Strong demand worldwide caused sales of Lincoln Electric Holdings, Inc., to leap 25% in the second quarter of 2004, compared with the same quarter last year. This was the highest sales increase in the company's history, and led to a jump in net income of 67%.

"Continuing strong demand in all of our markets — domestic and international — contributed to higher sales, increased production, and strong profitability in the quarter," said Lincoln CEO John M. Stropki. "The improving economy and the rise in worldwide industrial production are fueling economic growth in our major market segments."

**Gas Suppliers Announce Increased Sales**

Several welding gas firms have recently announced favorable financial results. Air Liquide posted a worldwide sales increase of 9.8% in the first half of the year. Praxair, Inc., reported a 14% sales growth in the second quarter, and projects a sales increase of 13 to 15% for the year.

Airgas Inc. completed its acquisition of The BOC Group's U.S. packaged gas business, which involved more than 120 retail stores and other operations in 21 states.

Matheson Tri-Gas predicted that its acquisition of six industrial gas plants in several states will lead to increased sales.

**Laser Beam Cladding System Recognized as Technologically Significant**

A laser-powered system that bonds new metal to worn machinery parts has been named one of the "Top 100 Most Technologically Significant Products of the Year" by R&D Magazine. The process, developed for the U.S. Navy by Alion Science and Technology, uses a 4000-W laser system, multi-axis robotics, and integrated monitoring technologies to refurbish metal parts by bonding a layer of new metal to them. This allows for a much greater life span for machinery parts such as driveshafts and valve gates by renewing the surface and protecting the parts from corrosion and wear.

**Louisiana Reports Industrial Job Losses**

The Louisiana Department of Labor reported a loss in manufacturing and construction jobs as of June over the previous year, including decreases in the oil support industry and chemical manufacturing. An overall improvement in unemployment was attributed to growth in service industries such as hospitality and health care.
ProMotion Controls and Koike Aronson Team Up to Offer Cutting Solutions

ProMotion Controls Inc., Medina, Ohio, has announced a five-year partnership with Koike Aronson Inc. to bring to market a new line of PC-based shape-cutting controls tailored for Koike Aronson’s plasma and oxyfuel cutting machines. The first product of the partnership is a 1400-in./min single-torch plasma cutting machine with CNC-based shape-cutting capabilities, priced at about $30,000.

Studies Praise and Criticize Outsourcing

A Columbia University survey of companies that outsource jobs abroad found that about 70% of them not only experience reduced costs, but also report better quality. The companies reporting the highest level of satisfaction were those that were making a long-term commitment to offshore outsourcing. The study found that geographical distance was not an obstacle to successful outsourcing, but that political risk and fear of the loss of intellectual property were major downsides.

A different report from a Washington think tank urges outsourcing of jobs only as a last resort. The Progressive Policy Institute study recommends that companies automate, innovate, and diversify domestically. It asks the federal government to reinstate investment incentives, focus on skills development, and require employers to give three months’ notice to employees before exporting their jobs.

Industry Notes

- Wolverine Tube, Inc., Huntsville, Ala., maker of Silaloy brazing products and other welding materials, posted an almost 40% gain in net sales for the first half of 2004 over the same period last year.
- A single-engine jet design by students from Virginia Tech and their teammates from Loughborough University in the United Kingdom won the best overall award in NASA’s annual Revolutionary Vehicles and Concepts Competition for university students.

Students from Virginia Tech and Loughborough University pose in a wind tunnel with a model of their winning entry in a NASA competition.

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<table>
<thead>
<tr>
<th>Stainless</th>
<th>Cast Iron</th>
<th>Cobalt</th>
<th>AISI</th>
<th>Nickel</th>
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<tr>
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<td>ENiCrFe-2</td>
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<tr>
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<td>4340</td>
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<td>21 Ni</td>
<td>21</td>
<td>ERNiCrMo-3</td>
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<td>2</td>
<td>2101</td>
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</tr>
<tr>
<td>E630 FC</td>
<td>3</td>
<td>904L FC</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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• The Association for Manufacturing Technology reported that shipments of work holding equipment in the United States increased 12.3% in the first quarter vs. the same period last year.
• Weldtech Training, Mississauga, Ont., has been awarded a contract from the city of Toronto to train and provide AWS certification to 80 municipal millwrights and apprentices.
• China has granted CCC certification to 14 Hypertherm plasma cutting products, approving them for import by Chinese distributors.
• Magnatech LP, E, Granby, Conn., has been awarded a contract by the Office of Naval Research to develop a double-sided arc welding process for shipbuilding.
• FKI Logistex White Systems has been granted GSA contract approval to sell its material handling equipment to federal agencies.
• The University of Oregon’s Center for Optics, Eugene, Oreg., has received a grant to build a laser lab that will be capable of manipulating light and matter at the atomic level.
• The Lincoln Electric Co. has become a corporate sponsor of the AeroShell Aerobatic Team, a precision-formation aerobatic team of four WW II aircraft that appears at air shows.
• Matheson Tri-Gas’s ULTIMA-Sorb dry abatement media received the Gases and Technology Product Innovation Award in the category of abatement/recycling from Gases & Technology magazine.
• Airgas, Inc., has entered into a two-year promotional agreement with Orange County Chopper to supply the world-famous motorcycle shop with welding consumables.

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Q: I'm trying to qualify a procedure for welding an annealed CD4MCu pump casting (ASTM A 890/A 890M Grade IA) to a 316L pipe. We will be doing many of these assemblies. I used ER316L filler metal and the GTAW process. Transverse bend tests are failing near the fusion boundary on the CD4MCu side. It doesn't seem like this should be a filler metal problem, but I'm not sure. What do I need to do to pass the bend test?

A: I agree that the filler metal is not the problem. The heat-affected zone (HAZ) of the CD4MCu is, in all likelihood, the problem. CD4MCu is a very old duplex stainless steel. It dates from before the time that steelmakers understood the importance of nitrogen to successful welding of duplex stainless steels.

Nitrogen is essential to the formation of a reasonable amount of austenite in the weld HAZ of duplex stainless steels in the as-welded condition. CD4MCu castings are put into a proper balance of ferrite and austenite by a high-temperature heat treatment, normally by holding at 1900°F (1040°C) minimum for some time, followed by water quenching. When the steel is reheated, as by welding, to near the melting temperature range, all of the austenite transforms to ferrite, so that the HAZ is essentially 100% ferrite. Then rapid cooling, as normally happens during welding, prevents reformation of the austenite so that the HAZ close to the fusion boundary is nearly 100% ferrite when it reaches room temperature. This ferrite is very coarse grained, which makes it brittle. Furthermore, the small amount of tramp nitrogen normally present causes precipitation of chromium nitrides because ferrite can dissolve very little nitrogen. The chromium nitrides add to the brittleness, as well as being very detrimental to corrosion resistance.

The solution to the problem of getting good HAZ properties in the as-welded condition is to add more nitrogen. Nitrogen is a very small atom and it diff-

---

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Table 1 — Composition Requirements (%) for CD4MCu and Similar Castings

<table>
<thead>
<tr>
<th></th>
<th>ASTM A890 Gr. 1A (CD4MCu)</th>
<th>ASTM A890 Gr. 1B (CD4MCuN)</th>
<th>ASTM A890 Gr. 1C (CD3MCuN)</th>
</tr>
</thead>
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<td>UNS No.</td>
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<td>J93372</td>
<td>J93373</td>
</tr>
<tr>
<td>C</td>
<td>0.04 max</td>
<td>0.04 max</td>
<td>0.030 max</td>
</tr>
<tr>
<td>Mn</td>
<td>1.00 max</td>
<td>1.00 max</td>
<td>1.20 max</td>
</tr>
<tr>
<td>P</td>
<td>0.040 max</td>
<td>0.04 max</td>
<td>0.030 max</td>
</tr>
<tr>
<td>S</td>
<td>0.040 max</td>
<td>0.04 max</td>
<td>0.030 max</td>
</tr>
<tr>
<td>Si</td>
<td>1.00 max</td>
<td>1.00 max</td>
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<tr>
<td>Cr</td>
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<td>Ni</td>
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<td>4.7–6.0</td>
<td>5.6–6.7</td>
</tr>
<tr>
<td>Mo</td>
<td>1.75–2.25</td>
<td>1.7–2.3</td>
<td>2.9–3.8</td>
</tr>
<tr>
<td>Cu</td>
<td>2.75–3.25</td>
<td>2.7–3.3</td>
<td>1.40–1.90</td>
</tr>
<tr>
<td>N</td>
<td>—</td>
<td>0.10–0.25</td>
<td>0.22–0.33</td>
</tr>
</tbody>
</table>

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fuses more rapidly than any other alloying element in the steel. The nitrogen promotes austenite formation at higher temperatures, where diffusion is more rapid, which allows virtually all of the nitrogen to find some austenite, and to promote formation of more austenite, before the temperature falls to a level that is too low for further diffusion. The steelmakers have recognized this problem, and the ASTM A 890/A 890M standard provides for two additional casting grades that are essentially the same in alloy composition as CD4MCu, except for the requirement for nitrogen. The two additional grades are Grade 1B (also known as CD4MCuN) and Grade 1C (also known as CD3MCuN).

Table 1 compares the compositions of the three related grades of castings as given in ASTM A 890/A 890M. Due to the nitrogen requirement, Grade 1B is more weldable than Grade 1A. However, Grade 1B can still have rather low nitrogen, as little as 0.10%.

In my April 2000 Stainless Q&A column, I noted the change in ASTM A 240 in the minimum nitrogen for the duplex stainless Alloy 2205, from UNS S31803 (0.08-0.20% nitrogen) to UNS S32205 (0.14-0.20% nitrogen) to make it more weldable. The same applies in your situation. The ASTM A 890/A 890M Grade 1C, with a 0.22% minimum nitrogen, is even better for as-welded properties. If you have the liberty to change your casting specification, I suggest you do that immediately.

If you must weld the low-nitrogen CD4MCu (Grade 1A), I am afraid that you cannot pass a bend test unless you anneal after welding. When you are heating to the annealing temperature, sigma phase will form in the CD4MCu and probably also in the 316L weld metal that is diluted by the CD4MCu. You must dissolve the sigma at the annealing temperature, which likely means that you will have to anneal at 2050°F (1120°C) to be safe. This is because the high nickel content of 316L mixed with the high chromium and molybdenum of the CD4MCu makes sigma stable to temperatures above the 1900°F minimum temperature that ASTM A 890/A 890M mentions for annealing duplex stainless steels. After a few hours at 2050°F, you must water quench immediately upon removing the weldment from the furnace.

I also suggest that you do not attempt to delay annealing of the casting until after welding. In the as-cast condition, CD4MCu, CD4MCuN, and CD3MCuN will all contain a great deal of sigma phase, which makes the metal very brittle.

The shrinkage associated with welding is likely to cause cracking in the casting near the weld. I suggest that the casting be annealed before welding, and again after welding, if you have to stick to CD4MCu as the casting material. You should certainly not have to anneal after welding if you can switch to the CD3MCuN grade of casting. If you use the CD4MCuN grade, it will be a gamble as to whether or not you need to anneal after welding to pass the bend test — that will depend largely upon how much nitrogen you can get. If the composition is very close to the top limit for nitrogen, you stand a good chance of not needing to anneal again after welding.

It is noteworthy that ASTM A 890/A 890M requires only 16% minimum tensile elongation for Grades 1A and 1B, but it requires 25% minimum for Grade 1C — this too is related to the nitrogen content.

DAMIAN J. KOTECKI is Technical Director for Stainless and High-Alloy Product Development for The Lincoln Electric Co., Cleveland, Ohio. He is an AWS Vice President, and a member of the ASD Subcommittee on Stainless Steel Filler Metals: D1 Committee on Structural Welding, DJK 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 Dr. Kotecki c/o Welding Journal, 550 NW LeJeune Rd., Miami, FL 33126, or send e-mail to Damian_Kotecki@lincolnelectric.com.
Site Offers More than a Nickel's Worth

Nickel Institute. Among the offerings on this comprehensive Web site are engineering details on nickel alloys, research data on human and environmental exposures, and information on recycling and sustainable development. The site is easy to navigate and to search. It features a "Technical Support" section that includes 375 technical papers available free of charge: 91 are in character-based PDF format and are searchable by keyword, another 94 are in "bit map" PDF format, and the balance are available only as printed editions that can be ordered for delivery by mail. Included in those are seven downloadable papers on welding and fabrication. These include Guidelines for Welding Dissimilar Metals, Guidelines for the Welded Fabrication of Nickel-Containing Stainless Steels for Corrosion-Resistant Services, Fabrication and Postfabrication Cleanup of Stainless Steels, and Welding of Stainless Steels and Other Joining Methods.

In addition, visitors can read articles from recent issues of Nickel magazine. An article titled "Unconventional Welding," by Dean Jobbs, which appeared in the July 2004 issue, discusses welding of dissimilar metals for the aerospace industry. An excerpt is reprinted here: "If the aerospace industry is to reach its goals of reducing emissions and lessening its burden on the environment, the next generation of jet engines will need to burn fuel more efficiently and at higher temperatures. But building engine components capable of doing so poses a technological challenge: while nickel-based superalloys offer the heat resistance needed, they are difficult to join using conventional welding techniques. "Engineers at the University of Manchester and Rolls-Royce plc, one of the world’s largest manufacturers of gas turbines for aircraft, have teamed up to tackle this problem by applying inertia welding techniques to the production of compressor drums, turbine discs, and shafts for jet engines. ‘Inertia welding has been around for some time,’ notes Prof. Philip Withers of the university’s Materials Science Centre, ‘what’s new is inertia welding as applied to aero-engines.’" "Inertia welding uses the heat generated by friction to fuse metal components together. A workpiece is spun at high speed on a flywheel and brought into contact with a stationary component. Within seconds, the pieces reach forging temperature at the point of contact and are bonded together without melting or the addition of liquid metal."

www.nickelinstitute.org

Site Highlights Metalforming Products

Pacific Press Technologies. This comprehensive Web site offers extensive product information on the Mt. Carmel, Ill.-based company’s line of hydraulic C-frame and straightside presses, press brakes, production shears, compression molding presses, and other pressworking equipment. It includes a “Customer Testimonials” section featuring five application stories. If visitors can’t take the time to read the entire testimonial, a handy boxed section lists the customer’s name and location, the products/markets it serves, statement of the problem it had and the solution it used, and downloadable brochures about the products involved.

The site also includes descriptions of the press maker’s capabilities and services, a complete set of literature and other marketing materials, news releases, and dealer locations. The listing of company employees includes their names, titles, phone numbers, and e-mail addresses.

www.pacific-press.com

Sound and Vibration Measurement Featured

The Modal Shop, Inc. This Web site provides an overview of the company’s line of application software and hardware for dynamic sound and vibration measurement in manufacturing environments. Included are descriptions of the company’s products, which include a digital signal processor, a machine vibration monitoring unit, and vibration sensors. Visitors can locate their closest sales representative by typing in their postal zip code or view examples of cost savings and improvements the company’s customers have realized on the “Dynamic Quality Overview” page. The site also includes four discussion forums related to general sound and vibration applications or specific products.

In addition, the site explains the NDT-RAM® inspection system, which can be used for part quality testing for powdered metal and castings. Included is a downloadable technical paper explaining the resonant acoustic method (RAM) of nondestructive examination. According to the abstract, “RAM NDT tests, reports, and screens for most common part flaws in a manner similar to the way NASA tests flight hardware and automotive manufacturers validate their new car designs. Utilizing structural dynamics and statistical variation, RAM NDT provides mature, laboratory-proven technology in a robust, economical, process-friendly manner.”

ARE YOU UP TO STANDARD?

www.aws.org/catalogs
EDITORIAL

-- continued from page 6

- Hoyt Fitzsimmons, formerly of Thermadyne Industries, executive vice president
- Tom Conard, formerly of Abicor Binzel, president and CEO
- Dean Wilson, Wilson Industries, president

Served as Subcommittee Chairmen

Image of Welding Committee
- Phil Plottica, ESAB, senior vice president business development, now a consultant
- Doug Beck, Harbert's Products, plant manager
- Jim Horvath, Thermadyne Industries, vice president

International Standards Committee
- Greg Erickson, Arc Machines, vice president engineering, now semi-retired
- Nigel Scotchmer, Huys Industries, president

Global Trade Committee
- Jack Bottle, Jackson Products, vice president sales and marketing, retired
- Don Lockhart, Mathey Dearman, president

Program Committee
- Tim DeMars, formerly of Miller Electric Co., executive vice president of marketing
- Dean Wilson, Wilson Industries, president
- Frederick Luening, Bohler Thyssen Welding USA, president

Membership Committee
- Chris Bailey, The Lincoln Electric Co., general manager, automation division
- Jim Tainter, Pandjiris, vice president
- Wayne Barstow, MK Products, vice president, sales

Market Statistics Committee
- Don Mottinger, Superior Products, president
- Bob Ennamorado, Fibre Metal Products Co., vice president sales and marketing

Information Technology Committee
- Frank Langs, Pferd Milwaukee Brush Co., president, retired

American Welding Society Staff
- Mary Ellen Mills, senior manager, WEMCO and WIN programs
- Richard L. Alley, AWS, associate executive director, retired

All of these individuals are to be commended for their true dedication and support, and I, for one, am proud to be a part of WEMCO. You should consider getting yourself and your company involved in this dynamic organization. You as an individual, your company, and the welding industry as a whole will reap the rewards.

Dear Readers:

The Welding Journal encourages an exchange of ideas through letters to the editor. Please send your letters to the Welding Journal Dept., 550 NW LeJeune Rd., Miami, FL 33126. You can also reach us by FAX at (305) 443-7404 or by sending an e-mail to Ross Hancock at rhancock@aws.org.
Friends and Colleagues:

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

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

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

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

For specifics on the nomination requirements, please contact Wendy Sue Reeve at AWS headquarters in Miami, or simply follow the instructions on the Counselor nomination form in this issue of the Welding Journal. The deadline for submission is February 1, 2005. The committee looks forward to receiving these nominations for 2006 consideration.

Sincerely,

H. E. Cable

H. E. Cable
Chairman, Counselor Selection Committee
CLASS OF 2006
COUNSELOR NOMINATION FORM

DATE ___________________________ NAME OF CANDIDATE ___________________________

AWS MEMBER NO. ___________________________ YEARS OF AWS MEMBERSHIP ___________________________

HOME ADDRESS ___________________________

CITY ___________________________ STATE ___________________ ZIP CODE __________________ PHONE __________________

PRESENT COMPANY/INSTITUTION AFFILIATION ___________________________

TITLE/POSITION ___________________________

BUSINESS ADDRESS ___________________________

CITY ___________________________ STATE ___________________ ZIP CODE __________________ PHONE __________________

ACADEMIC BACKGROUND, AS APPLICABLE:

INSTITUTION ___________________________

MAJOR & MINOR ___________________________

DEGREES OR CERTIFICATES/YEAR ___________________________

LICENSED PROFESSIONAL ENGINEER: YES __ NO __ STATE ___________________________

SIGNIFICANT WORK EXPERIENCE:

COMPANY/CITY/STATE ___________________________

POSITION ___________________________ YEARS __

COMPANY/CITY/STATE ___________________________

POSITION ___________________________ YEARS __

SUMMARIZE MAJOR CONTRIBUTIONS IN THESE POSITIONS:

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

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

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

SUBMITTED BY:

PROPOSER ___________________________ Print Name ___________________________

AWS Member No. ___________________________

The proposer will serve as the contact if the Selection Committee requires further information. The proposer is encouraged to include a detailed biography of the candidate and letters of recommendation from individuals describing the specific accomplishments of the candidate. Signatures on this nominating form, or supporting letters from each nominator, are required from four AWS members in addition to the proposer. Signatures may be acquired by photocopying the original and transmitting to each nominating member. Once the signatures are secured, the total package should be submitted.

NOMINATING MEMBER: ___________________________ Print Name ___________________________

AWS Member No. ___________________________

NOMINATING MEMBER: ___________________________ Print Name ___________________________

AWS Member No. ___________________________

NOMINATING MEMBER: ___________________________ Print Name ___________________________

AWS Member No. ___________________________

NOMINATING MEMBER: ___________________________ Print Name ___________________________

AWS Member No. ___________________________

NOMINATING MEMBER: ___________________________ Print Name ___________________________

AWS Member No. ___________________________

STUBMISSION DEADLINE FEBRUARY 1, 2005
Nomination of AWS Counselor

I. HISTORY AND BACKGROUND

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

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

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

II. RULES

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

III. NUMBER OF COUNSELORS TO BE SELECTED

Maximum of 10 Counselors selected each year.

Return completed Counselor nomination package to:

Wendy S. Reeve
American Welding Society
550 N.W. LeJeune Road
Miami, FL 33126
Telephone: 800-443-9353, extension 293

SUBMISSION DEADLINE: February 1, 2005
CL 400
Our newest high-precision thickness gauge quickly locks onto the reading with a precise and stable display. Data is displayed in large, easy-to-read numbers. An optional A-Scan display provides greatly increased accuracy.

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GE Inspection Technologies.
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USIP 40
With our new USIP 40 and its Echo Max Smart View function, you’ll never miss a peak. This high-performance, multi-channel system introduces new software architecture and a user-configurable operation that is designed to meet the most demanding inspections.

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The new PocketMIKE is a compact, cordless thickness gauge and ultrasonic transducer in one. It provides simple, single-handed operation in a rugged, go-anywhere stainless steel case. And its high-contrast display is backlit and can be rotated for easy viewing.

GE Inspection Technologies
50 Industrial Park Road, Lewistown PA 17044
(866) 243-2638
GEInspectionTechnologies.com
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The Lincoln Electric Co.
23601 St. Clair Ave., Cleveland, OH 44117

For more information, contact your authorized distributor or Lincoln Electric at: 1-800-521-4700

Power Supply Designed for Cleanroom Use

The Orbimat 160CR orbital welding power supply features anodized aluminum panels that eliminate the risk of shedding from painted panels, keeping contamination to a minimum. The 160-A unit includes automatic welding parameter generation and is capable of holding 2000 four-level welding procedures. Each procedure incorporates an application specification section that allows for storage of details of gas types and flow rates, tungsten electrode geometry, and material specifications.

Orbimatic GmbH
P.O. Box 414, Welbeck Way, Peterborough, U.K. PE7 3FT

Purge Monitor Cuts Welding Power before Oxidation

The HFT titanium purge monitor incorporates a universal cut-off feature for interlocking with automatic or manual welding equipment. This allows welding to be stopped when oxygen levels reach preset concentrations, to protect welds from oxidation, porosity, and unwanted reactions. Suited for welding titanium, exotic metals, and stainless steel, the unit is calibrated at 10 ppm or 0.001% oxygen and allows monitoring in real time.

Huntingdon Fusion Techniques Ltd. 102
Stokeley Meadow, Carmarthenshire, U.K. SA16 8BU
Power Source Supports Pulsed GMAW for Thin-Gauge Metal

Millermatic® Model 350P offers 208/230 or 460/575 V, single- and three-phase input power, a duty cycle rating of 60% at 300 A/32 V, 25-400 A output, and line voltage compensation. Operators can disconnect the GMAW gun and replace it with an optional push-pull wire feed gun. The unit has a four-roll wire drive system with two scaled tension adjustments and reversible drive rolls for 0.035- and 0.045-in.

Pocket Gauges Measure Up to 0.375 in. Thick

All-metal handheld Series BNC dial gauges measure thickness of sheet metal and other materials. A slight pull on the top plate of the unit opens the chrome-plated and lapped anvils, allowing material to be inserted. Thickness of material is displayed on a dial face in inches to an accuracy of 0.001 in., accommodating thicknesses up to 0.375 in.

Less handling, easier positioning, faster and cleaner welds.

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Other handling and welding aids...Atlas Pipe Supports, Atlas Roller Stands, Atlas Pipe Dollies

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Troy, MI 48099
800-962-9353
WWW.atlsweld.com  E-Mail: atlasswelding@ameritech.net

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Wireless Video Monitor Measures Dust in Real Time

The portable Haz-Dust Model VD-7500 measures levels of airborne particulates while simultaneously overlaying the dust concentration onto video images. All data are displayed in real time on a computer screen, allowing an operator to obtain and record events that are linked to worker exposure to airborne contaminants. This provides a way to implement recommendations for controlling employee health and can help reduce liability for occupational lung disease.

Environmental Devices Corp. 105
4 Wilder Dr., Bldg. 15, Plaistow, NH 03865

Robot Handles Hefty Payloads

The Model E2H853 heavy-duty SCARA robot offers 20 kg maximum payload and 0.45 kgm\(^2\) moment of inertia. The robot comes standard with RC+ software and an RC420 controller.

Epson Factory Automation 106
18300 Central Ave., Carson, CA 90746

Twin-Hose Reels Feature New Crank Design

The G2400 Series twin-hose welding reel features a new gear crank rewind, which faces forward for easy access. The reel handles ¼- or ½-in. oxygen/gas hose in lengths of up to 200 ft. The reel is also

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553 State Rte. 143, Westerlo, NY 12193-0159

Backup Pads Are Precision Balanced

The company's line of backup pad products for sanding and grinding in welding applications includes two sizes of molded urethane pads in a variety of hardnesses and facings. The pads feature heavy-duty riveted hubs and are precision balanced for vibration-free sanding. A soft foam interface pad can be added to the 6-in. backup pad for fine finish sanding and for full contact on irregular surfaces. Other accessories include a stiff, reinforced composite backing plate for aggressive sanding and grinding, and a buffing pad holder for both lamb's wool bonnets and foam polishing pads. A hook facing provides a secure hold while allowing for quick change of pads.

MotorGuard Corp.
580 Carnegie St., Manteca, CA 95337

Gloves Incorporate Stretchy Armor

HyFlex CR+ gloves employ new KEVLAR® Stretch Armor technology for metal fabrication applications that require a high level of cut protection, grip, and dexterity. The ergonomically designed gloves are offered in sizes 6 to 10.

Ansell Healthcare
200 Schulz Dr., Red Bank, NJ 07701

Water Jet Cutting System Produces 3-D Shapes

The Hydro-Jet five-axis water-jet cutting system produces complex three-dimensional shapes in single-pass opera-
The system can operate with either pure water or abrasive-added cutting heads and includes a computer-controlled gantry that guides the jet precisely over workpieces. The product is made of stainless steel and includes a regulated water reservoir and a four-chamber settling tank with a connector for an abrasive sludge removal system.

Knuth Machine Tools USA, Inc. 110
150 Chaddick Dr., Wheeling, IL 60090

Fume Extractor Is Portable

The Mini Flex™ welding fume extractor can be used in confined spaces and offers an automatic start/stop function. Its four-stage filtration system employs LongLife-H® and secondary HEPA filters, providing filtration capability of up to 99.9%. Its standard wheel set and optional wall-mounting bracket enable the unit to be moved around or positioned off the work floor. Powered by two 1.34-hp motors, the 33-lb unit operates at noise levels of 70 dB(A).

The Lincoln Electric Co. 111
22801 St. Clair Ave., Cleveland, OH 44117

Welding Carriage Features 4-Wheel Drive

The four-wheel drive, battery-operated Mini-Vert compact welding carriage will travel in flat or vertical positions, allowing production of continuous, uniform fillet welds. Quick torch-mounting hardware allows a welding gun to be rapidly switched from one side of the machine to the other.

Bug-O-Systems, Inc. 112
30H W. Carson St., Pittsburgh, PA 15204-1899

Device Monitors Resistance Welding Profiles

The Weldaware™ resistance welding monitor is programmed by turning a key switch to the “teach” position while welds are made. Then the key switch is removed, and the unit displays an alarm whenever the process drifts beyond acceptable parameters. The unit checks secondary current, secondary voltage, resistance, and power for each weld, and can be upgraded to monitor force or pressure.

WeldComputer Corp. 113
105 Jordan Rd., Troy, NY 12180
From bridges in Bilbao, Spain and Rolls Royce factories in Europe to fabricators throughout North America, Avesta Welding Products is the choice for welding standard or special grade stainless steels.

We offer the widest range of stainless steel, duplex, and nickel alloys — covered electrodes, flux cored products, solid wire and welding strip, and pickling chemicals — backed by the finest commercial and technical support.

And all of our high-quality products are available through a wide distribution network. Call for a distributor near you.
Diligent adherence to loss prevention measures and proper use of hot work protection products are among the preferred methods for preventing fires

BY MARK BLANK

It's one of the leading causes of multimillion dollar fires and explosions at commercial and industrial facilities, but also one of the most preventable. Yet, hot work mistakes continue to be costly problems for property owners ... and for those who cause hot-work-related disasters.

Case in point: an October 2002 fire at a Japanese shipyard that caused hundreds of millions of dollars worth of damage. Workers were constructing an enormous cruise ship and needed to weld brackets for pipes on a ceiling inside the ship. Investigators determined that the welding caused excessive heat, igniting furniture in a cabin directly above. Before being brought under control, the fire had spread, destroying nearly 40% of the vessel. The welder whose torch caused the fire was later charged with carelessness and sentenced to 18 months in prison.

Hot Work's Hazardous History

Commercial and industrial property insurer FM Global believes the majority of all hot-work-related fires, like the one in Japan, are preventable. That's why, for the past year, the company's engineers and researchers, along with its nationally recognized testing laboratory FM Approvals, have been studying the various threats associated with hot work procedures (e.g., welding, cutting, grinding, brazing, and torch-applied roofing) and testing the products that are designed to prevent them.

The study found that hot-work-related disasters reported to the company average nearly $2 million per incident, and since 1993, three out of every four such fires were caused by cutting or welding torches. The intangible impact of business interruption (e.g., reputation, loss of market share) caused by such fires is incalculably costly.

Another disturbing finding was uncovered: the risk of fire at commercial and industrial facilities can more than double when outside contractors perform unsupervised hot work. During the past two decades, contractors have accounted for nearly 75% of hot work losses at FM Global-insured properties.

The research and findings of this study have led to the development of Approval Standard 4950, Welding Pads, Welding Blankets and Welding Curtains for Hot Work Operations, a first-of-its-kind testing standard that specifically identifies products that can prevent potentially catastrophic hazards of hot work.

