WELDING Journal

October 2004

AWS

Spotlight on Brazing and Soldering

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PUBLISHED BY THE AMERICAN WELDING SOCIETY TO ADVANCE THE SCIENCE, TECHNOLOGY AND APPLICATION OF WELDING AND ALLIED PROCESSES, INCLUDING JOINING, BRAZING, SOLDERING, CUTTING AND THERMAL SPRAY

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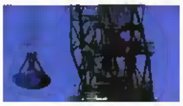

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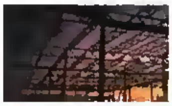

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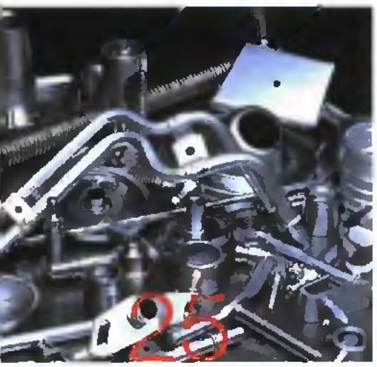

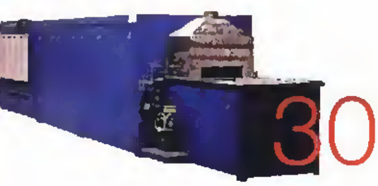

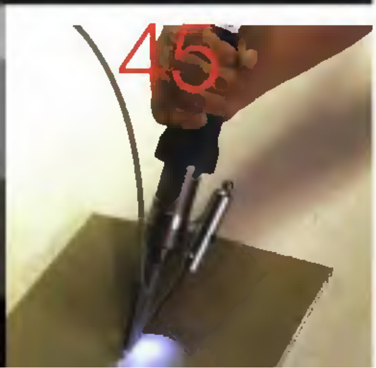

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BY HUGH K. WEBSTER
AWS WASHINGTON GOVERNMENT AFFAIRS OFFICE

Comprehensive Vocational Education Study Released

The final report of the Congressionally mandated National Assessment of Vocational Education (NAVE) has been released. The culmination of a three-year effort, the results of the report are mixed.

On the positive side, NAVE found that vocational education has important short- and medium-run earnings benefits for most students at both the secondary and postsecondary levels, and these benefits extend to those who are economically disadvantaged. Nevertheless, vocational education is an increasingly smaller share of overall high school curriculum. While there was little change in the amount of vocational course work taken by high school students during the 1990s, students earned more academic credits, therefore lowering vocational education's share of the overall high school curriculum — from 21.8% in 1982 to 17.8% in 1990 to 16.2% in 2000. Still, high school students earn, on average, more credits in vocational education (4.0) than in math (3.4) or science (3.1).

Other findings follow:

• Vocational education appeared to attract more academically talented students during the 1990s. Less progress was made on overcoming gender differences in vocational course participation.

• While results vary depending on occupational field, vocational education in community colleges appears to produce a substantial positive effect on earnings for the vast majority of participants, particularly for those who earn a degree or certificate.

• More than two-thirds of vocational majors complete the equivalent of a year or less of course work within a five-year time period; even among those who enroll with the goal of earning a degree or certificate, fewer than half actually complete a credential of any kind.

The report is available at *http://www.ed.gov/rschstat/eval/sectech/nave/index.html.*

Hexavalent Chromium Standard on Schedule

The U.S. Occupational Safety and Health Administration (OSHA) is moving forward with its proposed hexavalent chromium standard. According to a federal court order, OSHA is required to issue a proposed rule this fall and a final rule by January 2006. The agency has been receiving public comments over the past several months, and the proposed regulations should reflect those comments.

Workers in many different occupations, including stainless steel welding, are exposed to hexavalent chromium.

High Cost of Inadequate Supply Chain Integration

Billions of dollars are wasted annually by industry due to inadequacies in managing inventory, scheduling, and accounting information, most of which could be saved if there were adequate supply chain standards, according to a recent study sponsored by the National Institute of Standards and Technology (NIST).

According to the study, the lack of universally accepted and implemented standards for the format and content of messages that flow between supply chain partners reduces opportunities for cost savings and leads to duplication of effort, maintenance of redundant systems, and investment in inefficient processes such as manual entry of data when machine sources are available.

The study, which is available at *http://www.nist.gov/director/prog-ofc/report04-2.pdf*, is part of NIST's strategic planning process for implementing the 2002 Enterprise Integration Act, which authorizes the institute to help industry improve supply chain integration.

Standards Antitrust Liability Exposure Lessened

The U.S. Congress has passed, and the president has signed, legislation designed to reduce the antitrust liability exposure of standards developers. The "Standards Development Organization Advancement Act of 2003," which amends the National Cooperative Research and Production Act of 1993, will require that plaintiffs prove actual competitive harm from standards activity, and effectively limits recoveries to actual damages, rather than the treble damages that are generally recoverable under federal antitrust laws.

Organizations wishing to take advantage of these protections must file a notice with the Federal Trade Commission describing their standards activities.

At the same time, however, Congress also increased the maximum penalties for antitrust violations, raising the maximum individual fine from $350,000 to $1 million, the maximum corporate fine from $10 million to $100 million, and the maximum prison term from three to ten years.

Personal Protective Equipment Rulemaking

The U.S. Occupational Safety and Health Administration has reopened its rulemaking record on the proposed rule "Employer Payment for Personal Protective Equipment (PPE)." Due to the significant amount of comments received, OSHA determined that further information is necessary to fully explore the issues concerning paying for PPE that is considered to be a "tool of the trade."

The agency is seeking comments specifically on issues that relate to whether or how a general rule on payment for PPE should address types of personal protective equipment that are typically supplied by the employee, taken from job site to job site or from employer to employer, and considered to be "tools of the trade."

The provisions in current OSHA standards that require PPE usually state that the employer is to provide or ensure the use of PPE. Certain provisions specify that the employer is to provide PPE at no cost to the employee. Other provisions suggest that the PPE is owned by the employee, while others are silent as to who is obligated to pay for this equipment. ◆

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


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Miller Electric Ships Welding Generators to Hurricane Affected Area

As multiple storms impacted Florida in September, inventories of conventional portable generators ran out in many areas. To respond to the shortages, Miller Electric Mfg. Co. shipped 18 weeks worth of its production of welding generators to its Southeast distribution center to meet demand from homeowners for emergency power.

"Distributors in Florida and along the Gulf and Atlantic coasts are fully stocked with emergency power generators," a Miller product manager told news outlets. "There is no shortage of generators if you know where to look: welding supply distributors."

The company told consumers, most of whom have no need for the machines' welding capabilities, that the products could work as home generators for as long as needed, then could be sold with less depreciation than standalone generators.

Oshkosh Wins Marine Corps Contract for Truck Armor Kits

Oshkosh Truck Corp. received a contract of at least $72.3 million to manufacture armor upgrade kits for hundreds of Marine Corps trucks that are deployed in Iraq. The contract also covers upgrades to the suspensions and air conditioning for Oshkosh-made Medium Tactical Vehicle Replacements (MTVRs). Most of the kits will be delivered by the end of September 2005. The contract could ultimately be worth as much as $204 million if the Marines execute options for additional kits and engage Oshkosh to perform the installations.

Materials Engineer Honored at White House

Jian Shen of the Oak Ridge National Laboratory's Condensed Matter Sciences Division received a Presidential Early Career Award for Scientists and Engineers at a White House ceremony in September. A native of China, Shen's research work involves new ways to fabricate iron nanomaterials using magnetism. His award was presented by Energy Secretary Spencer Abraham.

SME Distributes Education Grants

The education foundation of the Society of Manufacturing Engineers (SME) has awarded a $207,536 grant to Alexandria Technical College, Alexandria, Minn., to teach manufacturing automation curricula to high school and postsecondary students as well as incumbent technicians. The foundation also provided grants totaling $157,000 to Farmingdale State University, Long Island, N.Y., to enhance the Long Island region's technical workforce with biotechnology and nanotechnology advanced manufacturing training.

The foundation awarded $47,435 to Arizona State University to expose engineering students to four semesters of actual work in a manufacturing enterprise.

Senators React to Proposed Cuts for Shipbuilding

Maine's senators have criticized the adminstration's plan to slash its shipbuilding budget for the fiscal year that begins October 2005. The Navy is requesting just four new vessels: a submarine, an LPD-17 amphibious ship, a T-AKE cargo ship, and a DD(X) destroyer. This is a decrease from the nine ships that are slated for the current fiscal year, and would impact employment at New England shipyards, including Maine's Bath Iron Works.

"We can't risk losing the skilled labor infrastructure that we have painstakingly built in our shipyards and across our industrial base, which would happen if we make cuts to vital shipbuilding programs," said Sen. Susan Collins (R-Maine.)

Sen. Olympia Snowe (R-Maine.) said, "As our nation continues to fight the global war on terror, now is clearly not the time to be eroding our critical military capabilities by diminishing the Navy's fleet size."

Change of Ownership for Robotic Workspace Technologies

Robotic Workspace Technologies, Inc. (RWT), Ft. Myers, Fla., has been acquired by Innova Holdings, Inc. The acquired firm will operate as a subsidiary and will continue to develop and market PC-based robot control hardware and software.