Understanding the Dangers of Hot Work

In most cases, hot work losses occur when companies, employees, or contractors fail to follow proper hot work safety guidelines. These guidelines are as simple as implementing a hot work permit system (a precautions checklist highlighting important steps to take during hot work operations), using alternative cutting or joining methods, moving hot work
to safe areas, conducting proper training, and providing adequate supervision.

All too often, however, it's not that the contractors or employees performing the hot work are irresponsible; they simply make mistakes, or they aren't aware of the hazards and the steps that are necessary to mitigate or prevent property loss. Sometimes, workers become complacent and are lulled into a false sense of security, especially at facilities where hot work is conducted routinely. As a result, precautions that may appear insignificant are not followed as strictly as they should be.

Of course, there are steps that contractors and facility managers can take to reduce the dangerous risks of hot work. For instance, discussing hot work projects prior to performing any job is a crucial first step. Managers also should inform contractors of their company's hot work policies and regulations and insist that they be followed, even requiring a signed contract to that effect.

Hot work should always be supervised by a specially trained "fire watch" (i.e., someone from the facility who can observe the hot work operations and be ready to respond in the event of a fire).

Due to hot work's volatile nature, it is imperative to adhere to every precaution. Sparks and molten slag from cutting and welding can easily ignite combustible materials located below or near hot work areas. But hot work hazards aren't always so obvious, even to seasoned hot work professionals.

Sparks and molten globules that fly or roll long distances can ignite combustible materials, like insulation, wood particles, or flammable liquid vapor. Sparks also can settle in areas that aren't easily seen. For instance, if they land on the tops of high ledges, or inside vents, recessed walls, floor openings, or ceiling openings, they can smolder undetected for hours before finally igniting a blaze.

What's more, combustible material isn't always visible. Cutting into a metal wall, for example, can ignite combustible insulation inside the wall or anything close to the opposite side of the wall. Flammable deposits, such as vapor or gas that often are invisible, can spark a fire or explosion. Poorly maintained hot work equipment, like hoses or connections that leak gas, is also a prime culprit.

**Approval Standard 4950's Tough Testing**

However, no matter how diligent contractors and facility managers are in following every precaution, it isn't always enough to prevent significant property losses. FM Approvals' extensive evaluations of the available hot work protection products found a large disparity in their quality and effectiveness.

The good news, of course, is that products that meet FM Approval Standard 4950 are now coming to market to help prevent hot-work-related disasters. Under the standard, hot work protection products are grouped into three categories: welding pads, welding blankets, and welding curtains. As manufacturers are well aware, the different types of hot work op-
Sparks and molten globules that fly or roll long distances can ignite combustible materials. They can also settle in areas that aren't easily seen. (©2004 Factory Mutual Insurance Company. Reprinted with permission. All rights reserved.)

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Abiusa.net • Abi1655@aol.com

The Payoff

Improper hot work procedures can be extremely costly, both to companies and to individuals who perform the work. However, the devastating fires that can result from improperly managed hot work can be prevented. Doing so requires the following:

- Diligent adherence to safety precautions. (Following proper safety procedures is an essential next step.)
- Proper use of quality products. (Using hot work protection products that meet Approval Standard 4950 is highly recommended.)

For commercial and industrial property owners, as well as contractors and their employees, taking these simple steps could mean the difference between a managed risk and a major threat to the future of one's business.
services a wide variety of industries in the ENERGY SECTORS of hydro, petro chemical, atomic, gas, oil, wind, etc. in addition to those in heavy manufacturing, steel, pulp & paper, mining, marine, forestry, etc. Hodgson's commitment to providing customers superior products and personalized professional service has earned itself a reputation for excellence, making the name HODGSON synonymous with "paramount quality and workmanship".

Hodgson Custom Rolling Inc. is one of North America's largest plate rolling, forming, section rolling and fabricating companies.

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Hodgson Custom Rolling specializes in the rolling and flattening of heavy plate up to 7" thick and up to 12 feet wide. Cylinders and segments can be rolled to diameters ranging from 10" to over 20 feet. Products made include ASME pressure vessel sections, Crane Hoist Drums, thick walled pipe, etc.

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Protect Your Most Valuable Asset — Yourself

Don't let yourself become lax about following the proper safety guidelines for using abrasives

BY MARV SCHIFSKY

It can be far too easy to ignore common safety guidelines for welding-related operations, such as grinding, in the name of comfort, convenience, or saving time. Many of us know first hand that working with machinery and abrasives can be hazardous to both operators and bystanders. Experienced operators often get caught off guard. As highly skilled craftspeople, they know what they are doing and are extremely confident in their mechanical skills. But they often take safety risks because for years they've been using techniques that get the job done faster or are more comfortable for them to use. More often than not, however, casual approaches to safety can turn even the most skilled craftsman into a work-related injury statistic.

Presented here are some important basic safety practices — guidelines that should always take precedence over comfort or getting the job done faster.

The Right Tool for the Job

Before ordering abrasives, conduct some research to determine the best products for your jobs. Select products that balance performance advantages and the requirements for the job, along with providing all the safety requirements. For example, fibre discs typically grind faster with higher performance than bonded wheels or cup wheels. They are also lighter in weight and often present an ergonomic advantage, but they tend to have a shorter work life. Conversely, bonded Type 27 wheels or cup wheels have longer life, but tend to generate more heat in the workpiece. They are also typically heavier than fibre discs.

Inspections

Most abrasives are subject to breakage, so it's important to inspect all products before using them. Never use an abrasive with visible damage such as a nicked edge, crack, or crease. Remember to stop grinding immediately when vibration or wobbling occurs during use. Determine the cause of the vibration and correct the problem or replace the abrasive before continuing.

Proper Use

Improper operation can cause personal injury. Read and follow the instructions for use for all products and machinery before beginning work. Use the product only as instructed by the manufacturer to help you obtain the optimal results and efficiencies. For example, fibre discs should always be used with the proper backup system recommended by the manufacturer. Matching the fibre disc to the application with the correct backup pad, tool speed (rpm), and air pressure optimizes performance and reduces grind time.

Always use a backup pad the same size as the disc — Fig. 1. For discs with irregularly shaped peripheries, the disc overhang should not exceed the backup pad by more than ¼ in. of the smallest radius. Some manufacturers also offer attachment systems providing quick changeovers, which help reduce grind time and increase productivity.

Higher speeds are not always better. Check the speed of the grinder and do not exceed the maximum operating speed for the product.

Optimum Tool Speeds (rpm) to Maximize Fibre Disc Cut Rates and Life

<table>
<thead>
<tr>
<th>Disc Size</th>
<th>Carbon Steel</th>
<th>Stainless Steel</th>
<th>Titanium</th>
<th>Aluminum</th>
</tr>
</thead>
<tbody>
<tr>
<td>4½ in.</td>
<td>8500</td>
<td>7000</td>
<td>2500</td>
<td>7000</td>
</tr>
<tr>
<td>5 in.</td>
<td>8500</td>
<td>6000</td>
<td>2500</td>
<td>6000</td>
</tr>
<tr>
<td>7 in.</td>
<td>6000</td>
<td>4500</td>
<td>2000</td>
<td>4500</td>
</tr>
<tr>
<td>9½ in.</td>
<td>4500</td>
<td>3500</td>
<td>1500</td>
<td>3500</td>
</tr>
</tbody>
</table>

MARVA. SCHIFSKY (maschifsky1@mmm.com) is a Technical Service Technologist for 3M Abrasive Systems, St. Paul, Minn., and a Minnesota State Certified Steel Fabricator/Fitter.

SEPTEMBER 2004

5 Quick Safety Tips for Grinding:

- Keep your work area clean
- Don't grind near flammable products
- Don't use electrical tools near water or wet floors
- Beware of electrical cords. Tape or mark them to prevent tripping
- Unplug tools when not in use or when changing abrasive products

(MOS). If the optimum tool speed is not used, you will not get the maximum value out of the product due to excessive heat generation, extra wear, and overall poor performance. Exceeding the MOS can also cause the disc or backup pad to break apart and cause injury. When grinding with abrasive fibre discs, 3M recommends using the following speeds with various metals and disc sizes.

Additionally, when working with fibre discs, start the tool just off of the workpiece then ease the disc onto the work. Do not jam the disc into sharp edges or tight places. Remember to run the disc off of the edge and not into it. Operate the tool with a disc incline approximately 5-10° from the workpiece. Remove depressions, molding limbs, and heavy molds with the tool moving away from the workpiece rather than into it.

Personal Safety Equipment

Proper equipment should always be used to assure personal safety. All persons involved with or near grinding operations should be required to wear impact-resistant safety glasses with side shields and a full-face shield. In addition, they should wear safety shoes, arm guards, leather gloves, aprons, and hearing protection.

Even when the air in the facility appears to be clean, it could contain unsafe levels of airborne contaminants. It's important to wear a respirator designed to remove the dust, fumes, vapors, and mists that grinding operations often produce. Also, be aware that no single type of respirator can protect the worker from all contaminants. The selection of an appropriate respirator is based upon an assessment of the hazard, its concentration, and certain user factors. The user factors include the wearer's fitness to wear a respirator, comfort, portability, and the presence of other personal protective equipment such as safety glasses or goggles, hard hats, and hearing protectors. A respirator offers little or no protection if not worn properly or if it has a poor face seal. The respirator must also be a type approved by the National Institute for Occupational Safety and Health (NIOSH) for the intended application. Look for the NIOSH approval identification on the respirator. Respirators without NIOSH approval identification should not be used.

When uncertain which safety equipment is best for use in your shop, consult an expert. Some manufacturers provide educational programs to help fabricators select and use the proper safety products for their specific requirements.

For example, 3M's Online Health and Safety Services Web site offers thorough online worker health and safety training and certification. This service is easily accessible on the Web, 24 hours a day.

You work for many great reasons. Becoming a safety or health statistic shouldn't be one of them. When proper guidelines are followed, grinding can be a safe and efficient operation.
Workplace Safety: The Human Factor

Workplace safety

begins with good communications, employee involvement, and management support

BY MIKE PANKRATZ AND DANE DORN

The most important safety tool is the human mind. A successful welding safety program requires not only a complete understanding of welding equipment and processes but a collaborative, human approach to safety in the workplace. To a greater extent now, successful safety management calls for humanized techniques and tools to realize safety goals, even as automation becomes increasingly familiar to welding practices. This article covers a proactive approach to some major machine and worker safety concerns, as well as some common welding safety issues.

Hands-on Safety

First and foremost, any successful welding safety program makes every effort to prevent injuries. Programs further rely on compliance with Occupational Safety and Health Administration (OSHA) regulations, keeping workers' compensation costs low, and, of course, knowledgeable, well-trained employees. More and more, achieving safety in the workplace also requires proactive management and employee support. Employee involvement — particularly for a large company — in the creation and application of safety procedures is directly related to job satisfaction and a safer workplace. When given the opportunity to provide valuable input about their work, employees are generally more satisfied with their jobs, and in turn help ensure safety compliance and lower workers' compensation costs.

Given that employee dissatisfaction is the number one reason why workers' compensation claims are made, maintaining a safe, satisfied workforce has taken precedence for safety managers. A small fabricator can use the safety philosophies and programs from larger companies as benchmarks for developing quality safety procedures and retaining skilled employees.

To lower workers' compensation costs and increase job satisfaction, company-wide safety programs are being developed to increase employee involvement in key objectives of the company, including weld-
ing safety goals. This practice needs to extend across company divisions, business units, or plants. In fact, plant performance can include evaluation of monthly workers’ compensation claims, lost-time injuries, and the development of safety projects. Such a program holds workers accountable for not only their own safety, but for the safety of people around them.

Effectively sharing good safety projects can be a challenge for a large manufacturer with multiple locations. To overcome this problem, safety representatives from different locations should meet on a regular basis to bring new ideas to the program. When brought to the table, even a trivial idea from one location could have a big impact on another.

Currently, two major machine and worker safety issues, an aging workforce and repetitive motion, are being addressed by some manufacturers through the development of monthly safety projects. Ergonomics, health and wellness sessions, in-house medical staffing, and emergency response plans are just some of the ways companies can address major safety issues.

**Ergonomics**

An aging workforce and repetitive motion issues make eliminating physical labor a priority. Many welders have been working in the industry for 20 years or more, often working with the same machines, repeating the same motions. Over time, repetition has a cumulative effect on tendons, ligaments, and muscles, making it difficult to grip objects and creating potentially hazardous conditions. To alleviate these problems, cumulative strength moves, material handling, and constant motion should be minimized or eliminated. For example, implementing hydraulic or pneumatic presses that decrease the amount of physical exertion — like swinging a hammer — reduces manual labor and repetitive motion, making the job easier and more comfortable.

Minimizing discomfort and injury often means improving the ergonomics of a welding workspace, or simply giving workers the tools to redesign their own workstations. It’s a joint effort; individuals recommend tools to satisfy their specific needs and preferences, and management provides the support for acquiring the tools. The workstation is fit to the individual, not the individual to the workstation, making the job as comfortable as possible.

There are a number of ways to make production jobs safer and more comfortable. Carts, lift tables, hoists, cranes, rotating fixtures, presses, and, wherever possible, automation can eliminate heavy lifting and repetitive movement — Figs. 1, 2.

Yet automation addresses safety concerns only to a point and presents other safety challenges, such as guarding robots with light curtains. From a repetitive motion and strength standpoint, automation will continue to increase for higher volume jobs, making some jobs easier and safer.

Simpler, less expensive tools in the long term include ergonomic mats, adjustable chairs and tables, and welding positioners/grippers. The long-term costs cannot be overemphasized. For example, a positioner/gripper (Fig. 3) may cost $5000. That pales in comparison to the costs of lost productivity and an injury claim if a welder is out of work for a month with an injury that could have been prevented with the right equipment. Imaple-
menting simple comfort upgrades can go a long way. An ergonomically designed workspace speeds material flow by eliminating the double handling of parts. Individually designed workstations ensure that only the appropriate materials move in and out as quickly as possible, as well as reduce the amount of material cluttering the weld area. Leading causes of workplace injuries include slips, trips, and falls, and clutter is a primary cause. In short, good housekeeping and a well-designed, ergonomic environment may well contribute to the manufacturing workforce. For example, beginning the day with stretching and exercise programs allows workers to loosen up, enjoy time with coworkers, and begin the workday fully alert. As part of safety education, companies can offer health and wellness sessions that cover a variety of worthwhile topics, such as stress, cancer, weight management, and diabetes. While management can't control health and wellness outside the workplace, they can encourage a healthy, thus safer, work environment.

Health and Wellness

The success of ergonomics in manufacturing may have indirectly produced another safety trend, one which demonstrates a positive link between safety and healthy employees. Workers' compensation costs present a primary challenge to safety personnel because they don't add anything to the bottom line, they only subtract from it. In other words, workers' compensation costs can, at best, be zero. Conversely, encouraging health and wellness among employees may well contribute to the bottom line through better productivity. With health care costs rising, safety managers are addressing this potential.

The idea that a healthy workplace is a safe workplace may not be new, but only recently has the idea been actively applied to the manufacturing workforce. For example, beginning the day with stretching and exercise programs allows workers to loosen up, enjoy time with coworkers, and begin the workday fully alert. As part of safety education, companies can offer health and wellness sessions that cover a variety of worthwhile topics, such as stress, cancer, weight management, and diabetes. While management can't control health and wellness outside the workplace, they can encourage a healthy, thus safer, work environment.

Onsite Medical Help

Another innovative approach to workplace safety is in-house medical staffing. Onsite doctors and nurses treat simple strains and sprains before serious injuries occur, such as treating numb fingers before they bloom into Carpel Tunnel Syndrome. While expensive, onsite medical personnel keep workers' compensation claims down, illness rates low, and, even more importantly, encourage employees to take responsibility for medical treatment and to seek it earlier.

Emergency Response

Emergency response plans have evolved into emergency "action" plans, indicating a down-to-business safety mindset. Procedures are skillfully honed, communicated, and practiced so that everyone is prepared for an emergency before it happens. Management can appoint and train a key contact from each business area to take quick action when called upon. Like clockwork, all personnel act, whether it means initiating an emergency procedure or dialing 911. These plans ensure that there are trained people in every area of the facility.

An effective emergency action plan also involves having the right safety equipment available. This requires multiple efforts to research health and safety issues and come up with innovative solutions. At Miller Electric, safety committee members were faced with the challenge of addressing medical research data on cardiac arrest that stated survival rates drop 10% every minute a patient goes without treatment. As a result, Miller invested in 11 defibrillators in February 2004. Just three months later, two Miller "first responders" (safety-trained personnel) saved a vendor's life when he had a heart attack while visiting the company. The price tag on the defibrillator became a nonissue when compared to saving a life. Looking ahead, the urgency for cardiac arrest treatment will make defibrillators as common as fire extinguishers someday.

Personal Protection

As a result of rigorous safety management programs, personal protective equipment policies should become second nature — Fig. 4. Safety projects develop by taking standard policies into account and creating positive peer pressure in the plant to adhere to safety policies. Handbooks further emphasize personal protective equipment policies, along with managers, who enforce compliance in each unit. As a result, injuries diminish.

Personal protective equipment policies include items that should be worn in weld areas:

- Flame-resistant gloves
- Safety glasses with side shields
- Welding helmet
- Apron or lab coat
- Steel-toed shoes
- Long-sleeved shirt
- Flame-resistant clothing

The American Welding Society and OSHA offer guidelines on the proper personal protective equipment, including what welders should wear in specific environments. With all equipment, be sure to read and follow the safety information in the operator's manual or contact the manufacturing company when in doubt.

Lacerations are another common cause of injuries, but safety managers don't always point to carelessness as the cause. Employees need to wear gloves for certain operations, such as handling sheet metal, cut metal, or other sharp objects.
However, gloves can also create a hazard if they can be caught in machinery, such as a rotating spindle. It's a judgment call.

For the welding operator, companies are increasingly investing in autodarkening helmets, particularly for tack and short welds. The nature of that type of welding means that operators are more prone to let safety slide and close their eyes to "shield" them from the arc because they become tired of having to raise and lower their hoods. An autodarkening helmet eliminates the need to raise the hood because the operator can see the weldment and reposition the torch before striking an arc — Fig. 5. After striking an arc, the lens darkens in 1/20000th of a second. For that fraction of a second, the eye may detect brightness, but harmful rays can't get through the UV protective lens.

As personal protective equipment changes, so do OSHA regulations. High on OSHA's priority list are respiratory standards, hazard communication, chemical labeling, machine guarding, and lockout/tagout, to name a few. Safety managers understand the importance of keeping up with changes so they can design a safer work environment and eliminate safety problems. Further, OSHA's Volunteer Protection Program, by partnering with companies, offers one way for businesses to remain informed about safety, meet safety requirements, and, ultimately, avoid OSHA's inspection list.

The most important method for preventing safety violations is proper training. A seasoned workforce, while it brings up aging and motion issues, has a distinct advantage in terms of safety-related knowledge and skill. In companies where welders turn over every two to three years, effective training is a much larger issue. Any welding safety or certification program should include thorough training on proper safety practices.

Responsibility

Managers can go to great lengths to put safety policies in place, but if policies aren't followed, some type of disciplinary action must be taken. Disciplinary action typically depends on the infraction and the employee's record, but more and more employees are being held accountable for safety through their merit. In other words, employees not only need to follow the rules but must demonstrate that they are taking an active role in setting the rules. Barring acceptable performance, employee compensation may be negatively affected.

Managers are held accountable for safety in their business areas. It is the manager's responsibility to make sure employees abide by safety policies and procedures and carry out disciplinary action when appropriate. Safety managers should hold meetings on a regular basis to not only emphasize safety, but also the importance of employee participation in meeting safety objectives. Additionally, managers must demonstrate their support for new ideas and ultimately make decisions that are right for the employee and the company.
Auto Parts Maker Goes Ductless

Company selects a welding cell ventilation system based on saving space

When Torque-Traction Integration Technologies Inc., a subsidiary of Dana Corporation, opened its new assembly plant in Auburn Hills, Mich., it was the culmination of a long initiative to standardize operations, assembly systems, and air filtration systems in Dana plants — and a result of a shift in thinking for plant management.

For many years, the Dana model was to assemble parts in the same plant as the parts were manufactured. In the early eighties, as the automotive business changed, it became necessary to become more flexible and responsive to customers, according to Marc Friedrich, engineering manager at the Dana Corporation's Auburn Hills Customer Focus Center, and one of the people responsible for selecting the air filtration systems in the plant. Dana changed its thinking and began assembling parts in plants that were closer to the customer, which made it easier to react to customer needs.

The company's first driveshaft assembly plant in the southeastern Michigan area was located in Troy. As the plant grew and needed more floor space, it was first moved to Pontiac, then to Auburn Hills, Mich. Most of its driveshaft customers today are within 30 miles of the new plant.

The move presented an opportunity to standardize operations in the plant using an optimized one-piece flow assembly-line concept. This move toward standardization provided the perfect opportunity to address air filtration and ventilation, an area where uniformity was needed, according to Friedrich.

"Over the years, the Dana Plant in Pontiac had inherited welding cells and ventilation systems from a number of other Dana plants that had closed or been refitted," Friedrich said. He said this was a common issue at other Dana plants, and the result was an air filtration system that was made from a variety of different equipment that was mismatched to welding cells and not 100% effective. Each plant also had to stock numerous filter types and sizes, and train employees on various filtering systems.

The auto parts maker put together a team to study the best path toward standardization with the goals of improved efficiency, conservation of floor space, balanced timing, improved health and safety, and return on investment.

Traveling that path was a big step and a long journey. Dana is a worldwide operation with annual sales in excess of $9.7 billion. The Auburn Hills plant assembles aluminum driveshafts and one- and two-piece driveshafts of steel. It also assembles universal joints that are sold separately from driveshafts.

The plant has about 200 employees working in three shifts, six days a week. It is a Tier One supplier for GM vehicles (Silverado pickups, and Tahoe, Yukon, and Denali SUVs) and some construction vehicles, and for DaimlerChrysler vehicles including the Dodge Ram pickup, Dakota, Durango, and the Viper.

The plant has nine automated welding cells that perform both aluminum and steel welding. The automated welding machines are unusual in that they are part of the assembly line in a flow-through style. The part goes in one side, gets welded, and then is sent out the other side of the welding cell and down the assembly line.

As plans for the new plant began to take shape in early 2002, Friedrich and Danielle Collins, a process engineer, began to look at air filtration and ventilation systems for the plant. Dana had had air filtration in its plants since the early eighties, and they wanted air filtration to be part of the new standardization initiative.

"Without proper air filtration the welders would not be able to operate," Friedrich said. "In our case, it's necessary to have air filtration because we're putting a 15-inch weld on a driveshaft every 30 seconds. That puts out a lot of smoke."

Friedrich and Collins started looking for a new ventilation system that could...
handle a variety of welding cells and provide maximum health and safety for employees. They also wanted a filtration system that was uniform to go along with the division initiative to standardize equipment and save space. Ideally, Dana wanted a standard air filtration unit that was a top-mounted, self-standing hood with four sides so they could move welding units easily.

A national search generated proposals from about five air filtration suppliers. Great Lakes Air Systems of Clawson, Mich., quoted two different air filtration system options — one with a ductwork system and one using its RoboVent™ FloorSaver product and no duct system. Friedrich said Great Lakes, which had worked previously with Dana, was the only supplier to quote a system without ductwork.

Ultimately, Dana selected the ductless Robovent FloorSaver from Great Lakes because of the space savings inherent in the unit and the ability to customize and standardize the air filtration hoods, Friedrich said.

“Our old systems took up more floor space, and floor space is something that we have been challenged by our division to reduce. We accomplished that in a bunch of different ways.”

Great Lakes developed a special enclosure for Dana that is uniform and works on a variety of different welding cells, regardless of size. The supplier also worked closely with Dana to develop a special curtain for the air filtration units. The curtain allows easy access and flexibility without sacrificing effectiveness, Friedrich said.

According to Friedrich, the RoboVent was the slightly more expensive option presented, but it accomplished all of Dana’s goals.

“Nobody beside Great Lakes had a space-saver design,” said Collins. “And it really wasn’t much more expensive than the other options.”

Dana also relies on a maintenance program from the supplier.

“It’s easier for us,” explained Collins. “We don’t have to worry about disposing of the waste from the air filtration units. Great Lakes takes it out and disposes of it properly.”

In the time that the plant has been open, it has become a model for the standardization initiative within the Dana organization. Employees have noticed the cleaner work environment, and the RoboVent units have become an integral element of the company’s drive toward uniform operations in all its plants.
A truly reliable safety control system must work even when some parts fail; therefore, force-guided relays represent an unseen component that adds another level of reliability.

Force-guided relays such as these in the FGR Series from Scientific Technologies, Inc., use a mechanical link between “normally open” and “normally closed” contacts to ensure they all move as one. They find applications in machinery, robotics, cranes, elevators, and doors.

BY RICHARD HARRIS

RICHARD HARRIS is Manager, Channel Programs, Scientific Technologies, Inc., Fremont, Calif., (888) 510-4357 or (510) 608-3400.

Safety interlocks, safety light curtains, and other safety equipment are the visible parts of a machinery-safeguarding system. As such, they receive the most attention. However, safety goes well below the surface of any machinery-guarding control system. Even when these safety devices work as designed and installed, they must be connected to a control-reliable circuit to complete the job.

Let’s look at an example to demonstrate this concept. Using a sensor or interlock to safeguard equipment is a necessary part of any machinery-guarding system, but it is only one part of that system. A simple circuit includes a safety interlock switch and a machinery power contactor. Either device can experience a fault, such as a sticking or welded contact. A short circuit can also occur. In each case, the fault renders the safety circuit unsafe — Fig. 1.

Figure 2 shows the same circuit restructured with redundant machinery power contactors and a double-pole interlock switch, which increases the probability that the circuit will work, even if a single component should fail. The addition of a safety monitoring relay unit allows users to determine whether the safety circuit is working properly. Reliable safety circuit designs include adding similar layers of redundancy and monitoring to ensure reliable operation as risk factors increase for a given machine.

Added Requirements

Applications that require machinery-safeguarding circuits that affect more than one circuit simultaneously must include relays with force-guided or positively driven contacts. The addition of a force-guided relay ensures that when a contact on the relay sticks or is welded, it will not allow other contacts to move.

The concept is similar to a three-phase motor contactor, where all three contacts are mechanically joined so they will move in unison. A force-guided relay employs a rigid mechanical linkage joining all contacts to ensure that they move in unison. This also ensures that they cannot move if any contact sticks or is welded.

The difference, in this case, is that a force-guided relay will have both normally closed (NC) sets of contacts and sets of normally open (NO) contacts. A motor contactor has all contacts working with the same function.

Force-guided relays also have a smaller gap tolerance and move more slowly due to design requirements that provide greater...
precision than a conventional snap-action switch. This comparatively slow-make and slow-break movement makes force-guided relays more prone to contact weld since there is a greater opportunity to cause arcing across the air gap.

Force-guided relays also have a "point of accumulation" closer to the contacts of the relays. This results in slower movement and allows arcing to occur over a longer duration — Fig. 3.

This difference in gap tolerance combines with the "teasing" characteristics of a slower snap action to speed contact wear and material transfer between contacts. It also increases electrical noise or static. When a force-guided relay is used in low-current applications, users should include arc-suppressing devices on the output elements. Any safety monitoring relays or contactors with low current ratings must include arc-suppressing devices in their circuits. Users should consult with the relay manufacturer.

The 'Controller' Configuration

The application of force-guided relays is illustrated in Fig. 4. The following sequence of operations forms the basic design for safety monitoring relays and controllers (identified in the rectangle) used on safety light curtains, pressure mats, and other devices requiring safe operation by means of redundant circuits.

The Machine Primary Control Elements (MPCE) 1 and 2 are typically a relay with force-guided contacts. When a safety interlock, light curtain, or e-stop switch opens a circuit, the MPCE NO contacts will open and the NC contacts will close. The relay is wired in this fashion so that the MPCE will revert to a safe state in case a power failure occurs.

Use of a force-guided relay ensures that if a welded or sticking contact occurs, it will keep the other set of contacts from moving. The safety-monitoring relay will go into a fault state and not reenergize until someone corrects or fixes the fault at the contact of the affected MPCE.

If a safety control circuit must carry a high current, the outputs from the safety monitoring equipment (light curtain, etc.) must be wired in series (i.e., buffered). The circuit should use a safety-rated relay with positively driven/force-guided contacts.

False Assumptions

System integrators sometimes incorrectly assume that the positively driven/force-guided relay contacts will operate together and that all contacts, either NO or NC, will remain in the same position. This is not always true.

According to the standard (EN50205) and Comité Européen de Normalisation Électrotechnique (European Committee for Electrotechnical Standardization) or CENELEC document CLC/BTWG 78-4(SEC) 11:

1) When a NO contact welds, the linkage will prevent the reclosing of NO contacts.

2) When a NC contact welds, the linkage will prevent the reclosing of NC contacts.

While these conditions will guarantee the required operations listed above on one MPCE, the second MPCE will continue to operate.

Fig. 1 — A simple safety circuit in which a sticking contactor has created a fault that renders the circuit unsafe.

Fig. 2 — Layers of redundancy added to the circuit, such as machinery power contactors and a double-pole interlock switch, increase its reliability. In all probability, the circuit will work even if one of its components should fail.

Fig. 3 — In comparison to snap-action switches, force-guided relays feature a smaller gap tolerance and a point of accumulation closer to the contacts of the relays that results in slower movement and allows arcing to occur over a longer period.
As machines become more automated and complex, they will have multiple end effectors that contribute to the hazardous condition in one way or another. Their response must be considered when developing the emergency stop strategy.

Each device or process must become a component of the “safety equation,” analyzed and addressed in the final safety circuit design. For instance, it may be necessary to keep cooling pumps or vacuum pumps running, or even to keep them running at higher capacity after the machinery reaches a nonhazardous state. Air handling fans may still need to run after a safety shutdown to clear hazardous vapors.

An emergency stop system may remove energy only from the end devices causing the hazard. It will not allow the system to restart until that safety device has been reset and the master reset has been activated. Remember that any and all other devices or control circuits and status indicators may be unaffected and remain energized.