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Making the Grade

Well, another school year is under way since we visited last, and I'd like to share a "report card" of what has been accomplished in the past year through the AWS Foundation's scholarship activities.

- One hundred forty-five students benefited from a total of $110,000 in scholarships awarded through our 22 AWS Districts.
- National named scholarships were awarded to 17 students who received $2500 each.
- Four national research fellowships were granted.
- One Congressional fellowship was awarded.
- Section scholarship activities documented to date have 38 AWS Sections awarding 182 Section scholarships totaling $94,569.00.

That's a good — but modest — start, considering the urgent need in industry for engineers, scientists, technicians, managers, inspectors, educators, knowledgeable salespeople, etc. With jobs going overseas, many talented people are in transition and seeking new careers. Since the most positive thing a person can do if he or she is not working is go back to school, many people are returning to the classroom to learn a new profession — one that will lead to more opportunities and provide a steady, stable source of income. A career in the welding field can offer such an environment, and providing education scholarship resources is the the prime focus of the AWS Foundation's existence.

Educating welding professionals requires support — in terms of both time and money — from all of us. We must help industries to thrive on U.S. soil by providing the educational resources needed in this competitive market. If they cannot secure well-trained workers, companies cannot be competitive and successful in today's global environment, which demands so much but also provides so many new opportunities.

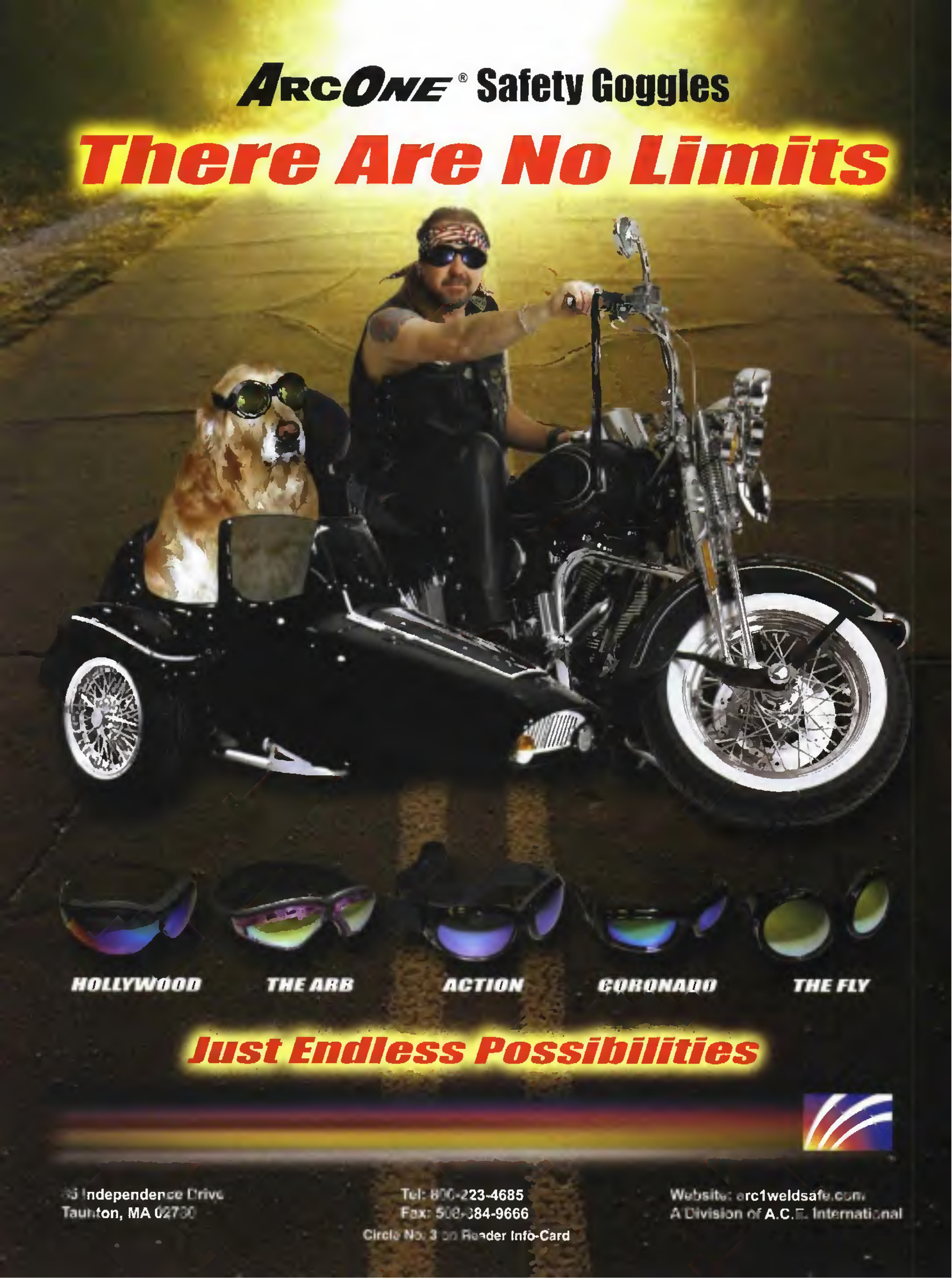
With support from the board of directors and the Foundation trustees, the American Welding Society recently enlisted the help of consultants to call on a number of its members and industry leaders. The purpose is to gather ideas and input on how to finance and develop more scholarships and fellowships, plus improve welding education in general, to help our industry be more productive.