Additional Emergency Stop Requirements

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NJC Projects Support Aircraft Carrier Program

The Navy Joining Center (NJC) is a member of a Navy ManTech project team that is developing advanced manufacturing technology to support the construction of CVN 78 (Fig. 1), the Navy's next-generation aircraft carrier. Other members of the project team include the Program Executive Office Aircraft Carriers; Naval Sea Systems Command; Naval Surface Warfare Center (NSWC), Carderock Division; Northrop Grumman Newport News; and the National Center for Excellence in Metalworking Technology.

CVN 78 is being designed to be the Navy's 21st century aircraft carrier that will ultimately replace the Nimitz Class nuclear aircraft carriers. New innovations that are being incorporated into the CVN 78 include enhancements to the flight deck, a redesigned island, a new nuclear power plant, automation of many functions, and the ability to accommodate future advanced technologies. The CVN 78 will make use of the latest materials and design concepts to produce the lighter weight structures needed to enhance performance. These materials include high-strength steel and lightweight materials such as aluminum and titanium.

The Navy ManTech Program has a number of advanced manufacturing development projects underway to support CVN 78 construction that is scheduled to begin in 2007. One of these projects is developing a high-strength steel and the welding procedures needed for this steel. The NJC is working with NSWC, Carderock, to develop welding procedures and optimized welding electrodes for the submerged arc, gas metal arc, and shielded metal arc welding processes that are critical to aircraft carrier construction.

Another project is focused on lightweight titanium structures for CVN 78. To date, the use of titanium on Navy ships has been limited to seawater service components such as piping systems, heat exchangers, pumps, and auxiliary equipment. Further development is needed in melting practices and in fabrication technologies to make titanium a practical material for large ship structures. This project will extend its previous titanium welding experience with ship piping systems and lightweight howitzers to support welded titanium structures for CVN 78. The project will address welding titanium to itself and joining titanium to other materials.

For more information on these joining projects, contact Harvey Castner via e-mail at Harvey.Castner@ewi.org; or telephone, (614) 688-5063.

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NJC Fellowships Awarded at AWS Show

Two Navy Joining Center graduate fellowships for the 2004–2005 academic year were announced at this year’s AWS Welding Show.

Each year, the Navy Joining Center supports two graduate fellowships as part of its commitment to further technical education and the advancement of materials joining technology. These fellowships are awarded through the AWS Foundation to support graduate students whose research topics address materials joining topics of interest to the Navy.

The NJC Fellowships for the upcoming academic year were awarded to Timothy Anderson of Lehigh University and Morgan Gallagher of The Ohio State University.

Anderson is pursuing both master's and doctorate degrees in materials science and engineering with studies in Alloy Development of a Robust Filler Metal for the Superaustenitic Stainless Steel Al-6XN.

Gallagher is pursuing a doctorate degree in welding engineering with studies in An Investigation of Hot Cracking in Hastelloy Alloy C-22.

Contact the AWS Foundation at (800) 443-9253, ext. 689, for more information on NJC fellowships.

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Fig. 1 — Construction of this CVN 78 next-generation aircraft carrier, scheduled to begin in 2007, will utilize high-strength steel, aluminum, and titanium in unique applications to enhance performance. NJC is exploring optimized welding processes to join these metals.
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American Ceramics Society Meetings. Sept. 12-16, Pacific Coast Regional and Basic Science Div. meeting, Seattle, Wash.; Sept. 12-16, International Conference on High-Temperature Ceramic Matrix Composites, Seattle, Wash.; Nov. 7-11, Glass and Optical Materials Division fall meeting, Cocoa Beach, Fla. Contact: customersrvc@acers.org; or www.ceramics.org.


Materials Solutions 2004 Conference and Exposition. Oct. 18-21, Greater Columbus Convention Center, Columbus, Ohio. For more information, contact ASM International at www.asminternational.org/materialssolutions.


15th IAS Rolling Conference and 2nd Conference on Uses of Steel. Nov. 3-5, Hotel Colonial, San Nicolas, Argentina. Sponsored by Instituto Argentino de Siderurgia (IAS). Contact IAS by telephone at 54 3461 460803, or genzano@siderurgia.org.ar.


9th Beijing Essen Welding & Cutting Fair. Nov. 10-13, China International Exhibition Centre, Beijing, China. Cosponsored by the German Welding Society (DVS) and the Chinese Mechanical Engineering Society (CMES). Contact: suxy@cmes.org, or www.cmes.org/gzhilan/aision/eindex/aision1.htm.

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  3. Everyday Pocket Handbook for Gas Metal Arc and Fume-Cored Arc Welding
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Circle No. 21 on Reader Info-Card
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300° pre-heated steel

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ClimaTech Cooling Vest

Whether it's the HeatShield™, with its synthetic ice core, or the AirVest™ that turns compressed air into your personal A/C, ClimaTech's patented cooling technology will change the way you work. And play. It's like night and day. Or better yet, hot and cold. Leave work with energy to burn. Ask your favorite distributor, call 800-266-5440 or visit www.climatechsafety.com.

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Patented Cooling Vests. Stay cool.


JOM-12, Twelfth International Conference on the Joining of Materials, and Fourth International Conference on Education in Welding. March 20-23, 2005, Helsingør, Denmark. Contact Institute for the Joining of Metals by telephone at 45 48355458; or send e-mail to jom_aw@post10.tele.dk.


Educational Opportunities

Women’s Welding Workshop and Retreat. September 5–11, Spitfire Forge, Taos, N.Mex. This hands-on welding and blacksmithing workshop includes all materials, field trips, lodging, and meals. Contact: Christina Sporrong at spitfire4rg@yahoo.com or visit the Web site www.spitfireforge.com for complete information.

Safety at Work Training. Sept. 7, Nov. 16. Pepperl+Fuchs® Inc., Twinsburg, Ohio. Hands-on training in the safety at work network operation and components. Cost is $20, including two meals. For further information, telephone Helge Hornis, (330) 486-0001; e-mail, hhornis@us.pepperl-fuchs.com.

Fundamentals of Visual Inspection. Sept. 8. Classes held at Hobart Institute of Welding Technology, Troy, Ohio. For further information and 2004 schedules, call (800) 332-9448 or e-mail hiwt@welding.org; www.welding.org.


The markers are available in two sizes: Standard and Jumbo and four fast-drying, lead-free colors: white, yellow, red and black.
### Educational Opportunities

**AWS 2004 Schedule CWI/CWE Prep Courses and Exams**

Exam application must be submitted six weeks before exam date. For exam information and an application, contact the AWS Certification Dept., (800) 443-9353, ext. 273. For exam prep course information, contact the AWS Education Dept., (800) 443-9353, ext. 229.

<table>
<thead>
<tr>
<th>City</th>
<th>Exam Prep Course</th>
<th>CWI/CWE Exam</th>
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</thead>
<tbody>
<tr>
<td>Anchorage, Alaska</td>
<td>Sept. 12-17</td>
<td>Sept. 18</td>
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<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
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<tr>
<td>Atlanta, Ga.</td>
<td>Oct. 24-29</td>
<td>Oct. 30</td>
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<td>(API 1104 Clinic also offered)</td>
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<tr>
<td>Baltimore, Md.</td>
<td>Oct. 31-Nov. 5</td>
<td>Nov. 6</td>
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<tr>
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<td>(API 1104 Clinic also offered)</td>
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<tr>
<td>Beaumont, Tex.</td>
<td>Nov. 7-12</td>
<td>Nov. 13</td>
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<td>(API 1104 Clinic also offered)</td>
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<tr>
<td>Chicago, Ill.</td>
<td>Oct. 24-29</td>
<td>Oct. 30</td>
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<td>(API 1104 Clinic also offered)</td>
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<tr>
<td>Corpus Christi, Tex.</td>
<td>EXAM ONLY</td>
<td>Sept. 18</td>
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<tr>
<td>Dallas, Tex.</td>
<td>Sept. 26-Oct. 1</td>
<td>Oct. 2</td>
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<td>(API 1104 Clinic also offered)</td>
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<tr>
<td>Denver, Colo.</td>
<td>Oct. 3-8</td>
<td>Oct. 9</td>
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<td>(API 1104 Clinic also offered)</td>
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<tr>
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<td>(API 1104 Clinic also offered)</td>
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<tr>
<td>Long Beach, Calif.</td>
<td>Nov. 7-12</td>
<td>Nov. 13</td>
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<td>(API 1104 Clinic also offered)</td>
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<tr>
<td>Louisville, Ky.</td>
<td>Nov. 14-19</td>
<td>Nov. 20</td>
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<td>(API 1104 Clinic also offered)</td>
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<tr>
<td>Miami, Fla.</td>
<td>EXAM ONLY</td>
<td>Sept. 16</td>
</tr>
<tr>
<td>Miami, Fla.</td>
<td>EXAM ONLY</td>
<td>Oct. 14</td>
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<tr>
<td>Miami, Fla.</td>
<td>Dec. 5-10</td>
<td>Dec. 11</td>
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<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
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</tbody>
</table>

| Milwaukee, Wis.       | Sept. 26-Oct. 1  | Oct. 2       |
|                       | (API 1104 Clinic also offered) |              |
| Minneapolis, Minn.    | Sept. 19-24      | Sept. 25     |
|                       | (API 1104 Clinic also offered) |              |
| Orlando, Fla.         | Nov. 15-20       | No Test      |
|                       | (API 1104 Clinic also offered) |              |
| Phoenix, Ariz.        | Oct. 3-8         | Oct. 9       |
|                       | (API 1104 Clinic also offered) |              |
|                       | (API 1104 Clinic also offered) |              |
| Portland, Oreg.       | Nov. 7-12        | Nov. 13      |
|                       | (API 1104 Clinic also offered) |              |
| Reno, Nev.            | Oct. 31-Nov. 5   | Nov. 6       |
|                       | (API 1104 Clinic also offered) |              |
| Sacramento, Calif.    | Oct. 4-9         | No Test      |
|                       | (API 1104 Clinic also offered) |              |
| St. Louis, Mo.        | EXAM ONLY        | Dec. 4       |
|                       | (API 1104 Clinic also offered) |              |
|                       | (API 1104 Clinic also offered) |              |
| San Juan, PR.         | Dec. 5-10        | Dec. 11      |
|                       | (API 1104 Clinic also offered) |              |
| Seattle, Wash.        | Sept. 19-24      | Sept. 25     |
|                       | (API 1104 Clinic also offered) |              |
| Sioux Falls, S.Dak.   | Nov. 14-19       | Nov. 20      |
|                       | (API 1104 Clinic also offered) |              |
|                       | (API 1104 Clinic also offered) |              |

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- Electrodes for Shielded Metal Arc Welding
  - Mild Steel Electrode E6013, E7018, E7016, E7016G...
  - Low alloy Steel Electrode E6014, E6011, E6911...
  - Stainless Steel Electrode E308L, E316L, E308...
  - Duplex & Super Duplex Electrode E410L, E410,
  - Ferritic & Ferritic-Austenitic Electrode E216B3, E216B5...
  - Duplex & Super Duplex Electrode E410L, E410,
  - Duplex & Super Duplex Electrode E216B3, E216B5...
  - Duplex & Super Duplex Electrode E410L, E410,
  - Duplex & Super Duplex Electrode E216B3, E216B5...
  - Duplex & Super Duplex Electrode E410L, E410,
  - Duplex & Super Duplex Electrode E216B3, E216B5...
  - Duplex & Super Duplex Electrode E410L, E410,
  - Duplex & Super Duplex Electrode E216B3, E216B5...

**WELDING WIRES**
- Stainless Steel Arc Welding Wires E316, E317...
  - Austenitic Stainless Steel Wires & Rods ER 308, 309, 316, 316L...
  - Duplex & Super Duplex Electrode E216B3, E216B5...
  - Duplex & Super Duplex Electrode E410L, E410,
  - Duplex & Super Duplex Electrode E216B3, E216B5...
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  - Duplex & Super Duplex Electrode E410L, E410,
  - Duplex & Super Duplex Electrode E216B3, E216B5...
  - Duplex & Super Duplex Electrode E410L, E410,
  - Duplex & Super Duplex Electrode E216B3, E216B5...
  - Duplex & Super Duplex Electrode E410L, E410,
POSTER COMPETITION
Participate in the 86th Annual AWS Convention Poster Competition
Dallas, Texas
April 26-28, 2005

Students, educators, researchers, engineers, technical committees, consultants, and anyone else in a welding- or joining-related field are invited to visually display their technical accomplishments in a brief graphic presentation, suitable for close, first-hand examination by interested individuals.

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

Two Categories
There are two major categories: Student and Professional.

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

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

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

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

Rules
1. Complete the poster session application (available on www.aws.org) and send as email attachment to dorcas@aws.org no later than Monday, November 15, 2004.
2. You will be notified in January if your proposed Poster Session topic has been accepted and will be provided specific guidelines for how to mount and display your poster.

Any questions should be directed to Dorcas Troche, Manager, Conferences and Seminars at (800) 443-9353 ext. 313 or dorcas@aws.org.
OPEN THE DOORS TO A WORLD OF WELDING.

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Top the huge Asian market for welding, cutting and testing products:

BEIJING-ESSEN WELDING AND CUTTING
November 10-13, 2004
Beijing, China

Exhibit at this major metalworking and manufacturing exhibition, in the heart of industrial northeastern Mexico:

EXPO MANUFACTURA
February 22-24, 2005
Monterrey, Mexico

Be a part of the world's largest welding and cutting exhibition, held every four years:

“SCHWEISSEN & SCHNEIDEN”—the International Essen Welding Fair
September 12-17, 2005
Essen, Germany

Exhibit in the AWS/WEMCO-SPONSORED AMERICAN PAVILION at all three of these shows.

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For more information, contact Mary Ellen Mills (800) 443-9353, ext. 444 or memills@aws.org.

Circle No. 23 on Reader Info-Card
Since 1919, we've established the standards that guide welding.

Doesn't it make sense to let us guide you to getting certified?

SIGN UP FOR THE AWS CWI OR CWE SEMINARS, AND PREP WITH THE EXPERTS.

We offer five and a half days of intensive seminars that help prepare you to pass the AWS certification tests. Our experienced teachers help you learn the material you need to know fast, and show you how to use and understand the latest standards. AWS seminars are an excellent value, saving you time and literally hundreds of dollars, by supplying you with many of the books you need FREE. Seminar topics include D1.1 Code, API 1104 Code, Welding Inspection and Technology, and Visual Inspection, followed by the certification exam at the end of the week. By grouping the preparation with the test, you can attend AWS seminars with less time off from the job and less travel expense.

When it comes to preparing for an exam that proves you're one of the best, then take it from the people who know it best—AWS.

FIND THE AWS SEMINAR NEAREST YOU.

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>SEMINAR DATES</th>
<th>EXAM DATES</th>
<th>LOCATION</th>
<th>SEMINAR DATES</th>
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<tr>
<td>DALLAS, TX</td>
<td>9/26-10/1</td>
<td>10/2/2004</td>
<td>PORTLAND, OR</td>
<td>11/7-11/12</td>
<td>11/13/2004</td>
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<td>DETROIT, MI</td>
<td>9/29-10/1</td>
<td>10/2/2004</td>
<td>LOUISVILLE, KY</td>
<td>11/7-11/12</td>
<td>11/13/2004</td>
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<td>MILWAUKEE, WI</td>
<td>9/29-10/1</td>
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<td>SIOUX FALLS, SD</td>
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<td>11/13/2004</td>
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<td>DENVER, CO</td>
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<td>ST LOUIS, MO (EXAM ONLY)</td>
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<td>PHOENIX, AZ</td>
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<td>11/2/2004</td>
<td>SJUAN, PR</td>
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<td>MIAMI, FL</td>
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<td>11/20/2004</td>
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<td>PITTSBURGH, PA</td>
<td>10/7-12</td>
<td>10/3/2004</td>
<td>PENSACOLA, FL</td>
<td>11/7-11/12</td>
<td>11/13/2004</td>
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<td>CHICAGO, IL</td>
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<td>COLUMBUS, OH (EXAM ONLY)</td>
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<td>11/2/2004</td>
<td>COLUMBUS, OH</td>
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<td>11/7-17</td>
<td>11/13/2004</td>
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<td>10/7-11/5</td>
<td>11/2/2004</td>
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<td>DALLAS, TX</td>
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<td>11/2/2004</td>
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<td>CHICAGO, IL</td>
<td>10/7-11/5</td>
<td>11/2/2004</td>
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<td>SEATTLE, WA</td>
<td>10/31-11/5</td>
<td>12/2/2004</td>
<td>SEATTLE, WA</td>
<td>10/7-11/5</td>
<td>11/2/2004</td>
</tr>
</tbody>
</table>

For more information, call 1-800-443-9353, Ext. 449

American Welding Society

American Welding Society

Founded in 1919 to Advance the Science, Technology and Application of Welding.

Circle No. 15 on Reader Info-Card

To become an AWS member, call 800-443-9353, ext. 480, or visit our website at http://www.aws.org
Chicago Section members were treated last June to a talk defining the history, metallurgy, and joining of jewelry presented by a local expert in the field, Eve J. Alfillé. "Jewelry of gold and silver," she said, "is believed to have made its appearance with the ancient Egyptians more than 3000 years ago. They were also among the first to incorporate precious stones in their jewelry, using amethyst, turquoise, and lapis lazuli."

Alfillé (pronounced al-fee-YAY) moved from her native France to Montreal, Canada, at age 16. She received degrees in business from McGill University, and in linguistics and medieval poetry from the University of Illinois. After each degree she worked as a field archaeologist in Mexico and Israel.

She began her career in jewelry in 1973, and has been running her own store and gallery in Evanston, Ill., since 1987, where each item is a handmade one-of-a-kind masterpiece. She has earned numerous Chicagoland jewelry design awards, and a first-place award from the American Gem Trade Assn.

Alfillé commented on the major turning points in the industry. "The Roaring Twenties created a huge demand for jewelry, and a new style made its appearance at the Exposition Internationale des Arts Decoratifs et Industriels Modernes held in Paris. The new look took its name from that fair, shortened to the term Art Deco. It featured abstract geometric forms and shapes using such diverse designs as those created by the Aztecs and Egyptians, and combined them with modern art."

The 1940s produced Retro Modern, featuring large pieces of jewelry with flamboyant curves and bows of yellow, pink, and even green gold combined with odd mixtures of colored gems. Today, Retro Modern is generally considered garish.

World War II created a shortage of platinum, so most jewelry was made of gold and silver, but platinum made a huge comeback in the early 1990s when such pieces as tennis bracelets and diamond solitaire pendants debuted.

The old-time jewelry-making skills are still necessary. "Wax carving jewelry is a delicate process," Alfillé said. "The wax models must be exact in size, especially for rings and stone settings, taking into account the calculated shrink-

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Modern laser beam welding (right), used for delicate repairs, can't replace ancient repousse forming (left) and delicate wax carving (below) when perfection is the goal.

-Alfillé continued on page 55
All AWS Technical Committee meetings are open to the public. Persons wishing to attend a meeting should contact the staff secretary of the committee as listed below at AWS, 550 NW LeJeune Rd., Miami, FL 33126; telephone (305) 443-8553. All meetings are open to the public. Persons affected individuals are invited to contribute to their development. Contact the staff engineer listed with the document.


B2.4:2004, Specification for Welding Procedure and Performance Qualification of Thermoplastics. This specification provides the requirements for qualification of welding procedures, welders, and welding operators for manual, semi-automatic, mechanized, and automatic welding. The processes included are electrical arc, gas, plasma, and laser welding. Base materials, filler materials, qualification variables, and testing requirements are also included. Stakeholders: Users of thermoplastics. New standard. Steve Hedrick, ext. 305


Testing at Ambient Temperature. Stakeholders: Manufacturing and inspection/testing facilities that use welding. New standard. Andrew Davis, ext. 466

C1.5:200X, Specification for the Qualification of Resistance Welding Technicians. This specification establishes the requirements for qualification of resistance welding technicians employed in the welding industry. The minimum experience, examination, application, qualification, and requalification requirements and methods are defined. This specification is a method for technicians to establish a record of their qualification and abilities in welding industry work such as development of machine troubleshooting, processes controls, quality standards, problem solving, etc. Stakeholders: Manufacturing organizations involved with resistance welding, such as automotive, aerospace, resistance welding equipment manufacturers, and suppliers to industry. New standard. Harold Ellison, ext. 299.

Standards for Public Review

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


Oxyfuel Techniques Featured in New Recommended Practices

Two newly released recommended practices offer valuable information on the safe use of oxyfuel torches and oxy-fuel techniques for heat shaping.


Listed below are the AWS members participating in the 2004-05 Member-get-a-Member Campaign. For campaign rules and a prize list, see page 51 of this issue of Society News.

You may wonder why Alfillé is elegantly dressed and adorned with jewelry in all of her pictures, even while she's performing manual work in her shop. She will laugh and tell you, "I must always be ready to meet my clients."
new sustaining companies

Contracting Engineering Consultants, Inc.
400 Fort Martin Rd.
Maidsville, WV 25541
Representative: John C. Ruth

Contracting Engineering Consultants is a full-service steel fabrication company. CEC strives to be the finest in all aspects of steel construction from design and detailing to fabrication and erection. CEC is an AISC-certified complex-structure fabricator and is proud to be associated with the American Welding Society to further enhance the quality of product and the production capacity of its current facilities.

new educational institutions

Stud Welding Associates, Inc.
41515 Schaden Rd.
Elyria, OH 44035
Representative: Shaun Blevet

Stud Welding Associates manufactures and distributes a full line of stud welding equipment, weld studs, associated parts, and accessories for all arc welding and capacitor discharge welding processes. The company’s services include welding equipment rentals, repairs to all makes and models of equipment, technical support, and application development.

District Director and Student Chapter Awards

The District Director Award provides a means to recognize individuals who have contributed their time and efforts to the affairs of their local Section and/or District.

District 8 Director Wallace Honey has nominated the following for this award:

James E. Kirby, Jr. — Nashville
Joe Livesay — Nashville
Don J. Russell — Chattanooga
Dave Hamilton — Chattanooga
Ronnie Smith — Chattanooga
Joseph T. Smith — Greater Huntsville
Robert G. Fellers — Western N.C.
Robert W. Humphrey — Western N.C.
Gary M. Gammill — N.E. Mississippi
Robbin A. Shull — N.E. Mississippi
Sam W. Gray — N.E. Mississippi
Jimmy Kee — West Tennessee
Jim Sears — West Tennessee
Elizabeth L. Thomas — West Tennessee
Kenneth D. Nicklas — N.E. Tennessee

District 14 Director Tully Parker has nominated the following for this award:

Frank McKinley — Lexington
Hill Bax — St. Louis

Bob Richwine — Indiana
Earl Young — Tri-River
Rich Howard — Louisville

District 22 Director Kent Baucher has nominated the following for this award:

Tim Youngberg — Fresno

The Student Chapter Member Award recognizes Student Members whose Chapter activities have produced outstanding achievements at their school, community or in industry. Student Chapter advisors, Section officers, and District directors use this award to recognize outstanding students, as well as to enhance the image of welding within their communities.

The latest recipient of this award is

Todd Shrir — Illinois Central College

Student Chapter, Peoria Section, District 13

Criteria and nomination forms are posted on the AWS Web site at www.aws.org/sections/awards/student_chapter.pdf, or call (800) 443-9353, ext. 260.

new distributor company

Indiana Oxygen
6099 W. Corporate Way
Indianapolis, IN 46278

new affiliate companies

First Class Construction LLC
363 Addison Rd. Ext.
Windsor, CT 06095

Fuel Systems LLC
5019 Hovis Rd.
Charlotte, NC 28208

Quality Stair & Rail LLC
300 Locust St.
Hartford, CT 06114

Santos Fabrication
2520 Acme Ct.
Turlock, CA 95380

Springer & Springer Inc.
11799 Lena Ln.
Cleveland, TX 77328

T & M Steel Services, Inc.
2155 S. Willow Ave.
Bloomington, CA 92316

new supporting company

Tecknoweld Alloys India Private Ltd.
48/1B Ponniamman Koil St.
Kottur Puram, Chennai
Tamilnadu 600 085, India

new supporting institution

Carpenters Training Committee for
Northern California
2350 Santa Rita Rd.
Pleasanton, CA 94566

Matanuska-Susitna Borough
School Dist.
501 N. Gulkana
Palmer, AK 99645

Sun Area Career & Technology Center
21st Century Dr.
New Berlin, PA 17855

Texas Engineering Extension Service
9350 S. Presa
San Antonio, TX 78223

new distributor company

Indiana Oxygen
6099 W. Corporate Way
Indianapolis, IN 46278

membership counts

Sustaining Companies ...................... 412
Supporting Companies* .................... 205
Educational Institutions .................... 319
Affiliate Companies ....................... 232
Welding Distributor Companies ........ 51
Total Corporate Members ............... 1,219

Individual Members ..................... 42,925
Student & Transitional Members ........ 4,307
Total Members ......................... 47,232

* During March 2003, the Society initiated the Welding Distributor Company membership category. Those Supporting Company members identified as welding distributors were at that time upgraded to this new corporate member category.
DISTRICT 1
Director: Russ Norris
Phone: (603) 433-0855

BOSTON
JUNE 21
Activity: The Section hosted its 52nd annual golf outing at the Ridder Farm Country Club. The morning golf tournament was followed by a hot steamers and chowder luncheon, and a lobster dinner in the evening.

CONNECTICUT
MAY 18
Speaker: Thomas Matecki, CWI
Affiliation: WTX School District
Topic: Weld discontinuities and defects
Activity: The program was held at Quality Inspection Services, Inc., in Hartford, Conn.

GREEN & WHITE MOUNTAINS
JUNE 27
Activity: The Section officers held a planning session for the new season. The meeting was held at West Lebanon, N.H.

DISTRICT 2
Director: Kenneth R. Stockton
Phone: (732) 787-0805

DISTRICT 3
Director: Alan J. Badeaux, Sr.
Phone: (301) 934-9061

DISTRICT 4
Director: Ted Alberts
Phone: (540) 674-3600, ext. 4314

SOUTHEAST VIRGINIA
JUNE 11
Activity: The Section hosted its annual golf outing at Countryside Golf Course in Roanoke, Va., for 45 participants. Steve Thomas won the closest to the pin prize; Joey Hart nailed the trophy for longest drive; and first-place score went to Jeff Cocks, Jerry Nixon, Joey Hart, and Rob Gilbert.

DISTRICT 5
Director: Leonard P. Connor
Phone: (954) 981-3977

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

DISTRICT 7
Director: Don Howard
Phone: (814) 269-2895

COLUMBUS
JUNE 10
Activity: The Section held its annual golf outing together with the local ASM International Chapter at Foxfire Golf Club in Columbus, Ohio. Tom Kuntzman coordinated the event.

DISTRICT 8
Director: Wallace E. Honey
Phone: (256) 332-3366
GREATER HUNTSVILLE
APRIL 16
Activity: The Section hosted a welding contest at Marshall Technical School. The first-year-class winners were Kyle Ayers, Zack Nail, and Randy Moore. The advanced-class winners were Henry Carden, Derric Foreman, and Joey Turner. The college-level-class winners were Mark Parker, Sharroan Chelsey, and Keith Colkitt. More than 100 attended the event.

WESTERN N. CAROLINA
MAY 27
Activity: The Section met at the BMW Co. in Spartanburg, S.C., for a lecture and tour of the facilities. Bernhard Eich made the introductory remarks, then Bill Allen discussed the welding processes used in auto assembly. Following the tour, the Section held its election of officers for the new term. Selected were Todd Thompson, chair; Bernhard Eich and Jamie Whims, vice chairs; Bob Fellers, treasurer; and Bob Humphrey, secretary.

DISTRICT 9
Director: John Bruskotter
Phone: (504) 394-0612

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

NORTHWESTERN PA.
JULY 13
Speaker: Steve Miley, director of operations, and Matt Hayes, engineer
Affiliation: Metro Machine
Topic: The future of shipbuilding
Activity: This meeting, held at Tri State Welding Lab in Erie, Pa., attracted 52 attendees.

DISTRICT 11
Director: Efthios Siradakis
Phone: (989) 894-4101

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

MILWAUKEE
JUNE 17
Activity: Chair John Kuzeinecki held a meeting to plan the Section's activities for the coming season. Attendees included Craig Wentzel, Michael Kersey, Mark Kowalski, Sandi Rode, Roger Edge, and Jay Wilson.
DISTRICT 13
Director: Jesse L. Hunter
Phone: (309) 359-8358

District 13 Conference
JUNE 4
Activity: Jesse Hunter, District 13 director, conducted the conference at Starved Rock Lodge in Utica, Ill.

CHICAGO
JUNE 16
Speaker: Eve J. Alfillé, owner
Affiliation: Eve J. Alfillé Gallery
Topic: The history, metallurgy, and joining of jewelry
Read more about Eve Alfillé on page 53 of this issue of Society News.

DISTRICT 14
Director: Tully C. Parker
Phone: (618) 667-7744

INDIANA
MARCH 17-19
Speaker: Dennis Klingman
Affiliation: The Lincoln Electric Co.
Topic: Welding — the path to your career
Activity: The Indiana Section members hosted its 26th annual Mid-West Team Welding Tournament, held in New Castle, Ind.

The contest consisted of five-member teams with each student performing a different role. The five areas were GMA, SMA, GTA, and FCA welding exercises and a 300-question test of theory. Each of the welding trials required the student to do a guided bend test on a V-groove butt joint. The SMA, GMA, and FCA bend tests were on 3/8-in. plate. The GTA project was done on 1/8-in. aluminum.

The “surprise” challenge this year for the GTAW contestants was to weld a watertight box, confirmed by submerging the boxes under water. The GMA and SMA contestants had to weld a 3-inch square tube onto a 1/2-in. plate in the vertical and overhead positions. These had to pass a liquid penetrant test. The flux core project was a three-bead T-joint in the overhead position.

The banquet was held at the Smith Building in the New Castle memorial Park where Dennis Klingman of Lincoln Electric addressed the students about the steps to follow in welding education.