Even many people who are directly involved in our welding and joining industry do not realize the full scope of welding's contribution — on land, sea, air, and outer space — to everyone's well-being and in our everyday lives. We are proud of what the Foundation has accomplished in its short 15 years of existence. Through our participation in the Foundation, together with industry, we can make a huge contribution to education.

We must awaken both youth and adults to the fantastic opportunities that await ambitious people in careers as welding professionals. There is such versatility in our industry. A person can select a direct hands-on approach, or choose an avenue that takes them into the furthest reaches of design, metallurgy, and engineering.

It is time for us all to make the grade. Please call the AWS Foundation today at (800) 443-9353 ext. 689 to find out how you can be a part of this extraordinary opportunity to make dreams — possibly your dream — come true.

Ronald C. Pierce
Chair, AWS Foundation Board of Trustees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Robot and Laser Orders Increased in First Half of Year

North American-based robotics manufacturers saw robot orders worldwide jump 18% in the first half of 2004 over the first six months of 2003, according to the Robotic Industries Association. A total of 8539 robots valued at $513 million were ordered by manufacturing companies through June of this year. The revenue figure is 6% higher than the first half of 2003. Auto companies and their suppliers are the largest share of the market, accounting for 65% of North American sales. New orders for arc welding robots increased 18%.

Orders for industrial laser equipment and systems jumped 60% in the first half, according to the Association for Manufacturing Technology. Cutting applications account for the largest share in the most recent period.

The association also reported a 31.9% increase in machine tool sales for the first half of the year.

Energy Dept. Working on Small Reactors for Developing Countries

The U.S. Department of Energy is developing tamper-proof nuclear breeder reactors that could meet the need for electric power generation in developing counties without posing the risk of diversion of fissile material, according to a story in the September 4 issue of *New Scientist* magazine. The proposed units would remain sealed for 30 years without service or refueling, and would be equipped with security monitoring equipment. A version producing 10 megawatts would weigh less than 200 metric tons and could be delivered by ship and truck. The unit would have steam pipes ready for connection to a turbine generator. The government hopes to have a prototype ready in about 10 years.

Researchers Want to Take Robots Off Assembly Lines, and Put Them in Unemployment Lines

A $411,000 grant from the National Science Foundation is funding research on replacing assembly-line robots with cheaper, simpler mechanical systems. Engineers at Florida Institute of Technology and the University of Dayton are developing design technologies for spatial assembly machines that will have fewer motors and require less maintenance than multiaxis robots.

Brazilian Oil Rig to Use Aluminum Extensively

The Brazilian state oil company Petrobras is constructing a semisubmersible offshore oil platform that will include South

America's first all-aluminum accommodation module. Extruded aluminum valued at $1.6 million is being produced for the rig on a custom-made 5500-ton press by an Alcoa plant in Brazil. The platform is scheduled to be completed in 2006 and will be deployed in the rich oil fields 70 miles north of Rio de Janeiro's coast.

Report Analyzes Transition to Lead-free Solder

With a European legislative deadline of July 1, 2006, looming, electronics manufacturers are racing to get the lead out of surface mount soldering. A report from consulting firm Frost & Sullivan, "World Surface Mount Technology (SMT) Roadmap" (available through *http://www.electronics.frost.com*) analyzes the trend. Alternatives to lead-based solder pastes, which are most widely used in Japan, require higher processing temperatures and 15 to 35% more energy.

Power Tool Companies Consolidate

The Swedish parent company of Milwaukee Electric Tool Corp. has acquired Chinese air tool maker Qingdao Qianshao Precision Machinery Corp., and will roll the business into its Chicago Pneumatic division in an effort to expand in Asia.

Meanwhile, power tool maker Black & Decker Corp. has agreed to purchase the power tool brands of Pentair Inc., which includes Porter-Cable, Delta, DeVilbriss Air Power, Oldham Saw, and Flex, for $775 million.

Huge Boom in Carbon Composites Predicted

A study from the consulting firm E-Composites predicts the growing market for carbon composite parts will reach $9.9 billion by 2010. The annual growth rate for the carbon fiber market has increased 12% per year on average for the last 23 years, as the material found its way into aircraft and other industrial applications. The report classifies use of carbon composites into three market segments: industrial, aerospace, and sporting goods, and predicts double-digit growth in the fuel cell, wind energy, industrial rollers, construction, and offshore markets.

Materials Lab Assists NASCAR Teams

Auto racing teams have been making pit stops at Oak Ridge National Laboratory's High Temperature Materials Laboratory, Oak Ridge, Tenn., looking for an edge on the competition. The lab has the ability to test and simulate advanced energy conversion systems, such as race cars. Technicians from Richard Childress Racing of Weldome, N.C., which has five cars on the NASCAR circuit, visited the lab for three days to test engine components to increase their performance and reliability. The lab has the capability to offer users micromechanical testing of high-temperature structural materials in a controlled environment. These services are available free to institutions and individuals conducting nonproprietary research.

Industry Notes

• A study by the Manufacturers Alliance/MAPI, a business research group, reports that manufacturing's share of the U.S.

economy has decreased in each of the five years from 1998 through 2003.

- The Kansas City, Mo., facility of Paulo Products Co. and American Brazing, Willoughby, Ohio, have received accreditation by the National Aerospace and Defense Contractors Accreditation Program for heat treating.

- Laser systems maker GSI Lumonics Inc., Billerica, Mass., posted an 89% increase in sales in the second quarter compared to the same period in 2003.

- Lincoln Electric welding expert Joe Kolasa appeared on a September episode of Speed Channel's *Two Guys Garage* to show how to avoid gas metal arc welding problems on race cars.
- General Motors has announced that it will start building Cadillac CTS sedans at its Shanghai factory, and will sell the cars in China by spring at about double their U.S. base price.

- Airgas, Inc., acquired Welding Supply House, Inc., of Lafayette, La. The acquired operation, which will be incorporated into the Airgas Gulf States regional division, had generated $3 million in sales in 2003.

- The Trumpf Group has delivered the 10,000th industrial CO_2 cutting laser of its TLF series, 19 years after the series debuted.

- Physicists at the University of Warwick in England have developed an ultrasonic crack detection technology that can potentially be incorporated into trains traveling as fast as 200 mph, to detect microscopic cracks in rails.

- Praxair, Inc., has been selected for the second consecutive year as one of 318 companies that are index components of the Dow Jones

Sustainability World Index, which tracks the financial peformance of companies that have high ratings for environmental, social, and economic commitments to global sustainability.

- Utility Trailer Manufacturing Co. will hire 100 workers in Paragould, Ark., as it invests $4 million in a new assembly line.
- DaimlerChrysler is investing $535 million in an onsite supplier park at its Jeep plant in Toledo, Ohio. The park will house three suppliers employing 3800 workers.
- Fleetwood Metal Industries will employ 100 workers at a new stamped metal Honda parts plant in Sylacauga, Ala.
- General Motors will add 300 workers to its Saturn plant in Kansas City, Mo., for the 2007 model year.
- Vanguard Mfg. will hire 100 to build hovercraft at a new plant in Cavalier, N. Dak.
- Masaba Inc. will hire 50 workers to build mining equipment at a new plant in Vermillion, S. Dak.

Do You Have Some News to Tell Us?

If you have a news item that might interest the readers of the *Welding Journal*, send it to the following address:

Welding Journal Dept.
Attn: Mary Ruth Johnsen
550 NW LeJeune Rd.
Miami, FL 33126.

Items can also be sent via FAX to (305) 443-7404 or by e-mail to *mjohnsen@aws.org*.

BY TONY ANDERSON

Q: Where can I find technical information that can help me improve my understanding of welding aluminum? Are there any useful textbooks and/or training programs available on this subject?

A: This is a fairly common question, usually asked by an individual who is moving into the welding of aluminum for the first time — typically, moving from steel fabrication, having heard that welding of aluminum is difficult or different.

Apart from being fairly common, it is also a question I like to hear, as it usually indicates that the individual is attempting to prepare for a change in environment, and is, therefore, much more likely to be successful in his or her venture.

Useful Textbooks

There are a number of publications available that address the welding of aluminum. I suggest two that I believe provide useful information for the fabricator moving to aluminum.