The winning team, headed by instructor Pat Perkins, included Jeremiah Forbes (theory), Trevor Keener (GTAW), Dustin Chrisholm (SMAW), Ben Myers (FCAW), and Mike Harrison (GMAW).

Keener (GTAW), Dustin Chrisholm (SMAW), Ben Myers (FCAW), and Mike Harrison (GMAW).

This year, the contest gave away $4000 in door prizes to the contestants. The prizes included two Campbell Housfeld welding machines, four auto-darkening welding helmets, a number of welding tools, and 50 pairs of gloves.


Special thanks go to District 14 Director Tully Parker, Vinny Flynn, Bob Richwine, Mike Anderson, and Dennis Klingman who labored both in front and behind the scenes to keep the event on track.
Participants in the Sacramento Valley CWI program are shown June 12 following the exam.

Shown at the District 20 conference are (from left) Pierrette Gorman (New Mexico), Dennis Clark (Idaho), and Woody Cook (Utah).

TRI RIVER
MAY 19
Activity: Ted Pinnick, sales manager, The Lincoln Electric Co., presented a demonstration of the company's Precision TIG 185 welding machine. The event was held at Evansville Armature Co., in Evansville, Ind.

DISTRICT 15
Director: J. D. Heikkinen
Phone: (800) 249-2774

DISTRICT 16
Director: Charles F. Burg
Phone: (515) 233-1333

KANSAS
JUNE 16
Activity: The Section leaders met for a dinner and planning meeting at Whiskey Creek to work out the details for a golf tournament in September as the season's kickoff event.

JUNE 30
Activity: The Section leaders held a follow-up planning meeting at Torrey's Pizzeria in Kansas City, Mo.

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

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

DISTRICT 19
Director: Phil Zammit
Phone: (509) 468-2310 ext. 120

EASTERN IDAHO/MONTANA
NOVEMBER 15, 2003
Speaker: Paul Tremblay, technical specialist
Affiliation: INEEL
Topic: NDE of weldments
Activity: This was a joint meeting with the Experimental Aircraft Association. The program was held at Aeromark Pilot's Lounge.

DISTRICT 20
Director: Nancy M. Carlson
Phone: (208) 526-6302

District 20 Conference
MAY 15, 16
Activity: The Utah Section hosted the District 20 conference in Park City, Utah, chaired by District 20 Director Nancy Carlson.

DISTRICT 21
Director: Jack D. Compton
Phone: (661) 362-3218

DISTRICT 22
Director: Kent S. Baucher
Phone: (559) 276-9311

SACRAMENTO VALLEY
JUNE 7-12
Activity: The Section hosted a week-long CWI course and exam for 35 attendees held at the Doubletree Hotel in Sacramento, Calif. Key personnel were David Diaz, Mike Raho, Mike Urinast, Dale Flood, Kerry Shatell, Mark Feuerbach, and Dave Rovegno.
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 Thomas M. Mustaleski, Chairman, National Nominating Committee, American Welding Society, 550 NW LeJeune Rd., Miami, FL 33126.

The next meeting of the National Nominating Committee is currently scheduled for April 2005. The term of office for candidates nominated at this meeting will commence June 1, 2006.

Honorary-Meritorious Awards

The Honorary-Meritorious Awards Committee makes recommendations for the nominees presented for Honorary Membership. National Meritorious Certificate, William Irrgang Memorial, and the George E. Willis Awards. These awards are presented during the AWS Exposition and Convention held each spring. The deadline for submissions is July 1 prior to the year of awards presentations. Send candidate materials to Wendy Sue Reeve, Secretary, Honorary-Meritorious Awards Committee, 550 NW LeJeune Rd., Miami, FL 33126. A description of the awards follow:

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

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

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

International Meritorious Certificate Award: This award is given in recognition of the candidate's significant contributions to the worldwide welding industry. This award 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 awards luncheon or at another time as appropriate in conjunction with the AWS President's travel itinerary, and, if appropriate, a one-year membership in the American Welding Society.

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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FOR MORE INFORMATION, VISIT WWW.AOSAFETY.COM.
Free Poster Details Hot-Dip Galvanizing Criteria

The free Design for Galvanizing wall poster offers fabricators, architects, and engineers a quick reference when designing steel fabrications to be hot-dip galvanized. It addresses the placement and sites of vent and drain holes, welding, identification marking products, service-life prediction, and other information essential for optimizing costs, turnaround times, and end-product quality.

American Galvanizers Assn.
681 S. Holly Cir., Ste. 108, Centennial, CO 80112

Machinery's Handbook Extensively Revised

The 27th edition of Machinery's Handbook has been completely reformatted. It includes 30% more math coverage from the basics to the advanced, including derivatives and integrals, matrices, and engineering economics. Profusely illustrated, new material is presented on cutting tools, screw threads, properties and materials, sheet metal, and updated standards. Its comprehensive list of manufacturing topics includes processes, tooling, gauging, strength of materials, fasteners, heat treatment of metals, etc. It is available in three formats: CD-ROM ($90), a 5 x 7-in., 2640-page toolbox edition ($85), and an 8 x 10-in. larger-print edition ($100). The CD, in PDF format, features a new “electronic math” feature to interface with an Internet connection to instantly calculate cutting speeds, hardness of materials, and numerous other computations. Available from Industrial Press Inc., 200 Madison Ave., New York, NY 10016, info@industrialpress.com; www.industrialpress.com.

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www.cor-met.com

Circle No. 31 on Reader Info-Card

Abrasive Blasting Equipment Pictured

Blast cabinets, blast pots, valves and kits, air blast accessories, blasting abrasives, and associated safety equipment are pictured in a 120-page catalog. Included are exploded parts diagrams, full-color photographs of parts and equipment, and information for renting or purchasing parts and other products.

International Surface Preparation
603 Park Point Dr., Ste. 200, Golden, CO 80401

OSHA-Compliant Safety Products Described

A 48-page catalog illustrates a wide selection of lockout/tagout devices, safety...
At the D1.1 Code Week, you will learn all the information you need to keep your jobs trouble-free and up-to-code. These seminars provide the in-depth knowledge you need about the D1.1 Structural Welding Code—Steel, from the people who know it best—AWS.

You can take any combination of the five intense one-day seminars or save BIG on travel and tuition by signing up for the whole D1.1 Code Week—A SAVINGS OF UP TO 60%.

Seminars offered are: Code Road Map, Design of Welded Connections, Qualifications, Fabrication and Inspection.

As a special bonus when you register for the full week, you'll get the latest edition of the AWS D1.1/D1.1.M: 2004 Structural Welding Code—Steel ABSOLUTELY FREE. Attend a single-day seminar and you'll get 50% off the list price—A SAVINGS OF UP TO $172. This is one code you can't afford to be without.

To register call 1-800-443-9353 ext. 223. For more information and course detail, or to register online, visit us at www.aws.org, click on “Services” then select “Conferences”.

The D1.1 Code Week—we'll show you how to crack the code and put it to work for you.
Norris Joins Acme Cryogenics

Aubrey O. Norris joined Acme Cryogenics, Allentown, Pa., as southern region service coordinator based in Houston, Tex. Prior to joining Acme, Norris was a field service manager for Firestone Cryogenics.

McGregor Appointed to Manufacturing Council

Jim McGregor, president of Morgal Machine Tool Co. and Ohio Stamping & Machine, Springfield, Ohio, was appointed a member of the Bush administration's Manufacturing Council. McGregor is one of 13 council members assembled to serve as a voice for manufacturers within the administration by advocating issues of importance to the nation's manufacturing sector.

AMETEK Names VP

Matthew C. French was named vice president and general manager of the technical and industrial motors products at AMETEK, Inc., Kent, Pa. An employee of the company since 1990, French since 1999 served as division vice president and business unit manager of technical and industrial products for the Rotron division.

ABICOR Binzel Fills Three Posts

ABICOR Binzel, Frederick, Md., has promoted Paul E. Pfingstom to national sales manager, and Robert R. Magers to customer service supervisor. Scott Heckert joined the company as a robotics laser specialist. Pfingston has extensive sales experience with NASCO, WISCO, and Union Tank Car. Magers previously served the company in its customer service department. Heckert, a welding engineer, previously worked for Modern Tool and Die.
Engeron Joins Lucas-Milhaupt

Wayne Engeron, AWS and his technical sales team have joined Lucas-Milhaupt, Milwaukee, Wis., as manufacturers' representatives in the southeastern states. Engeron is an AWS Certified Welding Inspector, a Certified Welding Educator, and an ASNT Level II inspector.

Three Senior Executives Named at FKI Logistex

FKI Logistex, a supplier of integrated material-handling solutions, appointed Dave Baker as president of the Manufacturing Systems Division, John Kelly as president of Airport, Post and Parcel Division, and John Westendorf as president of the Warehouse and Distribution Division. Baker previously served the company as CFO of the Alvey Systems, White Systems, and Cleco Systems, Inc. groups. Kelly most recently was president of the company's Crisplant Inc. and LogiLearn units. Westendorf formerly served as CEO of the company's Automation Division.

Obituaries

John S. Bird

John S. Bird, 78, died June 18 in Troy, Ohio. Born in Wembley, England, he was a graduate of St. Catherine's College, Ontario, Canada, and Princeton University.

Mr. Bird was retired from Hobart Brothers Co., where he served as a sales manager and superintendent of the Hobart Institute of Welding Technology in Troy.

As a veteran of World War II he saw active duty in both European and Pacific Theaters. He is survived by his wife Eileen, two sons, two grandchildren, and a great granddaughter.

Bohnart Honored at SkillsUSA

Edward R. Bohnart, AWS president 1995–1996, was awarded the prestigious Torch Carrier Award at the SkillsUSA National Leadership and Skills Conference held in Kansas City, Mo., June 25.

The award recognizes the nation's top business and labor leaders who assist and promote SkillsUSA.

Bohnart is the proprietor of Welding Education and Consulting. The firm designs and conducts customized training and consulting programs for the welding industry.

Bohnart is a graduate of the Nebraska Vocational Technical College, taught welding for seven years at Father Flanagan's Boys Town, and is renowned for his more than 40 years of experience in the welding industry.

Bohnart is a member of the SkillsUSA Welding Technical Committee and a member of WorldSkills Competition Executive Steering Committee. Under his tutelage, SkillsUSA competitors in the WorldSkills Competition have received two gold, one silver, and three bronze medals in the last seven international competitions.

Harrell E. Bennett

Harrell Edward Bennett, 74, died July 5 at the family residence. He served as District 8 director June 1998 through May 2001. For 20 years he owned and operated Bennett Welding Co., Cleveland, Tenn. He served in the U.S. Marine Corps during World War II. Mr. Bennett is survived by his wife, Barbara, two daughters, one brother and a sister, six grandchildren, and one great grandchild.

Robert V. Henning, Sr.

Robert V. Henning, Sr., 87, died May 1 in Glen Cove, N.Y. He was the recent past president of Belmont Metals Inc., Brooklyn, N.Y., a company his father founded in 1896.

Born in Brooklyn, he raised his family in Garden City, and later moved to Glen Cove. He was a graduate of Lehigh University and did postgraduate work in metallurgy at Columbia University.

Mr. Henning served Belmont Metals for 65 years, almost 30 of which as president. His son, Richard, succeeded him as president last fall.

NEW LITERATURE

--- continued from page 64 ---

posters, signs, dispensers for ear plugs and face masks, and Right to Know products including OSHA documents and Material Safety Data Sheets. Included are a number of complementary items from Brady Corporation's line of safety, facility, and equipment identification products.

Prinzing.—A Brady Company

Brochure Defines Three Lines of Cutting Wheels

A trifold brochure details the three types of cut-off wheels in the company's Choice Cuts job-matched series. Included are the Original Slicer for general-purpose applications, Slicer Plus for heavy-duty work, and the Super Slicer for extreme performance. Described are the construction features for added safety, wheel life, higher cutting speed, and the special sulfur-, carbon-, and chlorine-free formulation.

Metabo Corp.
Friends and Colleagues:

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

For specifics on the nomination requirements, please contact Wendy Sue Reeve, at AWS headquarters in Miami, or simply follow the instructions on the Fellows nomination form in this issue of the Welding Journal. Please remember, we all benefit in the honoring of those who have made major contributions to our chosen profession and livelihood. The deadline for submission is February 1, 2005. The Committee looks forward to receiving numerous Fellow nominations for 2006 consideration.

Sincerely,

Alexander Lesnewich

Dr. Alexander Lesnewich
Chairman, AWS Fellows Selection Committee
CLASS OF 2006
FELLOW NOMINATION FORM

DATE_________________ NAME OF CANDIDATE ________________________________

AWS MEMBER NO._________________YEARS OF AWS MEMBERSHIP __________

HOME ADDRESS _____________________________________________________________

CITY_________________STATE______ZIP CODE______PHONE____________

PRESENT COMPANY/INSTITUTION AFFILIATION ________________________________

TITLE/POSITION ____________________________________________________________

BUSINESS ADDRESS _________________________________________________________

CITY_________________STATE______ZIP CODE______PHONE____________

ACADEMIC BACKGROUND, AS APPLICABLE:

INSTITUTION _________________________________________________________________

MAJOR & MINOR _____________________________________________________________

DEGREES OR CERTIFICATES/YEAR ______________________________________________

LICENSED PROFESSIONAL ENGINEER: YES  NO  STATE ____________________________

SIGNIFICANT WORK EXPERIENCE:

COMPANY/CITY/STATE _________________________________________________________

POSITION _________________________________________________________________

YEARS

COMPANY/CITY/STATE _________________________________________________________

POSITION _________________________________________________________________

YEARS

SUMMARIZE MAJOR CONTRIBUTIONS IN THESE POSITIONS:

___________________________________________________________________________

___________________________________________________________________________

___________________________________________________________________________

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

SEE GUIDELINES ON REVERSE SIDE

SUBMITTED BY: PROPOSER ________________________ AWS Member No. __________

Print Name ________________________________________________________________

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

NOMINATING MEMBER: ________________________ NOMINATING MEMBER: ______

Print Name ________________________ Print Name ________________________

AWS Member No. ____________________ AWS Member No. ____________________

NOMINATING MEMBER: ________________________ NOMINATING MEMBER: ______

Print Name ________________________ Print Name ________________________

AWS Member No. ____________________ AWS Member No. ____________________

SUBMISSION DEADLINE FEBRUARY 1, 2005
Fellow Description

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

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

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

NUMBER OF FELLOWS
Maximum of 10 Fellows selected each year.

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

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

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

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

Return completed Fellow nomination package to:

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

Telephone: 800-443-9353, extension 293

SUBMISSION DEADLINE: February 1, 2005
Tips for Selecting Oxyfuel Cutting Tips

Learn the three basic things to know

BY J. JONES

All oxyfuel cutting tips have several things in common. They all have a center-cutting oxygen hole, with openings around the center hole for the preheat flames. These openings may be holes or splines. Cutting tips are constructed of various metallic alloys by numerous manufacturers, but they are all designed to cut metal. So how does one know how to choose the best tip for the job?

When choosing a cutting tip, one needs to know three basic things.

Torch Type

The first item is the type of torch being used in the process. The torch determines the design of the seating surface the cutting tip must have. The torch's design also mandates the maximum oxygen flow. The oxygen flow determines the thickness of metal that can be cut. Note: Placing a cutting tip rated to cut ten inches in a torch designed to cut six inches is a common mistake.

Gas Type

The second item to consider is the fuel gas being used. Fuel gases have different burning rates, and the cutting tip must be designed to match the burning rate. The end of the cutting tip is recessed to match the type of fuel gas. Fuel gases also have different temperatures and BTU ratings. Tips designed as two-piece tips with splines to carry the preheat gases deliver many more preheat flames. One-piece tips with preheat holes are available for many types of fuel gases. Keep in mind that a two-piece tip offers many more preheat flames than does a one-piece tip; however, when using acetylene, additional preheat flames are not necessary.

Application Type

The third item to consider is the application. What is to be cut? What is the size of the cut? The material must be capable of being cut with the oxyfuel process. The cut size will determine the tip size needed. Manufacturers often provide literature that recommends the proper size tip to do the job with approximate flowing pressures and gas consumption (cubic feet per hour, ft³/h). Gouging, descaling, scarfing, and rivet washing are applications where specially designed cutting tips assist the process.

Choosing the proper tip is just one of the many decisions the operator makes when using the oxyfuel process. The equipment's performance relies on the operator's skill.
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A summer day camp called "Rosie's Girls" seeks to build the confidence of girls with hands-on instruction in welding and other traditionally male trades. Designed for girls entering sixth, seventh, and eighth grades, the three-week program is expanding to six states, "building strong girls," as its slogan promises.

Rosie's Girls, named after Rosie the Riveter, the legendary symbol of World War II female factory workers, was founded in 2000 as a pilot program of Northern New England Tradeswomen (NNETW), Essex Junction, Vt., a nonprofit organization that supports women in the skilled trades, in collaboration with Strong Foundations, Inc., Richmond, Vt.

Under the supervision of experienced tradespeople, girls (mostly ages 10 to 13) receive hands-on instruction in shop-based trades such as welding, carpentry, electrical wiring, plumbing, and car repair. They often tackle projects to benefit the local community.

"The overall goal of Rosie's Girls summer camps is to increase the self-confidence and self-esteem of girls," said NNETW assistant director Cary Brown. "We do this using trades exploration. The reason we chose trades is that it's very empowering and satisfying to use tools to create something with your hands. We're asking girls to use equipment they never thought was available to girls, to push them beyond the barriers and preconceived notions."

Vanessa Nelson-Reed, who brought Rosie's Girls summer camps to South Carolina, said it even better: "Who's going to mess with a woman who knows how to use a torch? This really builds strong girls," she told The Sumter Item newspaper. Nelson-Reed is in charge of gender equality for the South Carolina Department of Education. Along with Rosie's Girls enthusiasts from several other states, she attended a weeklong annual Rosie's Girls Training Institute in Vermont, where adult attendees observe a real camp in action and learn how to set up their own programs. That experience helped Nelson-Reed create five new Rosie's Girls summer camps in Charleston, Sumter, Columbia, Rock Hill, and Lancaster, S.C., where girls learned, among other things, to cut steel with a plasma torch and weld the pieces into metal palmetto trees mounted on a base shaped like the state map.

The parks department of the city of Santa Monica, Calif., has been running multiple Rosie's Girls sessions every summer since 2001. The city opens its municipal shop facilities to the program, so the girls can obtain hands-on familiarity with carpentry shop and machine tools, fleet repair equipment, and firefighting gear.
Electra Bodnar, 13, cuts a pattern with a plasma arc cutting torch as welding artist Kate Pond looks on. The girls also experience metal shaping and riveting.

Afita Nelson-Maggiani, 13, bends a steel rod over an oxyacetylene flame as Keri-Ann Chamberlin (right) supervises. "It's great to watch the first time they heat up the metal and bend it, thinking it will take more force than it does," said a counselor.

The camps in Vermont include three days of welding with metal artist Kate Pond, using oxyacetylene welding (lighting the torches themselves) and plasma cutting to make freestanding sculptures. They also spend a day at Advanced Welding Institute in South Burlington, where they get to try GMAW, then move on to SMAW.

"There was lots of wire shooting out, and lots of buzzing going on while the rod stuck to the steel plates," counselor Zpora Perry said. "But they jumped right into it and would have welded the tables together if I had let them."

Perry described one girl's reaction to using an arc welding machine for the first time: "She turned to me and said, 'Now I know what I'm asking for Christmas!'"

A day at a Rosie's Girls camp isn't all work, though. The program includes team-building games and physically challenging activities, such as rope climbing and self-defense. The program creates an environment the founders and campers call "Girl's World."

"The girls have an opportunity to look at the messages the culture sends out about being a woman, and how to respond to those messages," said Brown. She said the program targets middle school girls because that is the phase of development when girls face the most challenges to their self-esteem.

"Not only can they use powerful tools to make stuff of their own," Brown said, "but they can do it in a field that they never thought was available to women."

"Research shows the power of role models to girls. If they can see a woman doing it, it has a much greater impact. They see that it's fun to weld, and it's done by women who make their livings day after day as welders."

The program, which maintains an informational Web site at www.netw.org/robbie.htm, quotes a camp attendee named Kelsie, who said, "Rosie's Girls meant to me that I could do anything I want."
WHAT BETTER WAY TO HELP INDIVIDUALS PURSUE THEIR CAREER GOALS IN OUR WELDING INDUSTRY THAN THROUGH THE AWS FOUNDATION SILENT AUCTION!

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Circle No. 18 on Reader Info-Card
Understanding Distortion

The heat from arc welding creates forces that result in contraction stresses

BY DAVE McGOWAN

What does localized heating of 1°F do to carbon steel or gray cast iron?
In order to answer this question we need to understand Young's modulus and the coefficient of linear expansion of iron.

Young's modulus is the physical constant that expresses the ratio between stress and strain below the proportional limit. For example, steel = 30,000,000 lb/in.².

\[
\text{Stress (load)} = 30,000 \text{ lb/in.}^2 = 30,000,000 \text{ lb/in.}^2
\]
\[
\text{Strain (result of load)} = 0.001
\]

which means that one pound of stress or load that is applied to a 1-in. cube of steel in one direction changes that dimension by 1/30,000,000 in. (0.000000033 in.). The change in length will be a decrease if the stress is compressive or an increase if the stress or load is tensile.

\[
\text{Load or Stress}
\]
\[
\begin{array}{c|c|c|c|c|c|c}
\hline
\text{Load or Stress} & 0 & 10 & 20 & 30 & 40 & 50 \\
\text{1000 psi} & 0 & 10 & 20 & 30 & 40 & 50 \\
\hline
\end{array}
\]

Figure 1 — A partial stress-strain curve to the proportional limit for steel.

Coefficient of Linear Expansion of Iron

The coefficient of expansion of iron is 0.0000067/°F/linear inch.
If 1 cubic inch of iron is heated 1°F, it will expand to 1.0000067 in.
The coefficient of expansion of iron rises with temperature, nearly 0 at absolute zero, rising to about 8.0 × 10⁻⁶ at 800°F.

To compress a 1-cubic-in. steel block that has been heated 1°F (75°F to 76°F) from a length of 1.0000067 to 1.00000 in., requires a compressive stress or load of 0.0000067 divided by 0.000000033, which equals approximately 201 lb/in.². Stated another way, 0.0000067 × 30,000,000 lb/in.² = approximately 201 lb/in.².

Young's modulus decreases as the temperature is raised.
The yield strength of mild steel is about 48,000 lb/in.². The tensile strength of mild steel is about 63,000 lb/in.².

If we apply localized heating of 1°F (75°F to 76°F) to a piece of steel plate, the compressive stress will be 0.0000067 × 30,000,000 lb/in.² = 201 lb/in.². If we multiply this amount by 400°F (75°F to 475°F of localized heating), we get 80,400 lb/in.², which is well above the yield or tensile strength of mild steel. These types of localized forces will distort the steel.
insofar as the steel has ductility. In some cases, such as a pipe that is installed through a steel bulkhead with excessive root opening, the first pass when cooled may crack either in the weld center or beside the weld due to extreme residual reaction forces.

When we are welding two pieces of steel together, the temperature of the weld zone is much higher than 400°F. The expansion forces we have discussed are taking place; but in most cases we do not see the forces in action due to the size and weight of the pieces being welded. A lot of these forces are taken up in the hot plastic weld zone. As the weld cools, the contraction stresses appear as visible distortion. It is no wonder that when we fusion weld steel we have to be very concerned about controlling distortion.

**Types of Distortion and Shrinkage**

Figure 2 shows the various types of distortion and shrinkage. When making fusion welds on fabrications, all of the types of distortion and shrinkage shown in Fig. 2 are taking place at the same time. These conditions make controlling distortion difficult. There are formulas for controlling transverse and longitudinal shrinkage for butt joints; however, the formulas lose accuracy if the cross-sectional area of the plate is greater than 20 times that of the weld. Changes in welding process, size of weld, weld travel speed, and heat input all have an effect on distortion.

**Controlling Distortion**

There is nothing that can take the place of knowledge and experience when it comes to controlling distortion. Each fabrication that has to be welded is unique. The following are acceptable methods for attempting to control distortion.

**Mechanical Control**

- Presetting, prebending, and prespacing the plates.
- Temporary stiffeners, clamps, strongbacks, special jigs (that do not restrain the weld joint), and back-to-back clamping.

**Welding Procedure Control**

- Use the minimum groove angle for the weld joint that will accommodate the filler metal.
- Maintain weld joint fitup tolerances as per the drawing, code, specification, or standard.
- Use backstepping or skip welding techniques.
- Weld outward from a central point using a backstepping technique.
- Weld about the neutral axis. Balance welds on either side of a centerline.
- Weld butt joints before fillet welds.
- Use chain or staggered intermittent fillet welds.
- Arrange the weld sequence so that each joint has the maximum freedom for the longest period.
- Use subassemblies.
- Weld before riveting.
- Select a welding process that reduces the heat input, such as gas metal arc welding in the short circuit metal transfer mode for gauge metal welding and in the pulsed spray metal transfer mode for austenitic stainless steels.
- Avoid making numerous small weld beads for a given weld groove.
- Utilize preheating to reduce residual, reaction, and structural stresses.

**Performing Interference Fits**

Understanding the previous information helps us to perform interference fits of sprockets or gears to shafts. If we apply heat only to the hub of the sprocket or gear, the cooler outer circumference of the sprocket or gear will prevent the expansion of the hole and the hole will shrink when cooled. When performing interference fits, it is important to have the shaft and sprocket or gear machined so it will fit properly when heated and cooled to room temperature. A common interference fit is one half thousandths per inch of shaft. If using multiple flames, it is important to heat the sprocket or gear evenly from the outside in. The best methods of heating are to use a heating oven or induction coil. When performing through-thickness heating, a digital readout pyrometer is preferred. Gears and sprocket teeth are hardened and tempered items. The tempering temperature is usually around 500°F, so it is important to not heat the gear or sprocket above that temperature or some temper will be lost. The formula for interference fits (which can be located in the Machinery's Handbook) is $0.0000067 \times \text{bore diameter} \times \Delta \text{F of through-thickness preheating}$.

**Repairing Gray Cast Iron**

If we take nonductile gray cast iron, which has a tensile strength of about 22,000 lb/in.$^2$, and apply localized heat of 400°F, there is a good chance that we will crack the cast on heating. This is why careful preheating procedures and welding techniques are required when repairing thin-section gray cast irons.

**For More Information**

If you'd like to learn more about what causes distortion and how it can be controlled, the following references are suggested.

**The Motto at SWIC Is ‘Mission Success’**

Southwestern Illinois College (SWIC) supports its courses, including welder training, with career counseling, course placement, career mentors (Fig. 1), job leads, on-campus recruitment opportunities, and résumé workshops. It's called "Mission Success." A special feature of the SWIC program is its students have the opportunity to gain extensive hands-on experience while learning about employer relationships in preparation for entering the job market.

Chuck Gulash, the enthusiastic program coordinator for the SWIC welding technology program, said, "The American Welding Society recognizes the welding program at Southwestern Illinois College as one of the best in the nation. We offer the AWS S.E.N.E. program Levels I and II. Our classes provide expert training to beginning welders in addition to offering courses for experienced welders to upgrade their skills." To keep abreast of the latest trends in welding, the welding instructors are active members of the AWS St. Louis Section. Altogether, there are 22 welding instructors on staff and about 200 students enrolled in welding courses.

The college's welding shop uses state-of-the-art equipment and shops (Fig. 2). Each welding instructor has many years of experience as well as knowledge of the latest needs in the welding marketplace.

Gulash, who is an AWS Certified Welding Inspector, noted, "SWIC’s welding programs have served as models for other schools. The college’s students consistently do well in state and national welding competitions." The college is a member of the Vocational Industrial Clubs of America (VICA) with an enviable record for winning the annual SkillsUSA welding competitions.

**Welder Training Options**

A number of training options are offered at SWIC. Students may opt for welding certificate courses requiring one or two semesters of study. Also presented is a two-year associate degree program that combines welding with academic courses. Part-time evening students often complete certificate programs in less than four semesters.

The Welding Technology certificate program is designed to train beginners for entry-level welder positions, and to provide more advanced technical information and skills training for those already employed in the welding field.

The laboratory is open six days (70 hours) a week to maximize hands-on experience. Day students attend classes four or five days a week; night students attend classes two or three nights a week. The students use about 30,000 lb of filler metal and 50 tons of metal each year in the welding labs.

Topics taught include shielded metal arc welding; gas metal arc welding, including short circuit, globular, and spray transfers; flux cored and plasma arc welding and cutting; acetylene welding and cutting; gas tungsten arc welding; blueprint reading, layout, fitup, and weld inspection.

The Industrial Safety Technology (Fig. 3) program provides in-service training for people employed in industrial and manufacturing settings. This program meets all OSHA criteria for employment as safety director, safety technician, or safety/compliance officer. Topics include OSHA awareness, first aid/CPR, personal protection equipment, lockout/tagout, hazardous waste operation, bloodborne pathogens, confined space entry, facility inspection, record keeping, and industrial forklift driving.

**Job Placement**

Gulash noted, "The market for skilled welders is expanding as the industry's use of technology advances. Welding is essential to manufacturing, construction, computers, electronics, and automobile and aircraft production. Welders also are needed for making repairs on pressure vessels and to repair or rebuild farm and manufacturing equipment. Southwestern Illinois College works with several local corporations and trade unions to train their welders. Presently," he added, "welders in the area earn between $10 and $25 per hour."

The SWIC Associate in Applied Science (AAS) degree program prepares welders, cutters, and related personnel to meet the needs of local and national industry. The emphasis is on practice and the principles used in industry. Students wanting to pursue their educations beyond the AAS degree can transfer their SWIC credits to Ferris State University toward a bachelor's degree.

**College Facilities**

The college operates an extensive instructional network with welding classes offered in Belleville, Granite City, and East St. Louis. It operates an Industrial Training Center (Fig. 4) at the Granite City campus, and additional facilities at 26 off-campus sites, most of which are located in district high schools. The main campuses, Belleville, Granite City, and Red Bud are linked by video, enabling an instructor at one campus to teach and interact with students at all three campuses simultaneously.

**Tuition, Scholarships, and Financing**

The current tuition rate at SWIC is $55 per credit hour. The tuition for four semesters, based on taking 16 credit hours per semester, is $3136. For comparison, the average tuition at a state university for four semesters is $7020, based on data posted at www.collegeboard.com.
The college offers many options to assist students financially. Presently, there are more than 160 privately funded awards ranging from $100 to $1500. Each award has its requirements. The diverse criteria reflect the preferences of the individuals, businesses, clubs, and organizations that provide these funds.

Students are encouraged to apply for as many scholarships as they are eligible for. To qualify, applicants must be a Southwestern Illinois College student, or a prospective student who lives in Community College District #522. There are a few exceptions to this policy and it is noted in the scholarships' criteria. The scholarship applications are reviewed by more than 30 different selection committees. Those interested in applying for scholarships can apply online at the SWIC Web site (www.swic.edu) and can also download the informative 2004-2005 Financial Aid Handbook. Free scholarship searches, as well as other helpful information, are available online at www.studentaid.ed.gov and www.collegezone.com.

Additional welding scholarships are offered by the American Welding Society and the AWS St. Louis Section. Contact AWS for more information at www.aws.org.

**SWIC History and Its Present**

Founded in 1946, Southwestern Illinois College was originally named Belleville Junior College. That year, the institution enrolled 169 students for its first fall class — more than 60% of the students were young veterans of World War II. On January 1, 2000, the college's name was changed to Southwestern Illinois College.

During fall 2001, 15,159 students were enrolled at SWIC with an average age of 28. It has a full-time faculty of 135, of which 25 hold doctorate and 99 hold master’s degrees; 24% of the district's high school graduates enroll at SWIC; 74% of are employed outside the home; and 44% hold full-time jobs.

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Fig. 3 — A welding student learns how to weld well and to weld safely at SWIC.

Fig. 4 — The Industrial Training Center, Granite City campus.

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**Southwestern Illinois College (SWIC)**

2500 Carlyle Ave.
Belleville, IL 62221
(618) 235-2700
Web site: www.swic.edu

**Contact:**
Chuck Gulash, coordinator
Welding Technology Dept.
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Circle No. 49 on Reader Info-Card
Gas Tungsten Arc Welding: Technique and Troubleshooting

<table>
<thead>
<tr>
<th>Problem</th>
<th>Cause</th>
<th>Troubleshooting Guide</th>
<th>Remedy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excessive electrode consumption</td>
<td>Inadequate gas flow, Operating on DCEP, Improper size electrode for current, Excessive heating in holder, Contaminated electrode, Electrode oxidation during cooling, Using gas containing oxygen or carbon dioxide</td>
<td>Increase gas flow, Use larger electrode or change to DCEN, Use larger electrode, Check collet contact, Remove contaminated portion, Keep gas flowing at least 10 to 15 s after stopping arc, Change to proper gas</td>
<td></td>
</tr>
<tr>
<td>Erratic arc</td>
<td>Dirty or greasy base metal, Joint is too narrow, Electrode is contaminated, Arc is too long</td>
<td>Use appropriate chemical cleaners, wire brush, or abrasives, Open groove; bring electrode closer to work; decrease voltage, Remove contaminated portion, Move closer to workpiece; shorten arc</td>
<td></td>
</tr>
<tr>
<td>Porosity</td>
<td>Entrapped hydrogen, nitrogen, air, or water vapor, Defective hose, or loose connections, Oil film on base metal</td>
<td>Blow out air from lines before striking; remove condensed moisture from lines; use 99.99% inert gas, Check gas hose for leaks, Clean with chemical not prone to break up in arc; do not weld on wet metal</td>
<td></td>
</tr>
<tr>
<td>Tungsten contamination of workpiece</td>
<td>Contact starting with electrode, Electrode melting and alloying with base metal, Touching tungsten to molten pool</td>
<td>Use high-frequency starter; use copper striker plate, Use less current or larger electrode; use proper electrode for metal welded, Keep tungsten out of weld pool</td>
<td></td>
</tr>
</tbody>
</table>

Technique for manual gas tungsten arc welding.
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Ventilation for Welding Operations

Fumes and gases from welding and cutting cannot be classified simply. The composition and quantity of fumes and gases are dependent upon the metal being worked, the process and consumables being used, coatings on the work such as paint, galvanizing, or plating, contaminants in the atmosphere such as halogenated hydrocarbon vapors from cleaning and degreasing activities, and other factors.

Adequate ventilation, however, needs to be provided for all welding, cutting, brazing, and related operations. Adequate ventilation is classified as enough ventilation such that personnel exposures to hazardous concentrations of airborne contaminants are maintained below the allowable limits specified by the authority having jurisdiction. (The Occupational Safety and Health Administration or others may be the authority having jurisdiction. Many of these levels are adopted from the publications of the American Conference of Governmental Industrial Hygienists, although it is not an authority having jurisdiction.)

When adequate ventilation isn’t practical, respiratory protective equipment is to be used.

Factors determining adequate ventilation include the following:

- Volume and configuration of the space in which operations occur
- Number and type of operations generating contaminants
- Concentrations of specific toxic or flammable contaminants being generated
- Natural air flow (rate and general atmospheric conditions where work is being done)
- Location of the welders’ and other persons’ breathing zones in relation to the contaminants or sources.

In cases where the values for allowable exposure limits vary among recognized authorities, the lower values should be used to effect the maximum personnel protection.

In welding and cutting, the composition of the fumes is usually different from the composition of the electrode or consumables.

Reasonably expected fume products of normal operation include those originating from consumables, base metals and coating, and the atmospheric contaminants noted. Reasonably expected gaseous products include carbon monoxide, carbon dioxide, fluorides, nitrogen oxides, and ozone.

The recommended method for determining adequate ventilation is to sample for the composition and quantity of fumes and gases to which personnel are exposed.

Avoiding the Fume

Welders and cutters should take precautions to avoid breathing the fume directly. That can be done by positioning of the work or the head, or by ventilation that captures or directs the fume away from the face. Tests have shown that fume control is more effective when the air flow is directed across the face of the welder, rather than from behind. Most of the fume appears as a clearly visible plume that rises directly from the spot of welding or cutting.

Types of Ventilation

If natural ventilation is insufficient to maintain contaminants below the allowable limits, mechanical ventilation or respirators are to be provided.

Natural ventilation is acceptable for welding, cutting, and related processes where the necessary precautions are taken to keep the welder’s breathing zone away from the fumes and where sampling of the atmosphere shows that concentrations of contaminants are below the allowable limits.

Mechanical ventilation includes local exhaust, local forced air, and general area mechanical air movement. Local exhaust ventilation is preferred.

Local exhaust ventilation means fixed or movable exhaust hoods placed as near as practicable to the work and able to maintain a capture velocity sufficient to keep airborne contaminants below the allowable limits. Local forced ventilation means a local air moving system (such as a fan) placed so that it moves horizontally across the welder’s face. General mechanical ventilation may be necessary in addition to local forced ventilation.

Examples of general mechanical ventilation are roof exhaust fans, wall exhaust fans, and similar large area air movers. While this type of ventilation is not usually as satisfactory for health hazard control as is local mechanical ventilation, it is often helpful when used in addition to local ventilation.

Ventilation shouldn’t produce more than approximately 100 feet per minute air velocity at the work (welding or cutting) zone in order to prevent disturbance of the arc or flame. Approximately 100 feet per minute is a recommended maximum value for quality control purposes in welding and cutting; it is not intended to imply adequacy in contaminant control for worker health protection.

Special Ventilation Concerns

Special ventilation precautions have to be taken when the following materials are identified as other than trace constituents in welding, brazing, or cutting operations unless breathing zone sampling under the most adverse conditions has established that the level of hazardous constituents is below the allowable limits:

- Antimony
- Arsenic
- Barium
- Beryllium
- Cadmium
- Chromium
- Cobalt
- Copper
- Lead
- Manganese
- Mercury
- Nickel
- Ozone
- Selenium
- Silver
- Vanadium.

Whenever any of those materials exceed the allowable limits in confined space operations, local exhaust mechanical ventilation and, when required, respiratory protection are to be used.

In addition, all persons in the immediate vicinity of welding or cutting operations involving those materials must also be protected.

Excerpted from ANSI Z49.1: 1999, Safety in Welding, Cutting, and Allied Processes.
Exhibiting at the AWS Welding Show 2005 is the most cost-effective way to gain broad exposure in a short time. As an AWS exhibitor, you will have the opportunity to meet those buyers who need your products. The AWS Welding Show has more to offer than any other show in the metal-fabricating and construction industries.

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To participate in any of the pavilions or for more information, please contact our Welding Show Exhibit Sales office at: 1-800-443-9353, ext. 295 or 242.
How to Make a Chandelier

This candle chandelier is a wonderful accent for cabins, porches, or even outside dining. Making the scrolls is easy, but if you want something a bit fancier, you can purchase wrought iron scrolls. Place the scrolls carefully around the couplers to ensure the fixture will hang straight. If you do not want to purchase a long section of round tube for two 2-in. pieces and can’t find any in the scrap bin at the steel yard, use threaded black pipe couplers.

Prepare the C Scroll Blanks

1. Cut the C scroll (A) and S scroll (B) blanks to size.
2. Clamp a C scroll blank to the 10-in. bending form. Shape the entire length of the scroll blank. Lightly tap the scroll with a hammer, if necessary, to get it to conform.
3. Remove the scroll from the form. Reclamp one end of the scroll to the 1-in. form and shape that end into a tight curve. Repeat this step to shape the opposite end.
4. Repeat steps 2 and 3 to shape the remaining C scrolls.

Prepare the S Scroll Blanks

1. Mark each S scroll blank 9½ in. from one end. Clamp the marked end to the 6-in. bending form.
2. Wrap the bar around the form, shaping it just past the mark.
3. Clamp that same end to the 2-in. form. Wrap the bar almost all the way around the form.
4. Unwrap the large curve slightly, refining the scroll into a pleasing shape.
5. To curve the other end in the opposite direction, turn the piece over and clamp it to the 2-in. form. Wrap the bar almost all the way around.

Assemble the Scrolls

1. Set a straight edge on a large piece of paper. Lay out one C scroll and one S scroll along the straightedge, and adjust them until they form a pleasing shape. Mark the contact point on the bars.
2. Remove the scrolls from the paper and weld them together at the contact point.
3. Trace the outline of this assembly on the paper — Fig. 3. Use this pattern to arrange and assemble the remaining arms.

Assemble the Chandelier

1. Cut the couplers (C) and insert (D) to length.
2. Drill a hole in the center of the insert large enough for the threaded nipple. Bend tabs on each end of the insert so it will fit inside a coupler.
3. Place the insert into a coupler with the tabs pointing down. Weld the insert to the coupler along the tabs. This forms the top coupler.
4. Draw a line around the outside of each coupler on paper.
5. Mark five equidistant points around the coupler outline. Place the coupler back on the paper and transfer the lines onto the coupler, using a combination square — Fig. 4.
6. Weld the arms to the couplers. Weld the bobeches to the arms.

- V/4 x 3½-in. flat bar (17 ft)
- 2½-in. round tube (4 in.)
- 2-in. threaded nipple
- Threaded brass washers (3)
- Decorative chain
- 10-, 6-, 2-, and 1-in. bending forms
- 2½-in. bobeches (5)
- Lock washers (2)
- Finial
- Candles (5)
Fig. 3 — After welding the first set of scrolls, trace the outline on a sheet of paper. Use this pattern to arrange the remaining scrolls.

Apply Finishing Touches

1. Place a lock washer and threaded brass washer on the threaded nipple. Set this in the hole in the insert and secure it with another lock washer and threaded brass washer.

2. Add a threaded brass washer and a finial.

3. Wire brush and clean the chandelier. Apply your choice of finish.

4. Clip the chain into the finial, and it's ready to hang.

Fig. 4 — Use a combination square to mark the arm placement on each coupler.


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SEPTEMBER 2004
Reliability of Weld Microstructure and Property Calculations

The AWS 2004 Adams Lecture explores modeling vs. experimentation for developing welding consumables for new alloys

BY H. K. D. H. BHADESHIA

We depend in our everyday life on the performance of vast quantities of steel, which we use without giving it a second thought. This is possible because the material is reliable and cheap (weight for weight, some 1000 times cheaper than potato chips). Yet, there are remarkable technologies and sciences working behind the scenes to create ever better steels that can be assembled into awe-inspiring structures.

Examples include the giant oil rigs that pepper the North Sea, the oil and gas pipelines that traverse the frozen wastes, and the 101 Tower in Taiwan, which is now the tallest building in the world — Fig. 1. These are all made from steel and rely on welding for their assembly.

Weld Design: Experiment or Model?

A weld is a heterogeneity introduced into a carefully manufactured steel. It is a defect that has to be managed. One way of doing this is through a deep understanding of metallurgy, thereby avoiding the engineering disasters of the kind that plagued, for example, the Liberty ships. A weld consists of distinct zones, each of which is the consequence of a particular interaction between heat flow and the phase transformation characteristics of the weld metal and the base metal.

Out of all these zones, the weld metal is particularly challenging to design because there is little that can be done once the weld is completed (Refs. 1–3). This contrasts with wrought steel, which can be processed and manipulated using all the facilities available in a modern steel plant. There is, therefore, a major industry devoted to the design and manufacture of welding alloys. Academic activity has supported this industry, both in terms of the underlying science and in the creation of quantitative methods for alloy design. Given all this effort, I shall use this lecture to explore whether it is any longer necessary to conduct experiments when developing welding consumables. Are the models sufficiently robust to be exploited by industry without supervision?

The focus of this paper is on ferritic steels, which form the bulk of the billion or so tons of steel consumed annually. The development of welding consumables involves all weld-metal tests in which a joint is deposited such that samples can be obtained without dilution with the base plates. It is fortunate that the literature is rich in data from tests of this kind, data which have been liberally exploited in the development of models.

Defining Characteristics of a Weld Metal

The essential variables needed in order to be able to calculate the microstructure and properties of steel weld metal are illustrated in the top row of Fig. 2 (Refs. 4, 5). The chemical composition, cooling conditions, and austenite grain size capture all the essential features of weld metal. The essence of the welding process and joint geometry is expressed via the cooling curve and there are many models with varying levels of sophistication capable of predicting the change in temperature as a function of time and position. As will be seen later, the chemical composition defines the thermodynamics of transformation and the nature of the heterogeneities that arise.

The austenite grain structure, a parameter sometimes ignored in the interpretation of microstructures, has a profound effect.

Cooling Curve

There is a huge amount of research that has been devoted solely to the calculation of the thermal cycle associated with welding. The most sophisticated of models account for joint geometry, gravitational forces, surface tension effects, buoyancy forces, electromagnetic forces, metal transfer, changes in thermophysical properties with temperature and turbulence, etc. (Ref. 6). Weld pool shapes can be fairly accurately calculated and when there are deviations, empirical correc-

KEY WORDS

Consumables
Cooling Curve
Experimentation
Ferritic Steel
Modeling
Solid-State Transformation
tions are made in a manner constrained by the physics. From the present point of view, it is really the cooling curve that is important, particularly in the regime where solid-state transformations occur, i.e., between about 900°C and the martensite-start temperature; this must be the reason why the time $\Delta t_{005-500}$ is a popular measure in the welding industry. This greatly simplifies the problem because the cooling rate $(dT/dt)$ within the weld metal can, to a high level of accuracy, be represented independently of position with a simple equation (Refs. 7, 8).

$$\frac{dT}{dt} = \frac{C_1(T-T_f)}{Q\eta}$$

(1)

where $Q$ is the heat input per unit length, $\eta$ is the transfer efficiency, and $T_f$ the preheat or interpass temperature. There are numerous weld cooling curves available in the welding literature; for a particular process and weld geometry, this equation can be fitted to derive the empirical constants $C_1$ and $C_2$. Such constants are available for a large variety of welding processes and this simple procedure works rather well in practice. Rigorous calculations in which the weld pool is properly modeled make only a small difference to the calculated microstructure. This is because the cooling rate in the transformation range is relatively insensitive to fluid flow phenomena.

The Austenite Grain Structure

The columnar austenite grains in the weld deposit derive, in most cases, from columnar B-ferrite grains that grow epitaxially from the fusion surface during the early stages of solidification. The columnar shape is quite different from the equiaxed grains found in most steels and requires a different approach in defining the amount of austenite grain surface per unit volume ($S_v$). It has been demonstrated that the columnar grains can be described as hexagonal prisms (length $c$ and side $a$) in three dimensions. It follows that two stereological parameters, the mean lineal and mean areal intercepts, are needed to quantify this anisotropic grain structure. However, because the grains are much longer than they are wide, a good approximation is that the mean lineal intercept measured on transverse sections of the weld ($L_{mn}$) in a direction normal to the columns, adequately describes $S_v$ (Ref. 9). There exist equations that then relate $S_v$ to the chemical composition of the weld metal and the heat input.

The Alloying Elements

A weld metal may contain twenty or more deliberate solutes, and others that are introduced accidentally during deposition: C, Mn, Si, Ni, Mo, Cr, V, Co, B, N, O .... Some of these, such as boron, may be present in minute quantities and yet can have a profound effect on the microstructure. Solutes act on steels by two essential mechanisms:

1) The relative stabilities of austenite ($g$) and ferrite ($\alpha$) are affected via a thermodynamic effect, which can be expressed rigorously in terms of the difference in Gibbs free energies, $G^g - G^\alpha$, often called the "driving force" for transformation. This thermodynamic quantity feeds directly into rate theory, for example in the equations governing classical nucleation. It is now routinely possible to calculate these free energies and, of course, to express them in terms of equilibrium phase diagrams. Such calculations can now be conducted routinely for multicomponent, multiphase steels, using proprietary or free software.

2) The second effect is more subtle because it depends on the rate at which change occurs. The equilibrium solubility of an alloying element is never identical in austenite and ferrite. If circumstances permit, the solute will therefore tend to partition between the phases during the course of transformation. The required diffusion may then limit the kinetics of the process. This is a gross effect involving large numbers of atoms and distances comparable to the size of the transformed product. Another kinetic effect of equal importance can be triggered by minute concentrations of solute; misfitting atoms can segregate to interfaces. In doing so, they reduce the interfacial energy per unit area. This is the mechanism by which boron renders austenite grain boundaries less effective as heterogeneous nucleation sites for ferrite. Traces of boron can therefore have a huge influence on hardenability, far in excess of that expected from its influence on $G^g - G^\alpha$.

Solid-State Transformations

Allotriomorphic Ferrite

Having described the three parameters that are seminal in the development of weld metal microstructure, we now address the complex array of phase changes that occur as the weld metal cools (Refs. 1-5). The essential features of the transformed microstructure are illustrated schematically in Fig. 3. It consists of allotriomorphic ferrite $\alpha$, Widmanstätten ferrite $\alpha_w$, acicular ferrite $\alpha_a$, and the so-called microphases, which might include small amounts of martensite, retained austenite, or degenerate pearlite. Bainite consisting of sheaves of parallel platelets is also found in some weld de-
where $q$, the parabolic thickening rate 

Theory shows that the thickness ($q$) of the 

The substitutional elements do not parti-

crostructure of weld metal.

Fig. 3 — Schematic representation of the mi-

$D$ is the diffusivity of carbon in

$D =$ \[ \frac{\int \frac{D(x)}{x-\bar{x}} \, dx}{\bar{x}} \]  

where $D$ is the diffusivity of carbon in 

and $\bar{x}_{\text{eq}}$ are the paraequilibrium carbon 

and $\bar{x}$ is the average carbon 

concentration in the alloy and $D$ is a 

weighted average diffusivity of carbon in 

austenite, given by

thickness is most sensitive to the carbon 

concentration when the latter is close to the 

solubility of carbon in ferrite; this is 

because the need to partition carbon 

decreases as the average concentration 

$X=\bar{x}_{\text{eq}}$. We shall see later that this explains 

some of the carbon equivalent equations 

prevalent in industry. Figure 4B shows 

that the nucleation stage of the layers 

of ferrite can justifiably be neglected 

because the volume fraction $v_{\alpha}$ correlates 

strongly with $q$, for a large variety of weld 

metals.

Welds cool continuously, so the above 

equations need to be integrated over the 

temperature range $T_h$ to $T_f$, the start 

and stop temperatures for $\alpha$. $T_f$ is estimated 

using calculated time-temperature-trans-

formation (TTT) diagrams (Ref. 10) (Fig. 

5) and Scheil's rule. $T_f$ is taken to be the 

point where displacive transformations 

become kinetically favored. Once the 

thickness of the layers of ferrite has been calculated, it is straightforward to relate it to the volume fraction of ferrite using the geometry of the austenite grains

\[ v_{\alpha} = \left[ \frac{1}{2} \tan \frac{30 \text{deg}}{a} \right] \left( \frac{a}{2a} \right)^2 \]  

so that the dependence on austenite grain size becomes obvious.

Widmanstätten Ferrite

Widmanstätten ferrite plates grow with 

paraequilibrium and lengthen at a rate 

($G$) controlled by the diffusion of carbon 

ahead of the plate tips. Because of the dis-

placements associated with the transforma-

tion, it is necessary to account for strain 

energy. The plates are confined within the 

austenite grains in which they nucleate, 

and they grow so fast that crossing the 

grains within a fraction of a second is typi-

cal — Fig. 6A. The theory used here is rig-

orous and proven, but the volume fraction 

of Widmanstätten ferrite ($v_{\alpha}$) hardly cor-

relates with $G$ — Fig. 6B.

The discrepancy arises because by the 

time the weld has cooled to induce Wid-

manstätten ferrite, acicular ferrite sprouts 

from inclusions dispersed within the 

austenite grains. There is, therefore, com-

petition for the austenite that remains and 

a strong possibility of impingement be-

tween intragranularly nucleated acicular 

ferrite and Widmanstätten ferrite. As il-

lustrated in Fig. 7, when the alloy content 

is small, the rapid growth of $q$ and $d\alpha/dt$

consumes much of the austenite, thereby 

reducing the ability to form $\alpha$. By contrast, 

in high-hardenability welding alloys, the 

acicular ferrite has an opportunity to de-

velop and indeed to stifle the penetration 

of Widmanstätten ferrite into the auste-

nite grains.

The volume fraction of Widmanstätten 

ferrite that can form is therefore a func-

tion not just of the growth rate, but also of 

the thickness of allotriomorphic ferrite, 

the time required for it to grow across an 

austenite grain, and the geometry of the 

austenite grains.

\[ v_{\alpha} = C_{\alpha} G / (2a - 4q \tan \frac{30 \text{deg}}{a}) \]  

where $C_{\alpha}$ is a constant independent of 

alloy composition and $t_f$ is a function of 

the impingement process. As will be seen 

later, with this accounting, good agree-

ment is obtained with experiments.

Finally, it is worth saying something 

about acicular ferrite, which is a highly de-

sirable phase (Refs. 1–5). Its microstruc-

ture consists of intragranularly nucleated
plates, which radiate in many directions from point nucleation sites. This leads to a chaotic microstructure, which is good at deflecting cracks. It is therefore strong and tough. There is much evidence to suggest that acicular ferrite is intragranularly nucleated bainite, the heterogeneous nucleation sites being the complex non-metallic inclusions common in welds, either as impurities or as deliberate additions. There is considerable qualitative understanding on the type of inclusions that are most favorable.

There also exist quantitative methods of estimating the type of inclusion that will form during solidification and subsequent cooling. The quantitative details of the calculation of acicular ferrite are discussed elsewhere (Ref. 11).

Solidification-Induced Segregation

In the discussion above, it has been assumed that the chemical composition of weld metal is uniform. This is not the case in practice because welds cool rapidly and there may be uncontrolled variations in the welding conditions. A good estimate of the magnitude of segregation comes from the partition coefficient $k_i$, which is the ratio of solute concentration $i$ in the solid to that in the liquid. The coefficient can easily be calculated, and used to give the compositions of the solute-rich and solute-poor regions of the weld (carbon is very malleable so it is assumed to be uniformly distributed). This information can then be used to estimate the effect on $T_h$ for allotriomorphic ferrite, which then influences all subsequent transformations.

To summarize, virtually every component of weld microstructure is amenable to calculation. Some examples are presented in Fig. 8. Predictions like these have been extensively validated using published experimental data and by designing new experiments.

An interesting prediction to emerge from these calculations is that the microstructure is sensitive to the carbon when its concentration is comparable to its solubility in ferrite. It seems that the welding industry has implicitly recognized this by proposing two different equations for the carbon equivalent.

**Fig. 5** — Calculated TTT diagrams for a variety of alloys. Each diagram consists of two C-curves, the higher temperature one representing reconstructive reactions (e.g. $\alpha_f$) and the lower curve, displacive transformations ($\alpha_o$, $\alpha_p$).

**Fig. 6** — $A$ — Calculated growth rate of $\alpha_f$. $B$ — poor correlation between volume fraction and growth rate of Widmanstätten ferrite.

**Yield Strength**

For an individual phase, the strength can be factorized into a number of intrinsic components (Ref. 12).

$$\sigma = \sigma_{Fe} + \sum_i x_i \sigma_{si} + x_i \sigma_{C} + K_L(L)^{0.5}$$  

where $x_i$ is the concentration of a substitutional solute which is represented here by a subscript $i$. The other terms in this equation can be listed as follows:

- $K_{Fe}$ strengthening due to grain size, $115 \text{ MN m}^{-1}$
- $K_{D}$ dislocation strengthening, $7.34 \times 10^{-6} \text{ MN m}^{-1}$
- $\sigma_{Fe}^0$ pure, annealed Fe, $219 \text{ MN m}^{-2}$ at $300 \text{ K}$
- $\sigma_{si}$ substitutional solute ($i$) strengthening
- $\sigma_{C}$ solid solution strengthening due to carbon
Complex Properties

The fabrication of useful devices and structures is based on more than just the strength. Properties such as fatigue, toughness, stress-corrosion resistance, creep resistance, etc. are routine considerations in the design process (Ref. 13). These properties are "complex" in the sense that they can be measured and used in design but cannot be predicted. There is no theory that has the rigor or sophistication to handle the large number of variables that are known to control such properties.

The conventional way to approach such problems is to apply regression analysis in which experimental data are best-fitted to some function, which is usually linear. The result is an equation in which each of the inputs $x_i$ is multiplied by a weight $w_i$; the sum of all such products and a constant $b$ then gives an estimate of the output $y = \sum w_i x_i + b$. This is precisely how the carbon-equivalent equations are derived.

A neural network is a more general method of regression analysis. As before, the input data $x_i$ are multiplied by weights, but the sum of all these products forms the argument of a hyperbolic tangent (Refs. 14, 15). The output $y$ is therefore a nonlinear function of $x_i$; the function usually chosen being the hyperbolic tangent because of its flexibility. Combining many of these functions increases the available flexibility. A few of the advantages of the network over conventional regression can be listed as follows:

1. There is no need to specify a function to which the data are to be fitted. The function is an outcome of the process of creating a network.
2. The network is able to capture almost arbitrarily nonlinear relationships.
3. With Bayesian methods, it is possible to estimate the uncertainty of extrapolation.

We shall now discuss these last two points in detail. The complexity and flexibility of the relationship that can be cre-
Fig. 10 — Two functions that exactly match the experimental data (2, 4, 6) extrapolate differently.

Fig. 11 — Recommended paths in the process of alloy development.

The point about extrapolation is illustrated in Fig. 10. The input values 2, 3, and 4 represent experimental data. Both the linear and nonlinear functions exactly represent the experimental data, but make different predictions when it comes to input values 5 and 6, i.e. when the functions are used to extrapolate beyond the experimental data. It is impossible, without physical understanding, to choose between these two.

This could be interpreted as a crisis, but instead, the difference in the predicted values can be taken as an indication of the uncertainty of extrapolation. This uncertainty arises because the functions representing the data extrapolate differently. It is extremely useful to have this indication of uncertainty when dealing with nonlinear functions that are not physically based. MacKay's work has been seminal in expressing neural networks in a Bayesian framework so that the modeling uncertainties become transparent (Ref. 16).

There are examples where neural networks, in combination with microstructural calculations and experience, have short-circuited the development of welding alloys. A number of these cases are documented in the series of books on the Mathematical Modelling of Weld Phenomena I-VII. One desirable feature of the network models is that they are readily updated as more experimental data become available. This is often paraphrased by saying that the models continue to learn and extend their knowledge base.

Proposal for Alloy Development Procedures

Mathematical models of welding will never replace experiments — the problem is too complicated to deal with. There is no doubt, however, that so much tremendous progress has been made that it can justifiably be argued that the process of welding consumable design should begin with calculations in the manner summarized in Fig. 11.

Once the need for the development of a new alloy is identified and design requirements have been formulated, the first step should be an attempt at calculations. There is a plethora of freely accessible software that can be used for this purpose. If a convincing theoretical solution emerges, a critical experiment can be designed in which a consumable is manufactured and tested.

There are circumstances where the calculations will look reasonable but the uncertainties (error bars) associated with the outcomes are large. A series of carefully designed experiments can be implemented to resolve the uncertainties. It would be of long-term benefit to the community if the data associated with these experiments are published so that the models can be modified for greater reliability.

If, at the decision stage (Fig. 11), calculations are impossible because the appropriate models do not exist (for example, creep-fatigue theory), it is justified to conduct empirical experiments based on experience.

It will be fascinating to see how alloy design progresses over the next few years, whether the practitioners are courageous enough to try using models and whether those who develop models have the appreciation necessary to recognize the complexity of welding. The models discussed here are freely available on
Finally, it should be emphasized that much of this work would not have been possible without the enormous amount of experimental work and contributions to understanding from a large number of people involved in the subject. References to that work are listed in Refs. 1-14. I apologize that it is not possible to present them in this short article.

Acknowledgments

I am immensely grateful to the American Welding Society for the opportunity to present this lecture and to many colleagues in industry and academia who have helped my career in welding metallurgy.

References


Preparation of Manuscripts for Submission to the Welding Journal Research Supplement

All authors should address themselves to the following questions when writing papers for submission to the Welding Research Supplement:

- Why was the work done?
- What was done?
- What was found?
- What is the significance of your results?
- What are your most important conclusions?