1) The American Welding Society's *Welding Handbook*, Eighth Edition, Volume 3, Chapter 1: Aluminum and Aluminum Alloys.

The first chapter of this ten-chapter book is dedicated to aluminum and contains excellent information about aluminum welding. If you are a member of AWS, you may have this book already on your shelf. If you haven't, you may want to acquire it along with the rest of the set. *Welding Handbook* can be ordered via a link on the Web site *www.aws.org*.

2) The Aluminum Association's *Welding Aluminum: Theory and Practice*, Fourth Edition.

If you are looking for a textbook exclusively dedicated to the practical aspects of welding aluminum, then you should seriously consider acquiring this publication.

The Aluminum Association recently published the fourth edition. This textbook is perhaps the best-recognized publication, currently in print, that relates exclusively to the welding of aluminum.

I came across a reference in a past edition of *Welding Journal*. The particular section that attracted my attention was the reference to a book review, performed by Secat Inc., and directed at the latest edition of *Welding Aluminum: Theory and Practice*.

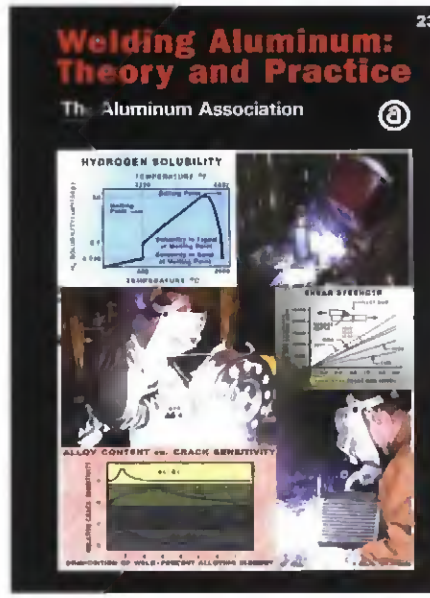


Fig. 1 — Cover of Welding Aluminum: Theory and Practice — Fourth Edition.

I would like to quote from the independent book review by Secat that I found on its Web site:

"To be competitive in the modern industrial world, a structural metal must be readily weldable." So starts The Aluminum Association's flagship publication in the area of joining, which has just been revised and published. The information it contains addresses both the "whys" and "hows" of the important processes that have partly enabled aluminum to achieve its stature as a widely used structural metal.

Welding Aluminum: Theory and Practice *has traditionally been the "go to" publication for information on joining aluminum. While it is not comprehensive in every aspect of joining, it gathers in one place the key topics. Perhaps the main accomplishment of this publication is its ability to bring together the metallurgical aspects of welding processes on a reasonably theoretical level with the practical elements of actually carrying out those processes in the real world. The book has been edited, revised, and expanded by the Aluminum Association's Technical Committee on Welding and Joining.*

The quote was taken from the initial section of the book review. The remainder continued to provide a fairly comprehensive overview of the entire book's content. I considered the book review to be favorable, which was extremely satisfying considering the hours I spent, along with other members of the Aluminum Association's Technical Committee, writing, reviewing and editing the fourth edition.

This publication has become the document that is traditionally provided to students attending aluminum welding seminars and/or aluminum welding training programs. Many welding engi-

— continued on page 16

— continued from page 15

neers and welding educators are using this book as both a technical reference document and as training material for aluminum welding technology.

If you are an engineer, a metal fabricator, a structural designer, a welder, or anyone who is serious about joining aluminum, *Welding Aluminum: Theory and Practice* is a reference that you cannot afford to be without.

Welding Aluminum: Theory and Practice can be ordered from the electronic book store at *www.aluminum.org*.

Training Programs for Aluminum Welding

Traditionally, there has been limited training in aluminum welding available compared to that available for welding steel. The more recent advancement of aluminum into the automotive industry, along with its increased use within the welding fabrication industry in general, has certainly promoted the need for additional training in aluminum welding. The requirement for welding engineers, technicians, inspectors, supervisors, and welders who have experience and technical training in aluminum welding technology has increased. Where do we find this training? Unfortunately, you will still find that the typical technical school has few, if any, formal training programs available in aluminum welding, although this situation would appear to be slowly improving. One method to help promote this change is for manufacturing organizations involved in aluminum welding to exert pressure and provide assistance to their local technical training centers to introduce training in aluminum welding. There are some well-established training programs available that specialize specifically in aluminum welding technology, and there are a few newcomers to the aluminum welding training scene. One organization that has been performing both practical and theoretical training in aluminum welding exclusively, for the last 20 years, is AlcoTec Wire Corporation. Information on its training programs is available on the Web site *www.alcotec.com*.