With those questions in mind, most authors can logically organize their material along the following lines, using suitable headings and subheadings to divide the paper.

1) **Abstract.** A concise summary of the major elements of the presentation, not exceeding 200 words, to help the reader decide if the information is for him or her.

2) **Introduction.** A short statement giving relevant background, purpose, and scope to help orient the reader. Do not duplicate the abstract.

3) **Experimental Procedure, Materials, Equipment.**

4) **Results, Discussion.** The facts or data obtained and their evaluation.

5) **Conclusion.** An evaluation and interpretation of your results. Most often, this is what the readers remember.

6) **Acknowledgment, References and Appendix.**

Keep in mind that proper use of terms, abbreviations, and symbols are important considerations in presenting a manuscript for publication. For welding terminology, the Welding Journal adheres to AWS A3.0:2001, Standard Welding Terms and Definitions.

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Direct Observations of Austenite, Bainite, and Martensite Formation during Arc Welding of 1045 Steel Using Time-Resolved X-ray Diffraction

J. W. ELMER, T. A. PALMER, S. S. BABU, W. ZHANG, AND T. DEBROY

ABSTRACT. In-situ time-resolved X-ray diffraction (TRXRD) experiments were performed during stationary gas tungsten arc (GTA) welding of AISI 1045 C-Mn steel. These real-time synchrotron-based experiments tracked phase transformations in the heat-affected zone of the weld under rapid heating and cooling conditions. The diffraction patterns were recorded at 100 ms intervals, and were later analyzed using diffraction peak profile analysis to determine the relative fraction of ferrite (α) and austenite (γ) phases in each diffraction pattern. Lattice parameters and diffraction peak widths were also measured throughout the heating and cooling cycle of the weld, providing additional information about the phases that were formed. The experimental results were coupled with temperatures calculated by a thermo-fluids weld model, allowing the transformation kinetics of the α-γ phase transformation to be evaluated. During heating, complete austenitization was observed in the heat-affected zone of the weld, and the kinetics of the α-γ phase transformation were modeled using a Johnson-Mehl-Avrami (JMA) approach. The results from the 1045 steel weld were compared to those of a 1005 low-carbon steel from a previous study. Differences in austenitization rates of the two steels were attributed to differences in the base metal microstructures, particularly the relative amounts of pearlite and the extent of the allotriomorphic ferrite phase. During weld cooling, the austenite transformed to a mixture of bainite and martensite. In situ diffraction was able to distinguish between these two nonequilibrium phases based on differences in their lattice parameters, diffraction peak widths, and their transformation rates, resulting in the first real-time X-ray diffraction observations of bainite and martensite formation made during welding.

Introduction

Transformations between the body-centered cubic (BCC) form of iron (α-ferrite) and the face-centered cubic (FCC) form of iron (γ-austenite) during heating and cooling are principally responsible for the microstructure and properties of steels. These transformations have been studied in great detail for many decades to establish optimum thermal-mechanical processing treatments for a wide variety of steels (Refs. 1-3). However, when steels are welded, the optimized base metal microstructures are altered by the localized weld thermal cycles. The result is the creation of nonequilibrium microstructures in the weld fusion zone (FZ) and heat-affected zone (HAZ). These microstructures are significantly different in both appearance and properties from those found in the base metal (Refs. 4-6). Such nonequilibrium phases can compromise the integrity of the weld joint, making it important to understand how the welding conditions lead to their creation.

In widely used C-Mn steels, the carbon content of the steel plays an important role in the microstructural evolution of the weld. As the carbon content increases, welding-induced changes in the microstructure become more pronounced due to the nonuniform distribution of carbon in the microstructure. These changes are most prominent during the rapid weld cooling, which further intensifies these effects, resulting in microstructures that deviate significantly from equilibrium. The mechanisms responsible for these transformations are well known (Refs. 4-6); however, few direct observations of the transformation sequence have been reported.

Previous investigations of low-carbon steel containing 0.05 wt-% C served as a baseline for the experiments on the medium-carbon 1045 steel presented here. The earlier work on low-carbon steel was performed in situ using synchrotron radiation under both spatially resolved (Refs. 7, 8) and time-resolved experimental conditions (Ref. 9). Kinetic parameters were determined, allowing the prediction of the α-γ transformation during welding of the low-carbon steel to be made (Ref. 8). In this investigation, a medium-carbon steel containing 0.46 wt-% C was rapidly heated and cooled during stationary arc welding. During welding, synchrotron radiation was used to track the phase transformations that occurred in the HAZ of the weld. These experiments produced a series of X-ray diffraction patterns revealing the real-time crystal structure of the weld. Results of these observations showed complete austenitization of the initial microstructure during rapid weld heating, and subsequent transformations during rapid weld cooling. Quantitative information about the phase transformation kinetics was extracted from these data through thermal and phase transformation modeling. These results were compared to those of the low-
Carbon steel to better understand the influence of carbon content on phase transformations that occur during the welding of steel.

Differences in the phase transformation behavior of the low- and medium-carbon steels were apparent. During heating, the kinetics of the α→γ transformation showed that the 1045 steel initially transformed at a higher rate than the 1005 steel but then slowed down, eventually requiring more time to transform than the 1005 steel. This difference was associated with the microstructures of the two steels. During cooling, the high rates produced during the stationary arc spot welding technique used in the TRXRD experiments proved to be rapid enough to produce a combination of bainite (nonlamellar ferrite plus Fe₃C) and martensite (interstitial carbon) in the microstructure of the 1045 steel, but these phases were not observed in similar experiments on the low-carbon steels.

The results presented here demonstrate not only differences in the phase transformation behavior between low- and medium-carbon steels, but also how in-situ X-ray diffraction can be used to provide real-time observations of important phase transformations during the welding of steels.

**Experimental Procedures**

**TRXRD Experiments**

Gas tungsten arc (GTA) welds were made on AISI 1045 forged steel bars having the following composition: 0.46 C, 0.85 Mn, 0.27 Si, 0.02 Ni, 0.11 Cr, 0.014 P, 0.01 Cu, 0.02 S, 0.027 Al, 0.001 Nb, 0.01 Mo, 0.005 V; by wt-%. These samples were machined from 10.8-cm-diameter forged bar stock into welding samples. 12.7 cm long and 10.2 cm diameter. Welds were then made on the cylindrical steel bars in an environmentally sealed chamber to avoid atmospheric contamination of the welds. A schematic illustration of the experimental setup is shown in Fig. 1, and a brief summary of the welding parameters used here is given in Table 1. Further details of similar welding experiments have been previously reported for titanium and titanium alloys (Refs. 10, 11), other steels (Ref. 12), and stainless steel alloys (Refs. 13, 14).

In situ TRXRD experiments were performed during welding using the 31-pole wiggler beam line, BL 10-2, at Stanford Synchrotron Radiation Laboratory (SSRL) with SPEAR (Stanford Positron-Electron Accumulation Ring) operating at an electron energy of 3.0 GeV and an injection current of ~100 mA. As illustrated in Fig. 1, a focused monochromatic synchrotron X-ray beam was passed through a 540-mm tungsten pinhole to render a submillimeter beam on the sample at an incident angle of ~25°. This setup yielded a beam flux on the sample of ~10¹² photons/s, which was determined experimentally using an ion chamber immediately downstream from the pinhole. A photon energy of 12.0 keV (λ = 0.1033 mm) was chosen to facilitate phase identification and to be far enough in energy above the Fe K-edge (7.112 keV) to minimize the background contribution due to Fe K-fluorescence from the steel sample.

X-ray diffraction patterns were recorded using a 50-mm-long 2048-element position-sensitive Si photodiode array detector. The array was mounted on a dual-stage water-cooled Peltier-effect thermoelectric cooler at a distance of approximately 10 cm behind the weld to cover a 29 range from 22 to 52 deg. This 29 range was optimized to contain a total of six diffraction peaks, three from the BCC phase (α-Fe) and three from the FCC phase (γ-Fe). Calibration of the X-ray diffraction patterns was performed using a thin niobium foil, which has a well-characterized BCC crystal structure.

Analysis of each peak in every diffraction pattern was performed to determine the semiquantitative volume fractions of ferrite and austenite present as a function of welding time. This analysis measured the integrated intensity of each peak using a sum of one or more Gaussian profile-fitting functions using an automated curve-fitting routine developed in Igor Pro®. Version 4.0 (Ref. 14). The raw integrated intensities of the diffraction peaks were then converted into phase fractions by dividing the integrated peak area for

**Fig. 1** -- Schematic diagram of the TRXRD experimental setup for synchrotron-based in situ observations of phase transformations during welding.

**Table 1** -- Summary of GTA Welding Parameters Used in the TRXRD Experiments

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Welding electrode</td>
<td>W (2% Th)</td>
</tr>
<tr>
<td>Electrode diameter</td>
<td>4.7 mm</td>
</tr>
<tr>
<td>Torch polarity</td>
<td>DCEN</td>
</tr>
<tr>
<td>Maximum current</td>
<td>175 A</td>
</tr>
<tr>
<td>Background current</td>
<td>131 A</td>
</tr>
<tr>
<td>Pulsing frequency</td>
<td>300 Hz</td>
</tr>
<tr>
<td>Peak on time</td>
<td>50%</td>
</tr>
<tr>
<td>Shielding gas</td>
<td>helium</td>
</tr>
<tr>
<td>Arc on time</td>
<td>17 s</td>
</tr>
<tr>
<td>Resulting fusion</td>
<td>9.9 ± 0.66 mm</td>
</tr>
</tbody>
</table>

**Fig. 2** -- Calculated pseudo-binary phase diagram for the AISI 1045 steel. The nominal carbon concentration of the alloy is indicated as the vertical dashed line.
the BCC phase by the total integrated areas of the BCC and FCC phases. The fraction of the FCC phase was then determined as the difference between unity and the BCC fraction, since only two phases were observed in this system.

Phase Equilibria and Base Metal Microstructure

The phase transformation sequence in the 1045 steel was calculated from thermodynamic relationships using ThermoCalc and the Fe2000 database (Ref. 15). These calculations were used to determine the transformation temperatures for the AISI 1045 steel by considering the effects of Fe, C, Si, Mn, Ni, and Cr on the liquid, ferrite, austenite, and cementite phase fields. The calculated phase-boundary temperatures for this multicomponent alloy are illustrated in the pseudo-binary diagram shown in Fig. 2. In this figure, the vertical dashed line indicates the nominal carbon content of the alloy.

The thermodynamic calculations indicate that the equilibrium starting microstructure of this alloy consists of a mixture of ferrite and Fe3C carbide phases. During heating, this microstructure begins to transform to austenite when the A1 temperature of 712°C is reached. Complete transformation to austenite occurs when the A3 temperature of 765°C is reached, and this austenite remains stable until melting begins to occur at 1410°C. These transformations reverse during cooling; however, kinetic limitations may alter the predicted phase transformation start and completion temperatures, and may produce nonequilibrium phases.

The starting microstructure of the 1045 steel is shown in Fig. 3A as revealed by polishing the base metal and etching in a 2% nital (nitric acid and alcohol) solution. This microstructure contains allotriomorphic ferrite, which is the light etching phase that outlines the prior austenite grain boundaries. Inside the prior austenite grains, the microstructure consists of pearlitic colonies, which etch dark and occupy the majority of the microstructure. A higher magnification micrograph highlighting the lamellar structure of the pearlite is shown in Fig. 3B. Quantitative metallography was performed on this microstructure using Image Pro®, Version 4.1. Measurements of the area fraction of allotriomorphic ferrite made at several locations indicate that the microstructure contains 12% allotriomorphic ferrite and 88% pearlite. The prior austenite grain size of the base metal was measured to be 92.8 μm in diameter. In addition, the size of the allotriomorphic grain boundary ferrite phase was shown to be 15 to 20 μm wide on average, with some patches reaching 30 μm or more in places.

Coupled Thermal-Fluids Numerical Modeling of Weld Temperatures

The TRXRD experimental results provide information about phase transformations as a function of weld time, but do not directly provide information about weld temperatures. In order to relate weld time to weld temperature, a numerical model was used, since transient weld temperatures are difficult to measure accurately. The weld model employed here is a well-tested 3-D numerical heat transfer and fluid flow model, which is described in detail in Ref. 16. The calculations are made in a fixed Cartesian coordinate system and take into account the electromagnetic, surface tension gradient, and buoyancy driving forces present in the transient weld pool convection (Ref. 16).

It should be noted that a common practice in the calculation of weld temperatures for linear welding is to use a constant arc efficiency to represent the amount of arc energy that transfers into the workpiece. This is a reasonable assumption, since the temperature field attains quasi-steady state soon after the start of welding. In contrast, for spot welding, temperatures change continuously and it takes several seconds for the arc to stabilize. In view of the lack of data on arc efficiency in the literature, a variable arc efficiency, which increases linearly from 0 to 75% in the first 3 s, is used to take into account the arc instabilities.

The thermo-physical properties used to represent the 1045 steel alloy in the calculations are given in Table 2 (Ref. 17). Since the 1045 steel contains 0.02 wt-% sulfur, the effect of sulfur on changing the surface tension is also included. In addition, at the weld top surface, the heat loss due to the helium shielding gas is considered by using Newton's law of cooling with an appropriate heat transfer coefficient, as described in a previous paper (Ref. 18).

For computational accuracy, the numerical model used a very fine grid system consisting of 108 x 54 x 59 grid points, and the corresponding computational domain had dimensions of 140 mm long, 70 mm wide, and 50 mm deep. Spatially nonuniform grids were used for maximum resolution of the variables. Finer grids were used near the heat source where the temperature gradients are the highest. The minimum grid spacing along the x and z directions were about 20 μm and 5 μm, respectively. Small time steps of 0.01 s were further required to track the weld pool size and shape under the high heating and cooling rates produced under the transient welding conditions (Ref. 16).

The cross-sectional shape of the calculated weld pool at its maximum size matched the experimental weld cross-sec
Table 2 — Summary of the Thermophysical Data for 1045 Steel Used in the Coupled Thermal Fluids Model to Predict Weld Temperatures

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquidus temperature, ( T_L )</td>
<td>1788 K</td>
</tr>
<tr>
<td>Solidus temperature, ( T_S )</td>
<td>1713 K</td>
</tr>
<tr>
<td>Density of liquid metal, ( \rho )</td>
<td>7.7 x 10^3 kg/m^3</td>
</tr>
<tr>
<td>Effective viscosity of liquid, ( \mu )</td>
<td>1.16 kg/m-s</td>
</tr>
<tr>
<td>Effective thermal conductivity of liquid, ( k_L )</td>
<td>335 W/m.K</td>
</tr>
<tr>
<td>Thermal conductivity of solid, ( k_S )</td>
<td>36.4 W/m.K</td>
</tr>
<tr>
<td>Specific heat of solid, ( C_p_S )</td>
<td>536 J/kg.K</td>
</tr>
<tr>
<td>Specific heat of liquid, ( C_p_L )</td>
<td>746 J/kg.K</td>
</tr>
<tr>
<td>Temperature coefficient of surface tension, ( \frac{d\gamma}{dT} )</td>
<td>-4.3 x 10^{-2} N/m.K</td>
</tr>
<tr>
<td>Coefficient of thermal expansion</td>
<td>1.51 x 10^{-5} K^{-1}</td>
</tr>
<tr>
<td>Convective heat transfer coefficient top surface</td>
<td>1.59 x 10^{3} W/m^2.K</td>
</tr>
</tbody>
</table>

Table 3 — Summary of JMA Modeling Results on 1045 Steel, and Comparison with Previous Data on 1005 Steel.

<table>
<thead>
<tr>
<th>Steel Type</th>
<th>( Q ) (kJ/mole)</th>
<th>( n )</th>
<th>( \ln(k_0) )</th>
<th>( E_{avg} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>AISI 1045 steel with</td>
<td>117.1</td>
<td>0.95</td>
<td>11.4</td>
<td>0.049</td>
</tr>
<tr>
<td>thermal cycle at ( R = 4.75 ) mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AISI 1045 steel</td>
<td>117.1</td>
<td>0.82</td>
<td>12.2</td>
<td>0.052</td>
</tr>
<tr>
<td>with thermal cycle at ( R = 5.0 ) mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AISI 1045 steel</td>
<td>117.1</td>
<td>0.60</td>
<td>13.4</td>
<td>0.075</td>
</tr>
<tr>
<td>with thermal cycle at ( R = 5.25 ) mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AISI 1045 steel</td>
<td>117.1</td>
<td>1.45</td>
<td>12.3</td>
<td>0.099</td>
</tr>
<tr>
<td>with thermal cycle at ( R = 5.0 ) mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: The activation energy for the diffusion of carbon in austenite was held constant, and the JMA parameters \( n \) and \( \ln(k_0) \) were calculated from TRXRD experimental data in all cases. The average error \( E_{avg} \) is defined as \( \sqrt{Q^2/Q^2} \), and the bold-faced values correspond to the recommended parameters for the two steels.

Results

The TRXRD experiments were taken at a single location in the HAZ of the 1045 steel bar during welding. In situ diffraction patterns were recorded over a sufficient amount of time so that the entire heating and cooling cycle of the weld could be captured. These data are summarized in Fig. 4, where the diffraction patterns are displayed in a pseudo-color format. In this figure, the baseline diffraction data are shown for several seconds before the arc was turned on, for 17 s during the time when the arc was on, and for an additional 20 s of cooling time. Here, the higher peak intensities are indicated by the light tones, and lower peak intensities are indicated by dark tones, so that the diffraction peaks appear as streaks along the time axis at their appropriate \( 2\theta \) locations over the range of times. Six diffraction peaks appear in Fig. 4. From low to high \( 2\theta \) values, these peaks correspond to the FCC(111), BCC(110), FCC(200), BCC(200), FCC(220), and BCC(211), as indicated by the calculated diffraction pattern shown in Fig. 5.

Only three peaks corresponding to the BCC phase are present before the arc is initiated. After the arc is turned on, these three peaks rapidly shift to lower \( 2\theta \) values due to the lattice expansion effect caused by weld heating. With continued heating, three new peaks, corresponding to the FCC phase, appear. All six peaks existed for several seconds before the BCC peaks began to fade in intensity, leaving only the FCC diffraction peaks. The FCC peaks are then stable until the arc is extinguished at \( t = 17 \) s, after which the FCC peaks rapidly shift to higher \( 2\theta \) values due to the cooling process.
to the lattice contraction effect as the weld cools. After an additional 1.5 s of cooling time, the BCC peaks reappear and increase in intensity as the weld cools.

In Fig. 4, there is a wealth of information about the phases that exist at all times during the welding cycle; for example, information about the lattice parameters of each phase and how they change with welding time, plus other information such as the width, intensity, and areas of each of the diffraction peaks during the welding cycle. These additional data can be determined through individual peak profile analysis, and based on a portion of these data, the volume fraction of each phase during welding can be semiquantitatively estimated to provide other clues about the phase transformations taking place during welding.

The most important data gathered from the peak profile analysis are the relative fractions of the BCC and FCC phases present throughout both the heating and cooling cycles. These data are plotted in Fig. 6, showing that the alloy investigated starts out fully ferritic, then at \( t=3.6 \) s, begins to transform to austenite. The transformation takes 3.6 s to go to completion under the increasing temperature of the welding arc. The austenite phase is stable until the arc is turned off at \( t=17.0 \) s, and then continues to be the only phase for an additional 1.5 s while the weld cools. The BCC phase then appears at \( t=18.5 \) s, and continues to increase in amount as the FCC → BCC transformation proceeds. At the end of the experiment, the transformation appears incomplete, leaving some untransformed FCC at this point during weld cooling.

The lattice parameters of each phase can be determined from the 20 positions of the diffraction peaks using Bragg's law and the energy of the X-ray beam (Ref. 19). The results are plotted in Fig. 7, showing the lattice parameters of the BCC and FCC phases as a function of welding time. The lattice parameter of the BCC phase at room temperature was measured to be 2.901 Å, and increases rapidly to 2.925 Å during the initial heating cycle of the weld. The austenite phase first appears at \( t=3.4 \) s, when the ferrite lattice parameter was measured to be 2.923 Å. The lattice parameter of the FCC phase increases with welding time until the arc was turned off, then decreases rapidly during weld cooling. The BCC phase reappears during weld cooling at \( t=18.5 \) s where it has a lattice parameter of 2.914 Å. The lattice parameter of the FCC phase then decreases until \( t=20.8 \) s where it unexpectedly increases from 2.906 Å to 2.908 Å before continuing to decrease again, as the weld cools.

The widths of the diffraction peaks are plotted in Fig. 8 for the BCC(110) and FCC(111) phases. Both phases show similar trends during welding, whereby the peak widths decrease during heating and increase during cooling. The results show that the width of the FCC(110) peak is 0.14 deg in the starting condition and decreases to 0.04 deg just before it disappears at \( t=7.2 \) s. When the austenite peaks first appear, at \( t=3.4 \) s, the peak widths are about twice as wide as they are just before the arc is extinguished. The decrease in peak width with increasing temperature is caused by annealing, which creates more perfect diffraction conditions at higher temperatures. These phenomena have been observed in similar TRXRD experiments on other materials systems (Refs. 11, 14). Once the arc is extinguished, the rapid weld cooling causes the widths of the peaks to increase. The results show that the BCC peak widths increase more during welding than during heating, suggesting that the rapid weld cooling has led to the creation of a different BCC phase after welding than before.

**Discussion**

\( \alpha \rightarrow \gamma \) Phase Transformation on Heating

The TRXRD results presented above provide information about the relative fractions of the BCC and FCC phases, their lattice parameters, and the widths of their diffraction peaks as a function of weld heating and cooling time. Included in these results is information related to the kinetics and types of phase transformations occurring in the HAZ during welding. Modeling of the experimentally measured transformation rates will be used to better understand the mechanisms behind each transformation and to develop parameters useful in the prediction of phase transformations.

It is known that the transformation of the pearlitic microstructure (ferrite and cementite) to austenite during heating is controlled by carbon diffusion in austenite (Ref. 20). In the experiments performed here, transformation of the microstructure during heating was shown to occur rapidly due to the high heating rate of the weld. Assuming the transformation is controlled by the diffusion of carbon in austenite, the kinetics of this transformation can be modeled by the Johnson-Mehl-Avrami (JMA) method (Refs. 4, 21). This approach has been used in a sim-
Fig. 8 — TRXRD measurements of the diffraction peak width of the BCC and FCC phases as a function of welding time.

Fig. 9 — Calculated weld temperature at the X-ray beam location, 5.0 mm, and two adjacent locations. The open circle and triangle represent the times where the TRXRD measurements observed the start and finish of the transformation to austenite on heating, while the open square represents the first observation of the BCC phase on cooling.

The JMA approach is represented by the following expression (Ref. 21):

\[ f_i(t) = 1 - \exp\left( -\left(kt\right)^n \right) \]  

where \( f_i(t) \) is the extent of the transformation at a given time \( t \), \( n \) is the JMA exponent, and \( k \) is a rate constant given as

\[ k = k_0 \exp\left( -\frac{Q}{RT} \right) \]

where \( k_0 \) is a pre-exponential constant, \( Q \) is the activation energy of the transformation which includes the driving forces for both nucleation and growth, \( R \) is the gas constant, and \( T \) is the absolute temperature. By knowing the time-temperature profile of the weld, the three JMA parameters can be used to calculate the transformation rate.

Although the activation energy of phase transformations occurring under isothermal conditions is often known, the overall activation energy under non-isothermal welding conditions, in which nucleation and growth are operating simultaneously, is rarely known. The addition of the nucleation stage complicates the calculations because nucleation is both temperature and rate dependent and is influenced by the starting microstructure (Refs. 4, 21). Thus, a unique activation energy for the overall transformation is not always possible to determine. However, if a given transformation has a large growth component, it may be treated as a growth-controlled mechanism, and the activation energy for growth provides a reasonable starting assumption.

The results of the thermal model are shown in Fig. 9, which plots the calculated weld temperature vs. weld time at locations 4.75, 5.0, and 5.5 mm from the weld center. The 5.0 mm location is in the weld HAZ and corresponds to the position of the X-ray beam during the TRXRD experiment. Superimposed on this plot are the A1 and A3 temperatures and three symbols. The open circle and triangle represent the times when the start and finish of the transformation to austenite on heating, respectively, are observed. The open square represents the first observation of the BCC phase on cooling. It is clear that superheating above the A3 temperature is required to complete the \( \alpha \rightarrow \gamma \) transformation on heating, and that significant undercooling is required below the A1 temperature to initiate the \( \alpha \rightarrow \gamma \) transformation.

Using the calculated time-temperature profile of the weld, Equations 1 and 2 were discretized and numerically integrated over the heating portion of the weld. This procedure was previously developed to calculate the degree of transformation in the two-phase field between the A1 and A3 temperatures of a 1005 C-Mn steel (Ref. 8). In these calculations, the TRXRD data were fit using the JMA parameters \( (n, k_0, Q) \) by selecting one of the JMA parameters and calculating the remaining two using a numerical optimization routine (Ref. 8). The equilibrium start and completion temperatures for the \( \alpha \rightarrow \gamma \) transformation used in the calculation are 712° and 765°C, respectively, as determined by ThermoCalc®. The equilibrium fraction of \( \gamma \) in the \( \alpha + \gamma \) two-phase region was determined from the phase diagram as a function of temperature.

The best-fit JMA parameters were then calculated from the TRXRD experimental data. An activation energy for the diffusion of carbon in austenite was assumed to represent the \( \alpha \rightarrow \gamma \) transformation. With a value of \( Q = 117.1 \text{ kJ/mole} \) (Ref. 8), a numerical fitting routine was used to determine the minimum error between the JMA fitting calculations and the experimentally determined austenite fraction as a function of \( \ln(k_0) \) and \( n \). The error \( (E_{\text{fit}}) \) between the two is defined by Equation 3:

\[ E_{\text{fit}} = \sum_{i=1}^{N} \left( f_i^m - f_i^c \right)^2 \]

where \( N \) is the total number of measured data points, and \( f_i^m \) and \( f_i^c \) are the measured and calculated \( \gamma \) fractions at the \( i^{th} \) data point, respectively. A total of 37 TRXRD data points were used in the calculation, and the optimization results are plotted in Fig. 10, showing that the optimal JMA values are \( n = 0.82 \) and \( \ln(k_0) = 12.3 \). Figure 11 compares the calculated and measured fractions of austenite as a function of time. The correlation is excel-
lent, showing that the JMA best fit to the experimental results adequately represents the data throughout the entire transformation range.

It should be noted that the above JMA kinetic parameters were calculated using the computed temperature vs. time data at X = 5.0 mm. There is good agreement between the TRXRD observations of the first formation of austenite and the calculated A1 temperature at this location. Although the distance from a monitoring location to the weld center is exact in the numerical calculation, there are certain errors in the spatial accuracy of the experimental TRXRD data. For the present TRXRD experiments, the uncertainty in the monitoring location of the beam is about ±0.25 mm. As shown in Fig. 11, the calculated temperatures for this uncertainty of ±0.25 mm in the monitoring location results in an uncertainty of ±0.7 K in the computed temperatures. This in turn contributes to uncertainties in the transformation kinetics.

To determine how much the temperature uncertainties affect the kinetic results, the optimization procedure described previously was used to calculate the JMA kinetic parameters for each of the three thermal cycles shown in Fig. 9. Table 3 summarizes these results, showing that the correlation for all three thermal cycles is reasonable. Due to the uncertainty in the monitoring location, the uncertainties in the values of n and ln(k₀) were calculated to be about ±0.2 and ±1.0, respectively. Due to the lack of kinetic data in the literature, the calculated JMA kinetic parameters cannot be further verified, and the lack of available data emphasizes the need for additional quantitative investigations on this topic.

A similar set of JMA parameters was developed in an earlier study for 1005 (0.05 wt-% C) (Ref. 8). The JMA kinetic parameters determined for this steel were n = 1.45 and ln(k₀) = 12.2, for an assumed activation energy (Q) of 117.1 kJ/mole. The JMA parameters determined for the 1005 steel were then used to compare transformation rates between 1005 steel and 1045 steel. To do this, the JMA parameters for the 1005 steel were used to predict the fraction austenite for the same time-temperature profile calculated for the 1045 steel weld in this investigation. The results are superimposed on the 1045 steel results in Fig. 11, where the dashed line represents the predicted transformation for 1005 steel, and the solid line for the 1045 steel. Even though the two curves start and finish at approximately the same times, there are some differences. For example, the transformation rate of the 1045 steel is initially somewhat higher than that of the 1005 steel, but slows down to values less than that of the 1005 steel. At approximately 5.5 s after the arc was initiated, the total fraction transformed in each steel is approximately the same (0.75). The higher transformation rate of the 1005 steel at this point allows it to complete the transformation to austenite approximately 1 s sooner than that of the 1045 steel.

There are several possible reasons for the differences in the transformation rates for the two steels. First, the different carbon contents of the two steels resulted in different starting microstructures. The principal microstructural difference is the amount of pearlite in each. In the 1005 steel, which contained less than 10% pearlite, small pearlite colonies were isolated along the ferrite grain boundaries. In the 1045 steel, which contained 88% pearlite, the pearlite occupied the majority of the microstructure, leaving a relatively small amount of allotriomorphic ferrite at the prior austenite grain boundaries. The second microstructural difference between the two steels was the starting grain size. Both steels contained equiaxed grains; however, the grain size of the 1045 steel was 92.8 μm, which is more than four times larger than that of the 1005 steel, which had a base metal grain size of only 21.5 μm.

The differences in starting grain size and amount of pearlite between the 1005 and 1045 steels lead to different transformation rates between the two steels. Since the austenite nucleation rate is higher in pearlite than in ferrite, due to its fine dispersion of cementite in the lamellar pearlitic structure, one would expect that the 1045 steel, which has the higher fraction of pearlite, would transform to austenite more quickly than the 1005 steel. However, the 1045 steel transforms more rapidly only during the early stages of the transformation, up to an austenite fraction of approximately 0.75. Thus, other factors are coming in to play that reduce the overall transformation rate of the 1045 steel relative to that of the 1005 steel as the transformation continues.

The other significant difference between the two steels was the starting grain size, which is four times larger for the 1045 steel than for the 1005 steel. It is known that the transformation rate of diffusion-controlled reactions will decrease as the grain size gets larger (Refs. 4, 21) because diffusion is required to take place over larger distances to complete the transformation in the larger grain sized materials. In the 1045 steel, the large amount of pearlite helps to offset the grain size difference by providing numerous nucleation sites within the pearlite. However, the large grain size of the allotriomorphic fer-
rite regions in the 1045 steel has an indirect effect on the transformation rate. These large ferrite regions should be the last portion of the 1045 steel microstructure to transform and, as such, will control the total amount of time required to completely austenitize the microstructure. Since the allotriomorphic patches in the 1045 steel exceeded 30 μm in places, one might expect that the total time required to transform the 1045 steel would be longer than that of the 1005 steel, which had an average grain size of 21.5 μm.

Therefore, the JMA kinetic analysis of the TRXRD data adequately describes the α→γ transformation kinetics of the 1045 steel, providing a quantitative means for predicting austenite formation in the HAZ of similar carbon content steel welds. Comparisons between the α→γ transformation kinetics of the 1045 steel and 1005 steel illustrated how the carbon content affects the transformation rate through its effect on the starting microstructure of the base metal. Additional work is planned to look at even higher carbon steel welds in order to further extend these observations.

γ→α Phase Transformation on Cooling

The cooling transformations in steel can be more complicated than the heating transformations because of the potential formation of nonequilibrium phases at high cooling rates. It is already known that diffusion-dependent transformations, such as the formation of pearlite, a lamellar microstructure of alternating ferrite and cementite phases, occur at low cooling rates (Ref. 3). As the cooling rate increases, diffusion of carbon may not be rapid enough to allow the lamellar pearlite microstructure to form. Shear-type transformations thus begin to dominate at these higher cooling rates. For example, bainite, which is characterized by a microstructure of mixed ferrite and cementite with non-lamellar features, forms through a combination of diffusion and shear at intermediate cooling rates (Ref. 3). Martensite, on the other hand, forms entirely by a shear mechanism and only at high cooling rates, producing a microstructure containing lath or plate-like characteristics with the carbon trapped in interstitial sites of the crystal lattice (Ref. 3).

The formation of bainite and martensite cannot be described by the equilibrium phase diagram presented in Fig. 2, since these transformations occur under nonequilibrium conditions. However, one can use calculated continuous cooling transformation (CCT) diagrams to provide information about microstructural evolution during continuous cooling. In this work, we used the model developed by Bhadeshia et al. (Refs. 22, 23), to predict the continuous cooling transformation diagram for the AISI 1045 steel - Fig. 12. The diagram was constructed from time-temperature-transformation (TTT) data calculated from paraequilibrium thermodynamics of the α→γ transformation by using the additivity rule (Ref. 24), and predicts the onset of the different transformations that can occur during cooling. The CCT diagram overlaid with three different cooling curves, one predicted by the heat transfer model is needed to avoid the formation of ferrite + pearlite microstructure. Moreover, a maximum cooling rate of 60°C/s is needed to avoid the formation of martensite. The bainite start temperature for this steel is predicted to be 485°C, and martensite start temperature is predicted to be 324°C. Both temperatures are far below the equilibrium A1 temperature. The predicted cooling rate by the heat transfer model is higher than 60°C/s and therefore a predominantly martensitic microstructure is expected in the final microstructure.

Figure 13 shows the results of TRXRD experiments on cooling for the FCC(111) and the BCC(110) diffraction peaks. As soon as the arc is extinguished, the FCC(111) peak rapidly shifts to higher 2θ values due to the lattice contraction effect. At t = 18.6 s, the BCC(110) peak first appears and has a relatively narrow peak width. This peak shifts to higher 2θ as the weld continues to cool and increases in intensity. At t = 20.8 s, both the BCC(110) and the FCC(111) peaks show a sudden increase in width. The wider BCC(110) peak exists throughout the remainder of the experiment, with the CCTRD peak width at low temperatures being observed in similar experiments performed on a low-carbon AISI 1005 steel (Refs. 7-9). The increase in peak width is caused by strain in the lattice, i.e., the opposite of the annealing effect and/or changes in the composition or crystal structure. The formation of martensite would explain the rapid broadening of the diffraction peaks since its formation would trap carbon in the BCC lattice. This would both strain the lattice and create changes in the lattice parameter through the formation of a body-centered tetragonal (BCT) crystal structure. The
strain induced by the martensite would also explain similar changes in the broadening of the austenite peaks that occurred at the same time.

In order to determine if the martensitic transformation is responsible for the peak broadening, the area fractions of the FCC(111) and BCC(110) peaks were measured from the TRXRD data to determine the transformation rate during weld cooling. These results are plotted vs. weld time during cooling in Fig. 14. The fraction of the BCC phases is given by the solid circles in this plot, which shows that the first BCC phase appears at t = 18. The initial rate of increase in the BCC phase is relatively slow, reaching approximately 15% transformed at t = 20.8 s. At this time, the BCC peaks rapidly increase in width, leading to a corresponding increase in the transformation rate. This increase in rate is more than two times higher than that measured up to this point, indicating that there is a change in the transformation mechanism. Such an increase in the transformation rate would not be expected at lower temperatures during weld cooling unless a different kinetic path is taken. The transformation continues as the temperature decreases, achieving approximately 60% transformed at t = 24 s.

A martensitic transformation would explain the change in transformation mechanism at these low temperatures, whereby the γ→α transformation initiated by a bainitic mechanism and switched to a martensitic mechanism at low temperatures. It is important to note that the CCT diagram of Fig. 12 did not predict the initial formation of bainite. However, bainite formation is possible if there was a nonuniform distribution of carbon in the austenite prior to the transformation. This nonuniform distribution of carbon would be possible if the weld HAZ were not completely homogenized during the rapid weld heating and cooling cycle.

Further indications of the martensitic portion of the cooling transformation are provided by changes in the peak widths and lattice parameters. The widening of the peaks, as described above, is consistent with a martensitic transformation, due to its stressed lattice and BCT crystal structure (Ref. 3). In addition, an increase in the lattice parameter of the BCC phase would be consistent with the formation of BCT martensite. Figure 14 also plots the measured lattice parameter as a function of welding time, and combines these data with the fraction of the BCC phase. A decrease in the lattice parameter for the BCC phase is observed during the initial stages of transformation leading up to the change in mechanism at t = 20.8 s. This behavior would be expected if the initial stage of transformation were occurring by either the formation of bainite, since its lattice parameter would decrease as the weld cools. At t = 20.8 s, when the transformation rate increases, there is an increase in the lattice parameter from 2.906 to 2.908 Å. This increase in lattice parameter is qualitatively consistent with the formation of martensite and provides further evidence that the transformation initiating at t = 20.8 s is martensitic.

The temperatures at which these transformations occur also give indications about the mechanisms governing the observed transformations. Figure 9 shows that the first BCC phase appeared at t = 18 s, and that martensite initiated at t = 20.8 s. Using the calculated temperature profile, the martensite initiated at a temperature of 280°C. This temperature is well below the A1 temperature, and is slightly lower than the martensite start temperature of 323°C predicted by the CCT diagram. Thus, this temperature is qualitatively consistent with the formation of martensite.

The temperature where the first BCC phase appeared on cooling at t = 18 s was calculated to be 526°C, which is also well below the A1 temperature of this steel. At this temperature, the cooling rate of the weld was calculated to be 178°C/s, which is fast enough to avoid the formation of pearlite. The calculated CCT diagram shown in Fig. 12 indicates that the nose of the bainite initiation curve occurs at approximately 550°C, which matches well with the TRXRD results of 526°C, and provides further evidence that the transformation from austenite to ferrite is initiated by a bainitic mechanism.

Microstructural observations of the weld HAZ indicate that the final microstructure does indeed contain a mixture of bainite and martensite phases. Figure 15 shows the microstructure of the HAZ at the location where the TRXRD data were obtained. In this microstructure, the prior austenite grain boundaries in the weld HAZ are much smaller than those in the original base metal as a result of the numerous nucleation sites provided within the original pearlite microstructure. No pearlite is present, and grain boundary ferrite is minimal. The bainitic portions of the microstructure appear as the darker etching patches of the microstructure localized at the prior austenite grain boundaries. Within the grains, the microstructure is highly refined, and is characteristic of lath martensite that forms during rapid cooling of medium-carbon steels (Ref. 3). Therefore, the TRXRD results were able to distinguish between martensite and bainite phases based on their transformation rates, lattice parameters, and temperatures where they initiated. Additional experiments are planned on higher-carbon...
steels where the amount of martensite formed will be greater, and where the effect of carbon on the microstructure will be even more apparent.

Conclusions

TRXRD experiments were performed in the HAZ of AISI 1045 steel during stationary arc welding. These experimental observations provided real-time in situ diffraction patterns of the phase transformations occurring during rapid weld heating and cooling.

Diffraction peak profile analysis was used to determine the relative fraction of BCC and FCC phases during the welding cycle, as well as the lattice parameters and diffraction peak widths for each of the phases during the entire weld cycle.

A 3-D transient numerical weld model was used to predict weld temperatures as a function of weld time and location. The model calculated the evolution of the FZ velocity fields and temperatures, and was validated by comparing the predicted and experimentally measured geometry of the FZ.

The TRXRD results and the weld temperatures were used to model the kinetics of the α→γ phase transformation during weld heating of the 1045 steel using a Johnson-Mehl Avrami analysis. The results yielded kinetic parameters for the JMA prediction of the transformation of $n=0.82$ and $\ln(\alpha_p)=12.3$ for an activation energy of $Q=117.1 \text{ kJ/mol}$.

The JMA results of the α→γ phase transformation of the 1045 steel measured here were compared with previously calculated JMA parameters for a low-carbon 1005 steel. Differences between the two steels showed that the initial transformation rate of the 1045 steel is more rapid than that of 1005 steel, but that the transformation rate of the 1045 steel slows down, eventually requiring more time than the 1005 steel to complete the transformation to austenite.

The transformation rates of both steels appear to be controlled by the diffusion of carbon, and were influenced by the relative fraction of pearlite in the starting microstructure and the starting grain size of the steel. The higher fraction of pearlite in the microstructure of the 1045 steel resulted in its high initial transformation rate, but its larger grain size, combined with its large patches of allotriomorphic ferrite, resulted in its longer total transformation time.

During rapid weld cooling, the austenite that formed in the HAZ of the 1045 steel was shown to transform to ferrite with significant undercooling below the A1 temperature. This transformation initiated as a BCC phase with a relatively narrow diffraction peak width at $526^\circ C$, which was shown to be the result of a bainite transformation mechanism.

During continued cooling, the transformation rate suddenly increased twofold, and the BCC diffraction peak width and lattice parameters increased dramatically at a temperature of $280^\circ C$. These effects were attributed to the formation of martensite, which completed the transformation.

These TRXRD experiments represent the first real-time diffraction observations of the formation of bainite and martensite during the welding of steels.

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References

Yttrium Hydrogen Trapping to Manage Hydrogen in HSLA Steel Welds

Hydrogen trapping and welding parameters can be used to reduce hydrogen-assisted cracking

BY C. A. LENISING, Y. D. PARK, I. S. MAROEF, AND D. L. OLSON

ABSTRACT. An investigation of hydrogen trapping and welding parameters for a gas metal arc welding process using hydrogen trap-containing metal cored electrodes was performed on high-strength low-alloy (HSLA) steel. The purpose of this study was to reduce and control the diffusible hydrogen content in the weld deposit and to understand the effects of welding parameters on the diffusible hydrogen content in the weld deposit. Effective control of weld diffusible hydrogen content has been achieved with the use of irreversible hydrogen traps in higher-strength steel weld deposits. The benefit of yttrium as an irreversible hydrogen trap in the weld metal was observed by decreasing the diffusible hydrogen content in the weld metal to appreciable levels around 1-2 mL of hydrogen per 100 g weld deposit. In addition, the weld metal diffusible hydrogen content is affected by variations in welding parameters, including voltage, current, travel speed, and oxygen contents, which in turn affect the heat input and metal transfer mode across the arc. The spray mode provides a more efficient transfer of yttrium to the weld deposit, resulting in less diffusible hydrogen (less than 1 mL/100 g weld deposit) and higher trapped hydrogen in the weld deposit compared to the globular transfer mode.

Introduction

Hydrogen is well known for its deleterious effects on steel weldments, causing cracking to occur, particularly when welding steels with high hardenability. After welding, cracking typically occurs at some temperature below 93°C (366 K), immediately upon cooling or after a period of several hours. This time for cracking depends on the type of steel, the magnitude of the welding stresses, the hydrogen content of the steel weld and the heat-affected zone (HAZ), and service temperature (Ref. 1). Weld metal cracking seldom occurs when the yield strength is below about 90 ksi (620 MPa), and its cracking susceptibility has been reported to be proportional to the yield strength of the weld metal deposit (Ref. 2). The resulting cold cracking problems have been termed hydrogen embrittlement, hydrogen-induced cracking, cold cracking, hydrogen-delayed cracking, or hydrogen-assisted cracking (HAC).

Hydrogen-assisted cracking is the most common cracking problem encountered during the fabrication of welded steel structures (Ref. 3). With the advances in high-strength low-alloy (HSLA) steel processing, cracking has moved from the HAZ to the weld metal. The susceptibility to hydrogen-assisted cracking has been primarily related to the steel composition, microstructure, and temperature (Ref. 4). Current preventive measures such as preweld and/or postweld heat treatment, proper electrode selection and handling, and edge preparation have been used to minimize the hydrogen concentration and stress level (Ref. 3). Through these practices, HSLA steel welds can maintain acceptable levels of hydrogen content as low as 2 mL of hydrogen per 100 g weld deposit. However, these practices require much effort, time, and expense.

For better understanding of HAC for steel weldments, two classifications of hydrogen must be considered. Diffusible hydrogen is the mobile hydrogen that is available for diffusion to the triaxial stress sites and is considered to be potentially harmful for HAC. Residual hydrogen is the hydrogen that is trapped at specific sites in the microstructure, preventing its transport. The prevention or control of diffusible hydrogen in the steel weld metal may reduce the susceptibility to hydrogen cracking.

The source of hydrogen can be reduced by controlling the flux components in flux cored, shielded metal, and submerged arc welding (Refs. 5, 6). The reduction of the activity of hydrogen by fluorides in the weld arc (Ref. 7) is an example of use of proper thermal practice are also known to be very effective. However, with the use of even higher-strength steels, new methods are needed to alleviate diffusible hydrogen from the weld. A new method for hydrogen management, which can help eliminate or reduce current preventive procedures (preheat, joint preparation, etc., to reduce the susceptibility to hydrogen-assisted cracking in HSLA steels), is the introduction of hydrogen traps in the weld. The desired end result is the reduction of diffusible hydrogen to a level that is insufficient to initiate hydrogen cracking, thus reducing the susceptibility to hydrogen-assisted cracking.

It has been reported (Refs. 8–11) that diffusible hydrogen can be suppressed by introducing selected rare earth metal and transition metal additions, as powder ferroadditions, to the weld metal to serve as hydrogen traps. These traps, in the form of oxides or carbonitrides, have high binding energies with hydrogen. A fundamental investigation using neodymium and yttrium as hydrogen-trapping elements in iron and low-carbon steel has been reported by Maroef et al. (Ref. 8). The yttrium resulted in being the most effective trap, due to a higher weld metal recovery than that of neodymium, thus reducing the diffusible hydrogen content by 40% of that of a steel weld made with no yttrium addition. Baune (Ref. 9) investigated the use of cerium fluoride and cerium oxide additions in basic flux cored welding electrodes and showed that cerium fluoride had a slightly better effect in reducing the diffusible hydrogen content than cerium oxide. The cerium fluoride had the advantage of the fluoride reducing the activity of the hydrogen in the weld arc plasma, which may contribute to the decrease in diffusible hydrogen as well as the high reactivity of cerium. However, other characteristics behavior, i.e., arc stability, by the addition of these cerium compounds was not discussed. Pokhodyna (Ref. 10) showed that the diffusible hydrogen content in the weld metal could be reduced by microalloying it with rare earth hydride.
forming elements. The redistribution of the diffusible hydrogen decreased with increasing rare earth content, corresponding to an increase in residual hydrogen content. The oxysulfide form of the rare earth compound was also found to be the trapping inclusion in the steel weld metal alloyed with manganese, nickel, and molybdenum (Ref. 11).

Eberhart (Ref. 12) postulated an orbital model to rationalize the effectiveness of traps in BCC iron. Throughout this model, it was argued that the binding energy of hydrogen to traps is largely determined through the Fermi energy orbital topology at the trap/BCC-iron interface. Estimates of trapping efficiency for several inclusions in steel were conducted using this model. As a result, Ce2O3 was predicted to be the most effective trap, followed by TiC, Y2O3, NbC, and finally Mo2C. Titanium carbide has a binding energy of approximately 100 kJ per mole.

The welding process parameters also have a significant effect on the hydrogen absorption in the weld deposit and need quantitative understanding if hydrogen management is to be achieved. A statistical analysis of the main welding parameters on diffusible hydrogen content in the deposited weld metal was performed by Kiefer (Ref. 13). The results showed the influence of independent variables on diffusible hydrogen for the flux cored arc process using several flux cored wires and a solid gas metal arc wire. All the welding variables showed a significant influence on the diffusible hydrogen content, except for travel speed, which indicated little effect. Through better understanding of the specific influence of welding process parameters on the resulting hydrogen content, the control of hydrogen with irreversible weld metal traps can become even more effective in the reduction of hydrogen cracking susceptibility in steel weldments.

The welding voltage will primarily affect the weld metal diffusible hydrogen content by altering the droplet transfer mode. Spray transfer is desired in welding because of the good head shape, smooth operation, and decreased spatter. Gedeon (Ref. 14) showed that globular transfer may be more desirable than spray transfer in welding high-strength steels with 0.5% hydrogen in the shield because it resulted in lower diffusible hydrogen contents. About 3 ppm of hydrogen increase was observed from globular to spray transfer mode. However, at lower diffusible hydrogen values, Gedeon (Ref. 14) did not observe a transition in transfer modes to change the diffusible hydrogen content.

Objectives of This Investigation

Phase one of this research is to experimentally determine if hydrogen traps are effective in HSLA steel welding, and to evaluate the performance of each selected rare earth metal and transition metal hydrogen trap in HSLA weldments to reduce the diffusible hydrogen content. The diffusible hydrogen content measurement and the verification of these traps are to be determined by gas chromatography, thermal desorption analyses, metallographic techniques, and XRD analyses, respectively.

Phase two is devoted to studying the influence of the welding parameters (including amperage, voltage, travel speed, and transfer mode, as well as the interrelationships) on the utility of hydrogen traps in managing diffusible hydrogen content of steel welds.

Experimental Procedures

Phase I: Hydrogen Trapping

Metal Core Wires

For phase one of this research, two sets of metal cored wires were fabricated using a mild steel sheath and a HSLA steel sheath in which ferro-powders were added to the metal core. Two types of irreversible traps, neodymium and yttrium, were used in the form of ferro-powders. These powders were made by forming a brittle intermetallic phase with iron, then by immersion in liquid nitrogen, followed by crushing and sizing. Three content levels for each trap type were used to study the effect of the amount of traps available for hydrogen trapping. The designations and target weld metal content of two metal cored wires can be seen in Table 1. The mild steel sheath was made with yttrium addition of 2000 ppm. The HSLA steel sheath was made with neodymium (1000 and 2000 ppm). These metal cored wires were drawn to form 0.0625-in.- (1.6-mm-)
diameter electrodes. The actual chemical compositions of the metal cored wire of the mild steel sheath and HSLA steel sheath are given in Table 2. All the fabricated wires were baked in a vacuum furnace for two hours at 600°C.

Hydrogen Measurement

With the exception of the steel base metal, diffusible hydrogen measurements were carried out following ANSI/AWS A4.3-93 (Ref. 15). The weld specimens for this procedure were cut from HSLA 100 steel plate and were either mechanically milled or ground to the dimensions of 12 × 25 × 40 mm and measured to maintain tolerances specified in the standard method. High-strength low-alloy steel with the composition given in Table 2 was used for all welding experiments as the base metal in both phases of this research.

Once the weld specimens had been prepared, the specimens were hydrogen degassed at 600°C for at least 6 hours in a vacuum furnace. Any subsequent oxide formation was immediately dried. The specimens were weighed and recorded. The welding parameters used to weld the metal cored electrodes are given in Table 3 and served as a starting point. After welding, the samples were ice quenched for 20 s within 5 s of weld completion. The weld samples were then stored in a dry ice and acetone mixture (-72°C). After all welds were made, the samples were dry sandblasted and the samples for diffusible hydrogen measurement were returned to the dry ice/acetone bath.

The preparation of the weld samples for diffusible hydrogen measurement required the samples to be cleaned with acetone and dried immediately before being placed in the canister where argon gas was flowing through the canister. All canisters were pressurized to 12 lb/in.² and 1 mL of helium gas was injected as the internal standard. Helium is useful in detecting any hydrogen loss due to leaks and is assumed.

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Table 1 — Industrial Fabricated Mild Steel Metal Cored Electrode Designation

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Table 2 — Industrial Fabricated Mild Steel Sheath Composition and HSLA Steel Sheath Composition (wt-%)

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<th>HSLA Steel Sheath</th>
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<td>0.082</td>
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<td>P</td>
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<td>0.010</td>
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<td>0.35</td>
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<tr>
<td>Mn</td>
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<td>0.65</td>
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<td>N/A</td>
<td>1.27</td>
</tr>
<tr>
<td>Fe</td>
<td>N/A</td>
<td>N/A</td>
<td>Balance</td>
</tr>
</tbody>
</table>

---

Fig. 3 — Thermal desorption analysis curve for a HSLA steel weld metal with no irreversible trap addition and with neodymium addition (Nd-2). A shift of diffusible hydrogen to high-temperature traps is observed as evident from hydrogen effusion peaks at the 700-900 K range. A 0.5% hydrogen gas in argon shield gas was used.

Fig. 4 — Thermal desorption analysis curve for a HSLA steel weld metal with no irreversible trap addition and with yttrium addition (Y-1). A shift of diffusible hydrogen to high-temperature traps is observed, as evident from hydrogen effusion peaks at the 700-900 K range. A 0.5% hydrogen gas in argon shield gas was used.
to be proportional if loss should occur.

The canisters were baked at 150°C for 8 h and allowed to cool to ambient temperature before measurement.

The gas chromatograph method proposed by Quintana et al. (Ref. 16) was used for the measurement of diffusible hydrogen. This gas chromatograph method allows for lower levels of hydrogen detection to 1 ppm content due to the sensitivity of the thermal conductivity detector used in gas chromatography. The sampling of the diffusible hydrogen gas from the canister required using a 1-mL syringe to inject the gas sample into the gas chromatograph for analysis. The ambient temperature and barometric pressure were recorded for each measurement. Initially, a standard gas mixture of hydrogen and helium was tested to verify reliable measurements before the samples were tested.

Table 3 — Welding Parameters Used for Phase One and Phase Two

<table>
<thead>
<tr>
<th>Phase</th>
<th>Voltage</th>
<th>Wire Feed Speed</th>
<th>Polarity</th>
<th>Electrode Extension</th>
<th>Shielding Gas</th>
<th>Shielding Gas Flow Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase One</td>
<td>25 V</td>
<td>240 in./min (102 mm/s)</td>
<td>DCEP</td>
<td>3/4 in. (19 mm)</td>
<td>Argon + hydrogen</td>
<td>45-50 ft/min (0.35-0.39 L/s)</td>
</tr>
<tr>
<td>Phase Two</td>
<td>20-30 V</td>
<td>200-300 in./min (85-127 mm/s)</td>
<td>DCEP and DCEN</td>
<td>13.5-18.7 in./min (5.7-7.9 mm/s)</td>
<td>0-4% oxygen</td>
<td>1.5-4 kJ/mm</td>
</tr>
</tbody>
</table>

Fig. 5 — Identification of yttrium oxide inclusion in HSLA steel weld metal by: A — X-ray diffraction using the bromine extraction technique; B — SEM micrograph of an yttrium oxide inclusion and EDS spectrum for the yttrium oxide inclusion.

Fig. 6 — Thermal desorption peak for a HSLA steel weld for: A — a 5 K/min heating rate; B — a 2 K/min heating rate. Peak 1: microvoids (reversible trap); peak 2: yttrium oxy-sulfide inclusion (irreversible trap); and peak 3: yttrium oxide inclusions (irreversible trap).
At least three injections were made for each sample, in which results were in good agreement, and the pressure of each canister was checked for any leaks.

The welds were made with 0.5% hydrogen in the argon shield gas, which produces much higher diffusible hydrogen contents than those contents typically found in welding HSLA steels in industry. Acceptable values are typically less than 5 mL per 100 g weld deposit, but with the development of higher-strength steels, lower values for weld metal diffusible hydrogen content are prevalent. A comparison between the gas chromatograph and mercury method was also performed and showed that the results are reliable with either method. The difference in the diffusible hydrogen values between the two measurement methods is about 2% at these levels of diffusible hydrogen content.

The thermal desorption analysis (TDA) was used to verify the high-temperature trapping of hydrogen in the HSLA steel weldments. A detailed description of this setup can be found in other reference materials (Ref. 17). A 4 degrees per minute heating rate was used and the measurement was carried out to 1000°C.

**Characterization of Hydrogen Traps**

The bromine method (Ref. 18) was used to extract nonmetallic inclusions in the steel weldments. The bromine method is useful in recovering nonmetallic inclusions in steel; the iron matrix is dissolved in the bromine solution, leaving behind the nonmetallic inclusions. These inclusions were collected by filtering and then were washed before analysis. A Philips XRD machine was used and the resulting XRD spectral was used to identify the inclusions.

Induced couple plasma (ICP) analysis was used to obtain the chemical composition of the weldments and metal core steel electrodes. Induced couple plasma analysis samples are prepared by dissolving a small amount, about 0.1 g, in a concentrated nitric acid solution. The solution is vaporized by plasma and detected by spectroscopy. The ICP method is useful when the material is completely dissolved, which may not be the case for certain oxides.

**Phase II: Welding Parameters**

Iron fill metal cored steel wire (plain carbon steel sheath) was made to serve as a baseline wire, and wire diameter was kept the same as in Phase I. Iron fill metal cored wires were made, containing four levels of ferroyttrium (Fe2Y) content. The yttrium contents in the iron fill metal cored wire are approximately 0, 650, 3000, and 6600 ppm. Three levels were chosen to study the effects of welding parameters and trap content, and the wire with no yttrium served as a baseline. The iron fill metal cored wires had a powder fill of about 1 wt-% and an AISI-SAE 1005 carbon-steel sheath. Details of the tubular wire bench-form operation and flux/powder flow characterization are discussed in another reference (Ref. 7). Powder flow characteristics, such as flow rate and composition, were performed on ferroyttrium powders with a size range between 200 and 600 microns. Mass flow rate and sampling at 30-s intervals for composition distribution were performed and resulted in a uniform flow rate, as well as a uniform composition.

A metal cored wire with a HSLA steel composition was also fabricated with about 1600 ppm of yttrium, and its chemical composition is shown in Table 4. The same standard procedure was used in phase one for the measurement of diffusible hydrogen. These wires were used to study the weld parameters on the diffusible hydrogen content for phase two of this research. The test matrix has been established to vary the heat input by varying the voltage while the current (wire feed speed) and travel speed remain constant. Voltages were chosen for much of the complete range where welding was possible. Similarly, the current was varied, and the voltage and travel speed were held constant. The effect of travel speed was varied while voltage and current were held at a constant value. The effects of oxygen content, introduced through the shielding gas, were examined by using four levels of

### Table 4 — Plain Carbon and HSLA Steel Metal Cored Wire Chemical Composition for Welding Parameter Study (wt-%)

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>Mn</th>
<th>Ni</th>
<th>Mo</th>
<th>Ti</th>
<th>Y</th>
<th>Fe</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSM 6-0</td>
<td>0.04</td>
<td>0.63</td>
<td>2.53</td>
<td>0.44</td>
<td>0.07</td>
<td>0</td>
<td>Balance</td>
</tr>
<tr>
<td>CSM 6-1</td>
<td>0.04</td>
<td>0.63</td>
<td>2.53</td>
<td>0.44</td>
<td>0.07</td>
<td>1600 ppm</td>
<td>Balance</td>
</tr>
</tbody>
</table>
Results and Discussion

In phase one, the use of hydrogen traps to lower the diffusible hydrogen content and to identify the form of the hydrogen trap was examined in HSLA steel welds. The thermal desorption analysis was used to verify the presence of high binding energy hydrogen traps. Phase two discusses the effects of welding parameters, such as voltage, current, travel speed, heat input, hydrogen and oxygen potential, and polarity, on the diffusible hydrogen content in the presence of yttrium as an irreversible hydrogen trap-former.

Phase I: Irreversible Hydrogen Trapping

In a prior investigation (Ref. 8), the welding of pure iron using similar trap additions shows a reduction in the diffusible hydrogen content by 50% by adding neodymium or yttrium in mild steel metal cored wires. Also, a 50% reduction in diffusible hydrogen content from 6 to 3 mL hydrogen per 100 g weld deposit was achieved when 0.4-0.8% rare earth metal was added to the electrode coating with a corresponding increase in residual hydrogen. However, in the prior investigation (Ref. 8), the addition of irreversible trap-formers in HSLA steel weld deposits did not result in any significant reductions using the HSLA steel metal cored wires. The effectiveness of irreversible hydrogen traps in HSLA steel weld metal was investigated to determine if the diffusible hydrogen content of HSLA steel weld deposit could be reduced. Welding HSLA steel with HSLA steel metal cored wire with neodymium (0.26 wt-% neodymium, Nd-1) and mild steel metal cored wire with yttrium (0.32 wt-% yttrium, Y-1) was performed with 0.5% hydrogen in argon shielding gas. With the use of these metal cored wires, it was found that neodymium and yttrium could reduce the diffusible hydrogen content in HSLA steel welds as seen in Fig. 1. Neodymium and yttrium show promise in reducing the diffusible hydrogen content compared to the reference metal cored steel wire with no elemental irreversible trap additions.