Summary

Because the welding of aluminum is different from welding steel, it is very wise to seek information and/or training in aluminum welding before embarking on an aluminum welding project for the first time.

Yes, there is training literature, and there are training courses available for welding aluminum. However, because aluminum welding is a smaller and more specialized section of the welding industry, there are typically fewer available than for steel. ◆

TONY ANDERSON is Technical Director of AlcoTec Wire Corp., Traverse City, Mich. He is Chairman of the Aluminum Association Technical Advisory Committee on Welding and Joining; Chairman of the AWS Committee for D10.7 Gas Shielded Arc Welding of Aluminum Pipe; Chairman of the AWS D8.14 Committee for Automotive and Light Truck Components — Aluminum; Chairman of the AWS D3.7 Guide for Aluminum Hull Welding; and Vice Chairman of the AWS Committee for D1.2 Structural Welding Code — Aluminum. Questions may be sent to Mr. Anderson c/o Welding Journal, 550 NW LeJeune Rd., Miami, FL 33126 or via e-mail at tanderson@alcotec.com.

BY R. L. PEASLEE

Q: We have been brazing 304L with BNi-2 at our facility for more than ten years. To the best of my knowledge, we have not had problems regarding corrosion resistance until we subjected an assembly to a mixture of salt fog, sulfur, nitrogen oxide, and aircraft exhaust. This mixture forms a highly acidic (pH 2.4–4.0) moisture film. Do you have any knowledge as to whether there are any electrolytic issues between 304L and BNI-2 braze material?

Fig 1 — Microphotograph of an etched 304L joint brazed with BNi-2.

A: Yes, I know about this problem; it is a result of interfacial corrosion.

Under certain conditions during brazing, as the boron in BNi-2 diffuses out of the brazed joint, it combines with the chromium in the 304L, leaving the iron free to be attacked interfacially in the base metal, along the edge of the joint. (See Fig. 1, an etched micro of a 304L joint brazed with BNi-2. The dark, heavily etched area in the base metal is the area that will be attacked by the corrosive media.) In your ten years of brazing 304L, it would appear that no corrosive media have been encountered, as is usual in most of the brazed joints of this combination.

In cases where there is sufficient base metal, the assembly can be held at the brazing temperature for longer diffusion times. The boron will then be diffused further into the base metal, leaving the chromium, which will reconstitute with the nickel and iron of the 304L base metal, preventing further interfacial corrosion.

Unfortunately, your parts are sheet metal, and there will be insufficient metal to fully diffuse the boron away from the chromium at the base-metal interface.

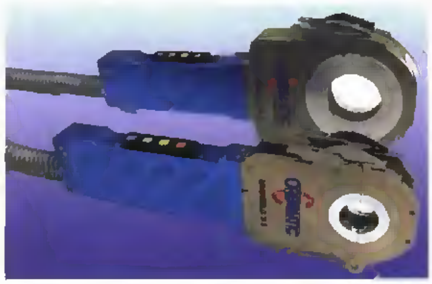
When it comes to the corrosion problem, I do not recommend the boron-containing brazing filler metals for brazing 304L, or any of the similar iron-based metals. I would recommend that BNi-5, BNi-12, which contains 25% chromium, or a more recent brazing filler metal, which is a Ni-Cr-Si-P filler metal, be substituted for the BNi-3. BNi-5 is a 19%-chromium brazing filler metal that could be substituted; however, it has a higher brazing temperature. The Ni-Cr-Si-P is a modification of the BNi-5 and has a lower brazing temperature.

Another solution is to protect the fillets and edges of the fillets where the interfacial corrosion starts, by painting or by applying electroless-nickel plating or some similar materials. Since interfacial corrosion progresses from the edge of the fillet and base metal, protection of this initiating area will prevent the attack.

I hope this answers your question about interfacial corrosion of 304L stainless steel and similar base metals brazed with brazing filler metals containing boron, when exposed to highly corrosive media. ♦

R. L. PEASLEE is Vice President Emeritus, Wall Colmonoy Corp., Madison Heights, Mich. Readers, may send questions to Mr. Peaslee c/o Welding Journal, 550 NW LeJeune Rd., Miami, FL 33126 or via e-mail to bobpeaslee@wallcolmonoy.com.

Orbital Weld Heads Designed for Limited Access Applications



Designed for welding closely packed stainless steel tubes and fittings in pipeline systems, the Orbiweld S series slim-line weld heads feature a quick-fit, snap-in collet system. The design incorporates water-cooling channels around the weld head body, and all main process functions are controlled on an in-handle panel. Suited for on-site use, applications include electronics, offshore, pharmaceutical, and aerospace industries.