Although neodymium has a higher calculated binding energy than yttrium, neodymium is not necessarily a better hydrogen trap. The addition of neodymium effectively reduces the diffusible hydrogen content about 25%, whereas the yttrium reduces the diffusible content by 50%. The effectiveness of yttrium over neodymium is most likely due to the higher recoveries in the HSLA steel weld deposit rather than the trapping ability of neodymium.

Hydrogen trapping was investigated...
for a metal cored wire with a HSLA steel composition, which was also fabricated with about 1600 ppm of yttrium (CSM 6-1) and without yttrium (CSM 6-0). This HSLA steel metal cored wire, fabricated to study the welding parameters in phase two and its chemical composition, is shown in Table 4. A comparison is made for welds with metal cored low-carbon steel wires with iron powder fill and iron powder with 3000 ppm yttrium added, and HSLA steel metal cored wires with no yttrium and 1600 ppm yttrium added. These iron fill carbon steel cored wires and HSLA steel metal cored wires were welded at 25 V and 240 in./min (102 mm/s) wire feed speed and 0.1% hydrogen in argon shielding gas. In Fig. 2, two wires with no yttrium additions have the same diffusible hydrogen content at about 6.5 mL per 100 g weld deposit. The two wires with yttrium additions show a significant reduction in diffusible hydrogen content below 2 mL per 100 g. The diffusible hydrogen content is reduced from about 7 to 2 mL of hydrogen per 100 g weld deposit for both iron fill (3000 ppm yttrium) and HSLA steel composition (1600 ppm yttrium). The addition of 1600 ppm yttrium in HSLA steel metal cored wire reduces the diffusible hydrogen significantly by 70%. It has been noted that a small addition of neodymium or yttrium in the metal cored steel wire can significantly reduce diffusible hydrogen to levels where preventive procedure such as preheat and postheat treatments may be alleviated.

**Thermal Desorption Analysis Measurement for Hydrogen Trapping Identification**

To verify that neodymium and yttrium form irreversible traps for hydrogen, a thermal desorption analysis (TDA) technique was used and the results are shown in Figs. 3 and 4. At a constant rate of heating, the relative amount of hydrogen released from the trap site is measured by gas chromatography. The identified peaks are associated with trap binding energy and the temperature at which the hydrogen can escape from its trap. In Fig. 3, superimposed are the HSLA steel weld sample with no irreversible traps and a sample containing neodymium irreversible hydrogen traps. The weld sample with no irreversible traps releases hydrogen at temperatures associated with grain boundaries/dislocations and microvoids. When irreversible traps are introduced by addition of neodymium, hydrogen evolution occurs at higher temperatures by desorption from the neodymium-containing...
irreversible trap. A shift in the hydrogen evolution from grain boundaries and dislocations with no irreversible trap additions to that of neodymium added to this high-temperature trap is observed in the thermal desorption curve. Thus, neodymium is identified as an irreversible trap-former to reduce the weld metal diffusible hydrogen content.

As shown in Fig. 4, the effect of yttrium on the shift of hydrogen desorption in the thermal desorption analysis curve shows evidence of the presence of an irreversible high-temperature (high binding energy) yttrium-type trap in the HSLA steel weld metal. A sharp yttrium peak at 760 K is observed with a possibility of a second peak at slightly higher temperatures around 860 K. A shift in diffusible hydrogen content can be seen in the reduction of hydrogen desorption at grain boundaries and microvoids peaks to the higher temperature hydrogen traps in the weld metal when comparing the no-addition-of-yttrium curve to the curve with yttrium addition. Since the yttrium influences arc stability and transfer mode, it is likely effect that spray mode will have better oxidation formation to serve as hydrogen traps.

To determine that yttrium oxides were present in the HSLA steel weld metal, electron microscopy and the bromine extraction method were used to identify the type of weld deposit irreversible traps yttrium formed. In Fig. 5A, the XRD pattern was indexed for yttrium oxide inclusions extracted from a HSLA steel weld made with yttrium metal cored wires. The indexing of the XRD pattern identified yttrium oxide (Y₂O₃) inclusions and was supported by energy-dispersive spectroscopy (EDS) measurements on the SEM, as seen in Fig. 5B. The recovery of yttrium in the weld metal by using ICP was not useful because the nonmetallic inclusions do not dissolve in the acid solution used in the analysis.

The thermal desorption was also performed on HSLA steel welds using the CSM 6-1 HSLA steel metal cored wire to verify high-temperature trapping of hydrogen by the addition of yttrium. Figure 6A shows two desorption peaks for a heating rate of 5 K/min. Peak 1 and peak 2 are microvoids and yttrium oxysulfide irreversible traps, respectively, and peak temperatures are 650 and 950 K, respectively. Iron-yttrium intermetallic inclusions were reported by Maroof (Ref. 8) as possible high-temperature traps in pure iron welds and have a similar desorption peak temperature. However, from EDS measurements, sulfur peaks are evident and, due to their thermodynamic stability, can exist in the form of yttrium oxysulfide inclusions in the weld metal, as shown in Fig. 7.

In Fig. 7, at position “A,” yttrium oxide inclusion on the order of one micron in size was formed. However, at position “B,” yttrium oxysulfide inclusions were typically found in an agglomerated form with other element constituents such as aluminum, nickel, manganese, and silicon. This complex yttrium oxysulfide inclusion is characterized to have a higher binding.
energy than an yttrium oxide trap. Also, more trap sites are associated with this complex yttrium oxysulfide inclusion, given the wider thermal desorption peak and its superposition on the yttrium oxide peak. From the TDA analysis, calculations show more hydrogen trapped at the yttrium oxysulfide traps.

At slower heating rates, a third peak is observed in which the resolution of the thermal desorption plot becomes better — Fig. 6B. The third peak has been identified as the yttrium oxide inclusion from EDS analysis and has a peak temperature at 800 K. The yttrium oxide peak is consistent with the peak identified in Fig. 8A with a peak temperature of 800 K.

Kissinger Analysis for Hydrogen Trapping Activation Energy

The Kissinger analysis was used to experimentally determine the binding energies of the hydrogen traps in the HSLA steel weld metal. To calculate the trap binding energy, several heating rates were performed on HSLA steel weld samples welded under the same welding conditions. A shift in the desorption peaks due to different heating rates allows the calculation of the trap activation energy. As observed in Fig. 8A, the 2, 3, and 6 K/min heating rates are shown for HSLA steel welded with HSLA steel metal cored wire containing 1600 ppm yttrium (CSM 6-1). Microvoids, yttrium oxide inclusions, and complex yttrium oxysulfide inclusion traps were calculated to have activation energies of 58, 78, and 96 kJ/mole, respectively, as shown in Fig. 8B. Because the measured activation energy term contains the activation energy for iron lattice interstitial diffusion and the trap binding energy, the activation energy of the interstitial diffusion in iron lattice has been assumed to be about 6.8 to 8 kJ/mole. The trap binding energies were found to be 50.1 to 51.3, 70.1 to 71.3, and 88.2 to 89.4 kJ/mole for microvoids, yttrium oxide inclusion, and complex yttrium oxysulfide inclusion, respectively. The summary of the trap activation energy ($E_A$) and binding energy ($E_B$) for HSLA steel weld metal traps using metal cored HSLA steel wire containing yttrium is shown in Table 5. Microvoids fall into the category of reversible traps, whereas yttrium oxide and yttrium oxysulfide inclusions are irreversible traps.

Phase II: Welding Parameters on Diffusible Hydrogen Content

The influence of welding parameters such as voltage, current, travel speed, etc., on the effectiveness of yttrium traps and diffusible hydrogen contents is discussed. First, a comparison is made regarding the effect of welding parameters with no irreversible trap additions. Then, yttrium additions are discussed and the welding parameter space for lowest diffusible hydrogen contents is developed.

Effect of Weld Parameters on Iron Fill Metal Cored Steel Wires

The influence of the welding parameters on the utility of hydrogen traps in managing diffusible hydrogen content was investigated. The results of this study will be beneficial by providing a recommended practice in minimizing the hydrogen pickup during welding and to optimize the hydrogen trap content in the weld deposit. To distinguish if there is an effect from other HSLA steel alloying elements, metal cored wires (plain carbon steel sheath) were fabricated without these elements so that a comparison could be made with HSLA steel metal cored wires in the welding parameter study.
Welds were made by changing the welding voltage, thus varying the heat input, while the current and travel speed remained constant. Five welding voltages were selected, from 25 to 40 V, to cover the range of welding ability, i.e., short circuiting to globular transfer modes, with the metal cored steel wires. Because the gas metal arc welding process is a constant voltage process, the weld current was adjusted indirectly by the wire feed rates. The wire feed rates ranged from 200 to 300 in./min (≈ 85 to 125 mm/s), which resulted in weld currents in the range of 300-400 A.

Welds made with iron fill wire with no yttrium trap additions as the reference base were performed — Fig. 9. In Fig. 9A and B, the effect of weld voltage and weld current on diffusible hydrogen content is observed and discussed in this order, respectively. A significant reduction in the diffusible hydrogen content is observed at low welding voltages around 28 V. A 50% reduction, 7 to 3.5 mL of hydrogen per 100 g of weld deposit, is achieved in the diffusible hydrogen content when compared to welding voltages greater than 32 V. From 25 to 32 V, a linear increase in diffusible hydrogen is observed and levels off at voltages greater than 32 V. Without the benefit of yttrium additions, reducing the weld voltage can significantly reduce the diffusible hydrogen.

In the case of the weld voltage above 40 V, melting of the contact tip is observed due to the large arc length associated with high voltages. The large arc lengths with increasing voltage may expose the weld arc to the atmosphere for more hydrogen or moisture pickup as well as promoting globular transfer modes at high voltages. As voltage is increased, electrode extension was also observed to effectively decrease. Harwig et al. (Ref. 5) reported that reduction of electrode extension causes less heating of the wire and burning off of lubricants, resulting in higher diffusible hydrogen content in the weld metal. At low voltages, the short circuiting metal transfer mode was observed, resulting in low weld deposition and high degree of spatter. These welds were made with 0.1% hydrogen in argon shielding gas and a wire feed rate of 240 in./min (≈ 100 mm/s). The polarity was direct current electrode positive (DCEP) and the travel speed remained constant.

The effect of weld current, as shown in Fig. 9B, on the diffusible hydrogen content shows a similar trend with weld voltage changes. The diffusible hydrogen content at currents reaching 385 A is doubled compared with the diffusible hydrogen of about 3.5 mL of hydrogen per 100 g of weld deposit at weld currents around 320 A. At 350 A, a transition from a linear increase with current to a constant level is observed. The influence of electrochemical reactions of hydrogen transfer at the arc plasma/metal interface may play an important role on the diffusible hydrogen content, especially at high current densities. Short circuiting transfer modes predominate at low voltages and high currents, whereas globular transfer mode predominates at high voltages and low currents. All welds were made with 0.1% hydrogen in argon shield gas and a welding voltage of 30 V.

Table 5 — Summary of Trap Activation Energy (E_a) and the Binding Energy (E_b) for HSLA Steel Weld Metal Traps Using Metal Cored HSLA Steel Wire Containing Yttrium

<table>
<thead>
<tr>
<th>Peak Number</th>
<th>Trap Type</th>
<th>Trap Classification</th>
<th>E_a (kJ/mol)</th>
<th>E_b (kJ/mol)</th>
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</thead>
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<tr>
<td>Peak 1</td>
<td>Microvoids</td>
<td>Reversible</td>
<td>58.1</td>
<td>50.1-51.3</td>
</tr>
<tr>
<td>Peak 2</td>
<td>Yttrium oxide</td>
<td>Irreversible</td>
<td>78.1</td>
<td>70.1-71.3</td>
</tr>
<tr>
<td>Peak 3</td>
<td>Yttrium oxide</td>
<td>Irreversible</td>
<td>96.2</td>
<td>88.2-89.4</td>
</tr>
</tbody>
</table>

Effect of Weld Voltage on Iron Fill Metal Cored Wires with Addition of Yttrium

The yttrium hydrogen trap effectiveness on reducing the diffusible hydrogen content can be seen in Fig. 10. Gas metal arc welding was performed on HSLA steel using a 1.5 kJ/mm heat input and 0.1% hydrogen in the argon shielding gas. A reference weld was made using the iron fill wire to serve as a baseline for comparison to welds made with hydrogen traps under the same welding conditions. The iron fill wire shows diffusible hydrogen contents around 6.7 mL per 100 g weld deposit. Welds were also made with the 650 ppm (0.065 wt-%), 3000 ppm (0.3 wt-%), and 6000 ppm (0.6 wt-%) yttrium-containing steel wires, respectively. A significant reduction in the diffusible hydrogen content with these yttrium hydrogen trap additions is seen, except for the 650 ppm yttrium.

The apparent increase in diffusible hydrogen content for 650 ppm yttrium is most likely due to yttrium dropping of oxygen content in the arc. Thus, an increase of hydrogen content in the arc and in the weld pool is due to the water reaction. With contents...
The diffusible hydrogen content for the 3000 ppm yttrium addition reduced the diffusible hydrogen content from 6.7 to 3.2 mL/100 g weld deposit. By adding 6000 ppm yttrium, the diffusible hydrogen content can be reduced to levels below 1 mL/100 g weld deposit, at the detection limit of the gas chromatograph.

The diffusible hydrogen content with yttrium levels of 3000 and 6000 ppm are unaffected by the welding voltage, as shown in Fig. 11. The diffusible hydrogen content significantly drops to about 0.5 mL of hydrogen per 100 g of weld deposit, and definitely below 1 mL of hydrogen per 100 g of weld deposit. The low levels of the diffusible hydrogen content are at the detection limit of the gas chromatograph measurements. A diffusible hydrogen content of 3.5 to 7 mL of hydrogen per 100 g of weld deposit with no traps can be reduced to about 0.5 mL of hydrogen per 100 g deposit with the addition of at least 0.3 wt-% yttrium (3000 ppm) in the metal cored wire. The diffusible hydrogen content in the steel weld metal can be reduced to a minimum with 0.5 wt-% yttrium (6000 ppm yttrium).

A metal cored steel wire was made with iron powder (99) and 600 ppm of yttrium added to see if the welding voltage had any effect. As shown in Fig. 11, for the entire welding voltage range, the yttrium at this content level had very little effect on reducing the diffusible hydrogen content. The yttrium promoted a greater diffusible hydrogen content than the iron fill metal cored steel wire reference. The recovery of yttrium in the weld metal may be too low and may be lost weld arc reactions. In the presence of oxygen, most or all of the yttrium could react with the oxygen and float to the surface of the weld pool as slag. The resulting oxygen loss in the plasma would cause a hydrogen increase due to the oxygen-hydrogen water reaction.

Also, the range of voltages has shifted for yttrium additions showing a lower welding voltage than without yttrium additions, as seen in Fig. 12. The higher level of yttrium addition in the metal core steel wire results in a voltage drop from 4 to 8 V. The addition of yttrium in the weld arc allows lower voltages and currents for arc ignition due to the lower ionization potential of yttrium than of argon. These welds were made with 0.1% hydrogen in argon shield gas and with the weld voltage at 30 V.

The effect of yttrium additions to the amount of heat, i.e., heat input, can be seen in Fig. 13. The heat inputs ranged from 1.3 to 2.7 kJ/mm. The heat input is an indication of the cooling rate the weld pool will experience. At slower cooling rates, or larger heat inputs, more time is available for diffusion of hydrogen to be trapped by yttrium-type traps and the effusion of hydrogen from the weld pool. With no yttrium, there is an apparent increase in diffusible hydrogen with higher heat input. However, for a given yttrium addition, no significant effect of heat input on diffusible hydrogen content is observed.

### Table 6 — Comparison of Hydrogen Content and Partitioning to Trap Sites in HSLA Steel Welds Made with 0 and 4% Oxygen in Argon Shield Gas (HSLA Steel Metal Cored Wires Containing 1600 ppm Yttrium)

<table>
<thead>
<tr>
<th>% Oxygen in Shield Gas</th>
<th>Diffusible Hydrogen Content</th>
<th>Trapped Hydrogen Content</th>
<th>Total Hydrogen Absorbed</th>
<th>Hydrogen Partitioning between Trap Sites</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Micovoids</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0%</td>
<td>0.5–0.9 ppm</td>
<td>8–9 ppm</td>
<td>8.5–9.9 ppm</td>
<td>2.6 ppm</td>
</tr>
<tr>
<td>4%</td>
<td>5.8–6.2 ppm</td>
<td>1.6–2 ppm</td>
<td>7.4–8.2 ppm</td>
<td>0.1 ppm</td>
</tr>
</tbody>
</table>

### Table 7 — Comparison of Hydrogen Content and Partition to Irreversible Trap Sites in HSLA Steel Welds in the Globular and Spray Transfer Modes for GMAW Process (HSLA Steel Metal Cored Wires Containing 1600 ppm Yttrium)

<table>
<thead>
<tr>
<th>GMAW Metal Transfer Mode</th>
<th>Diffusible Hydrogen Content</th>
<th>Trapped Hydrogen Content</th>
<th>Total Hydrogen Absorbed</th>
<th>Hydrogen Partitioning between Trap Sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Globular</td>
<td>1.2–1.6 ppm</td>
<td>8–9 ppm</td>
<td>9.2–10.6 ppm</td>
<td></td>
</tr>
<tr>
<td>Spray</td>
<td>0.5–0.8 ppm</td>
<td>12.5–13.8 ppm</td>
<td>13–14.6 ppm</td>
<td></td>
</tr>
</tbody>
</table>

The resulting oxygen loss in the plasma significantly drops to about 0.5 mL of hydrogen per 100 g of weld deposit, and definitely below 1 mL of hydrogen per 100 g of weld deposit. The low levels of the diffusible hydrogen content are at the detection limit of the gas chromatograph measurements. A diffusible hydrogen content of 3.5 to 7 mL of hydrogen per 100 g of weld deposit with no traps can be reduced to about 0.5 mL of hydrogen per 100 g deposit with the addition of at least 0.3 wt-% yttrium (3000 ppm) in the metal cored wire. The diffusible hydrogen content in the steel weld metal can be reduced to a minimum with 0.5 wt-% yttrium (6000 ppm yttrium).

A metal cored steel wire was made with iron powder (99) and 600 ppm of yttrium added to see if the welding voltage had any effect. As shown in Fig. 11, for the entire welding voltage range, the yttrium at this content level had very little effect on reducing the diffusible hydrogen content. The yttrium promoted a greater diffusible hydrogen content than the iron fill metal cored steel wire reference. The recovery of yttrium in the weld metal may be too low and may be lost weld arc reactions. In the presence of oxygen, most or all of the yttrium could react with the oxygen and float to the surface of the weld pool as slag. The resulting oxygen loss in the plasma would cause a hydrogen increase due to the oxygen-hydrogen water reaction.

Also, the range of voltages has shifted for yttrium additions, showing a lower welding voltage than without yttrium additions, as seen in Fig. 12. The higher level of yttrium addition in the metal core steel wire results in a voltage drop from 4 to 8 V. The addition of yttrium in the weld arc allows lower voltages and currents for arc ignition due to the lower ionization potential of yttrium than of argon. These welds were made with 0.1% hydrogen in argon shield gas and with the weld voltage at 30 V.

The effect of yttrium additions to the amount of heat, i.e., heat input, can be seen in Fig. 13. The heat inputs ranged from 1.3 to 2.7 kJ/mm. The heat input is an indication of the cooling rate the weld pool will experience. At slower cooling rates, or larger heat inputs, more time is available for diffusion of hydrogen to be trapped by yttrium-type traps and the effusion of hydrogen from the weld pool. With no yttrium, there is an apparent increase in diffusible hydrogen with higher heat input. However, for a given yttrium addition, no significant effect of heat input on diffusible hydrogen content is observed.

### Welding Parameters on HSLA Steel Metal Cored Wire

#### Effect of Polarity

High-strength low-alloy steel welds were made with both direct current electrode positive (DCEP) and electrode negative (DCEN) modes. Higher diffusible hydrogen content resulted from welds made with a direct current electrode negative polarity. If electrochemical reactions predominate at the anode and cathode regions of the arc.
plasma, DCEP is more favorable than DCEN because the cathode reaction promotes the absorption of hydrogen into the weld pool. Because DCEN has a higher diffusible hydrogen content than DCEP, this result suggests that the electrochemical reaction must not be the dominant reaction and may not significantly contribute to the hydrogen pickup.

Similar electrode polarity results were observed for submerged arc welding for the hydrogen pickup into the weld metal (Ref. 19). The effect of DCEP, DCEN, and alternating current (AC) polarities gave diffusible hydrogen values of 5.8, 9.5, and 12.7 mL/100 g weld deposit, respectively. Because greater heat transfer to the workpiece that accompanies DCEP welding decreases the weld metal cooling rate, this behavior allows more time for hydrogen to diffuse out of the weld metal. No explanation for AC was given, but both DCEP and DCEN characteristics would contribute to the hydrogen pickup in some form of cyclic pickup.

Effect of Voltage

The effect of voltage on diffusible hydrogen content is seen in Fig. 14A. The wire feed rate and travel speed were held constant and the weld voltage was varied for the complete range for sufficient welding. High-strength low-alloy steel metal cored wire with a nominal yttrium content of 1600 ppm was used in making the welds. In general, the complete range of voltages gave low diffusible hydrogen content in the weld metal on the order of 1 mL of hydrogen per 100 g of weld deposit. However, more scatter of diffusible hydrogen is shown for voltages of less than 32 V. Larger voltages show very low diffusible hydrogen contents.

The overall level of hydrogen for any voltage is below 4 mL of hydrogen per 100 g weld deposit, which is the typical level for practical welding of high-strength steels. The large range of acceptable voltages makes the metal core cored steel wire more forgiving for the welder to use. However, at proper voltage settings, the diffusible hydrogen content can be achieved below that of 1 mL per 100 g weld deposit.

Effect of Current

The welding current was varied by systematically changing the wire feed rate indirectly. High-strength low-alloy core wires containing 1600 ppm yttrium were used. In Fig. 14B, the current range showed, diffusible hydrogen levels were below 2 mL of hydrogen per 100 g of weld deposit. An apparent transition in diffusible hydrogen values around 350-400 A is shown. The diffusible hydrogen content is insensitive to the range of currents used during welding, suggesting that voltage and arc length have a more significant effect on the diffusible hydrogen content. Any current within this studied range ensures the welder that factors that influence current do not influence the achievement of low diffusible hydrogen contents.

Effect of Travel Speed

Using the 1600 ppm yttrium-containing HSLA steel cored wire, the effect of travel speed on the diffusible hydrogen can be seen in Fig. 14C. At higher travel speeds, the diffusible hydrogen apparently increases from about 0.5 to 1.8 mL of hydrogen per 100 g weld deposit for travel speeds from 13.5 to 18.7 in/min (85 to 127 mm/s). The significance of these reported values is low for it is at the detectable limit of the diffusible hydrogen analysis. The time for hydrogen diffusion out of the weld pool is much shorter at higher travel speeds.

Effect of Oxygen Content in Argon Shielding Gas

The effect of oxygen content in the shield gas and diffusible hydrogen content is shown in Fig. 14D. High-strength low-alloy steel metal cored wires containing 1600 ppm yttrium were used. The oxygen content increases linearly with the amount of diffusible hydrogen content in the weld metal. Oxygen content from 0 to 4% results in diffusible hydrogen contents from as low as 0.5 to 6.5 mL of hydrogen per 100 g weld deposit. The inverse relationship between oxygen and hydrogen as suggested by water reaction would predict that when oxygen content increases, the hydrogen content would be decreased. However, the presence of yttrium and its potential as a strong deoxidizer may react so completely with the oxygen, preventing the oxygen from reacting with the hydrogen. The classical oxygen-hydrogen relationship appears not to be significant when the yttrium content is above 1600 ppm. The effect of 4% oxygen content in the shield gas on the trapped (residual) hydrogen content in the weld metal is compared to that with no oxygen is shown in Fig. 15A. With 4% oxygen content, the formation of yttrium oxide and yttrium oxysulfide irreversible traps in the weld metal would be expected to increase due to the higher amount of oxygen available. However, the results from a shielding gas with no oxygen content show that more hydrogen is being trapped at these trap sites. These experimental results showing that an increase in the diffusible hydrogen content with oxygen increase in shielding gas suggest that a more complex hydrogen model is needed when yttrium is used as a hydrogen trap addition.

The effect of oxygen on yttrium transfers through the welding arc must take place on the droplets in the arc or on the surface of the weld pool as a slag. However, no slag was evident, suggesting that yttrium oxide forms in the droplets and transfers with these droplets across the welding arc. This result is supported from analysis of the residue and spatters, which showed evidence of yttrium.

The thermal desorption analysis as a function of oxygen content in the shielding gas was used to quantify hydrogen contents and distribution between the weld metal traps (Table 6). The total hydrogen absorbed in the weld metal was about 8-9 ppm of hydrogen for both 0 and 4% oxygen content in the shield gas. The difference is that the 4% oxygen had higher diffusible hydrogen content but a lower trapped hydrogen content than the 0% oxygen.

The partitioning of the trapped hydrogen between microvoids, yttrium oxide, and yttrium oxysulfide traps shows that yttrium oxysulfide traps are the most effective hydrogen traps; this observation may be due to the greater number of trap sites available and the high binding energy of yttrium oxysulfide. Microvoids and yttrium oxide inclusion show about the same proportion of trapped hydrogen but may vary due to poor peak resolution of the yttrium oxide peak.

The effect of weld voltage for 1% oxygen in the shield gas is shown in Fig. 16A. The addition of 1% oxygen helps maintain a constant level of diffusible hydrogen below 1.5 mL per 100 g weld deposit. A transition voltage around 32-34 V is observed, similar to that observed when oxygen was added to the shield gas. Also, the range of voltage was shifted to a lower voltage for 1% oxygen, showing a slightly lower voltage than 0% oxygen in argon shielding gas — Fig. 16B.

Effect of Heat Input

The effect of heat input for welds was investigated with HSLA steel metal cored wire containing 1600 ppm yttrium. The contact tip-to-work distance was maintained at 0.75 in. (19 mm). Higher heat inputs tend to reduce the diffusible hydrogen content below 1 mL per 100 g weld deposit, as seen in Fig. 17. However, the full range of heat inputs and diffusible hydrogen values can be obtained below the 1 mL/100 g weld deposit. More welds with higher heat inputs and different electrode extensions are needed to better evaluate the effect of heat input on diffusible hydrogen contents.

GMAW Metal Transfer Mode Plots

A metal transfer mode plot was made for steel metal cored wire arc welding with...
HSLA steel metal cored wire containing 1600 ppm yttrium. Welding voltages and currents were matched with their metal transfer types (globular, spray, and short circuit) and the diffusible hydrogen contents were plotted. Figure 18 shows that the spray transfer mode results in diffusible hydrogen levels below 1 mL of hydrogen per 100 g of weld deposit. Globular and short circuit transfer modes have diffusible hydrogen contents greater than 1 mL and less than 4 mL of hydrogen per 100 g of weld deposit. The spray transfer mode provides the most efficient arc for yttrium transfer to the weld metal for the formation of yttrium oxide or yttrium oxysulfide. The high frequency of small metal droplets may promote a greater surface area for yttrium to react with oxygen in the arc plasma. The globular and short circuit transfer modes, because of their less stable arc behavior, do not provide conditions for efficient yttrium transfer to the weld metal. The globular mode, with larger metal droplets and with less frequency than the spray mode, may have fewer surface reactions with yttrium and oxygen in the arc. With a smaller amount of yttrium-containing traps in the weld pool, high levels of diffusible hydrogen are observed. Yttrium oxide is identified as the residue after welding with globular and short circuit metal transfer is observed. An optimum operating window shown as a nonshaded box in Fig. 18 is shown for welds made resulting in less than 1 mL of hydrogen content per 100 g weld deposit. The spray mode is the predominant mode for this optimum operating window. The transition current and voltage for entering this optimum operating window for the low hydrogen content shown in Fig. 18 are about 385 A and 30 V. In the spray mode, yttrium is more effectively transferred across the arc that in other modes and thermal desorption analysis shows that these yttrium-containing traps have trapped a significant amount of the diffusible hydrogen.

**Conclusions**

**Hydrogen Trapping**

An HSLA steel metal cored wire with 1600 ppm yttrium can reduce the diffusible hydrogen content at 1-2 mL hydrogen per 100 g steel weld deposit.

Two irreversible hydrogen traps in HSLA steel weld metal were found to be yttrium oxide inclusion and a complex yttrium oxysulfide inclusion. Thermal desorption analysis measurements showed that yttrium oxide inclusions had an increased hydrogen content and yttrium oxide inclusions.

According to the Kissinger analysis, yttrium inclusions (yttrium oxide and yttrium oxysulfide) have binding energies of 70 and 88 kJ/mole, respectively, and both are irreversible hydrogen traps.

**Weld Parameters**

Iron fill metal cored wires showed that welding voltage and current can affect the diffusible hydrogen content in the weld metal for the given weld parameter.

High levels of yttrium addition to the metal cored wire, 3000 and 6000 ppm yttrium, resulted in low diffusible hydrogen contents, but were unaffected by weld voltage or current. However, HSLA steel metal cored wires with 1600 ppm yttrium showed that weld voltage has more influence on the diffusible hydrogen content than the weld current.

The addition of oxygen in the shielding gas with HSLA steel metal cored wire containing 1600 ppm yttrium showed an increase in diffusible hydrogen content and a reduction in the hydrogen content, according to TDA.

Metal transfer mode plots with weld metal diffusible hydrogen values show that the spray transfer mode promotes diffusible hydrogen contents lower than 1 mL hydrogen per 100 g weld deposit, whereas the globular and short circuiting transfer modes have a range of 1-4 mL hydrogen per 100 g weld deposit.

The optimum operating welding parameter range for use of yttrium trapping agents to achieve a significant low diffusible hydrogen content has been identified.

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**References**

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