Orbimatic GmbH 100
P.O. Box 416, Welbeck Way, Peterborough PE7 3FT, U.K.

Power Source Suits Pipe Welding Applications

Designed for multipass welding operations, the digital Pipemaster Model 515 can operate any of 15 weld head models, incorporating controls for torch rotation, wire feed, torch oscillation, and arc voltage control functions. It features autoranging input of 110–480 VAC, 200-A output, and a waterproof remote pendant. To create new time- or position-based weld programs, users fill in blanks with data and let the unit's program generate welding procedures.

Magnatech Limited Partnership 101
6-T Kripes Rd., P.O. Box 260, East Granby, CT 06026

Plastic Welding System Offers Automatic Tooling Protection

Featuring a rigid cast alloy column, the ultrasonic Model K35-XT welding system combines computer control, position sensing, and servomotor control to prevent accidental horn-to-fixture contact. The system enables consistently high joint strength by automatic compensation for part variations within tolerances during the weld cycle. With an operating frequency of 35 kHz and a supply voltage of

230 VAC, the system produces 900 W from a digital generator. Amplitude is programmable from 30 to 100%.

Stapla Ultrasonics Corp. 102
375 Ballardvale St., Wilmington, MA 01887

Hardfacing Wire Offered in ⅙-in. Diameter

A small-diameter, high-hardness hardfacing wire, Stoody 101HD, is designed to better match high-chemistry, hardfaced plate in aggregate, concrete, power plant, and mining applications. It is supplied on

a 33-lb wire basket and is a hybrid alloy of 101HC wire.

Thermadyne Industries, Inc. 103
101 S. Hanley Rd., Ste. 300, St. Louis, MO 63105

Multiprocess Welding Machine Available with Gasoline Engine

With its fully enclosed case, the Ranger® 250 is available with a Robin/Subaru 20.5-hp OHV gasoline engine that operates at noise levels to 101.9 dBA at full load. The unit provides 250 A DC and 275 A CV output at 100% and 60% duty cycles, respectively. The multiprocess DC machine features four welding modes, delivers 9000 W peak and 8500 W continu-

ous AC auxiliary generator power, and incorporates Chopper Technology™ for control of DC welding output.

The Lincoln Electric Co. 104
22801 St. Clair Ave., Cleveland, OH 44117

Dual-Purpose Torch Offers Flameless Heat-Gun Mode

The Microtorch® Model MT-51H functions as an adjustable torch with a 2500°F broad or pinpoint blue torch flame, and as portable flameless heat gun with temperatures to 932°F. It can be used as a handheld or tabletop, butane-powered torch with a separate heat tip and a 1-in.-diameter shrink attachment. The unit features a self-igniting switch, a hands-free slide lock, a nonslip grip, and a built-in, refillable fuel tank with 120 minutes fuel capacity.

Master Appliance Corp. 105
2420-T 18th St., Racine, WI 53403

Stud Welder Makes Welds without Reverse-Side Marring

With weld times of 0.01 s and a charge

time of under 3 s, the Capacitor Discharge (CD) 110 Stud Welder may be used for contact and gap CD stud welding. Abbreviated weld time minimizes heat buildup, resulting in minimal discoloration, burning, or reverse side dimples. The unit achieves single-sided welds with minimal distortion on materials as thin as 0.020 in. and offers 110,000 μF of user-selectable capacitance to handle up to ⅜-in. steel weld studs.

Image Industries, Inc. 106
11220 E. Main St., Huntley, IL 60142

Pre-Sintered Preforms Feature Low Porosity

Suited for high-temperature brazing applications, the company's pre-sintered preforms feature less than 2% porosity, which helps eliminate shrinkage. Curved, tapered, and cylindrical shapes are available with thicknesses from 0.010 to 0.200 in. The curved preforms eliminate a second braze cycle on convex and concave surfaces, while cylindrical preforms will not sag or overflow during brazing. Intended for dimensional restorations and crack repairs, preforms are suitable for aerospace engine components.

Morgan Advanced Ceramics 107
225 Theodore Rice Blvd., New Bedford, MA 02745

Force Sensors Suited for Material Testing

Piezoelectric force sensors measure dynamic compression, tensile, and impact forces in various applications. Offered in ICP® and charge output types, the sensors measure full-scale compression forces from 10 to 5000 lb, and full-scale tensile forces from 10 to 500 lb. ICP force sensors contain built-in microelectronics to convert a high-impedance charge to low-impedance voltage. Charge output versions are available for high-temperature applications.

PCB Piezotronics Inc. 108
3425-T Walden Ave., Depew, NY 14043

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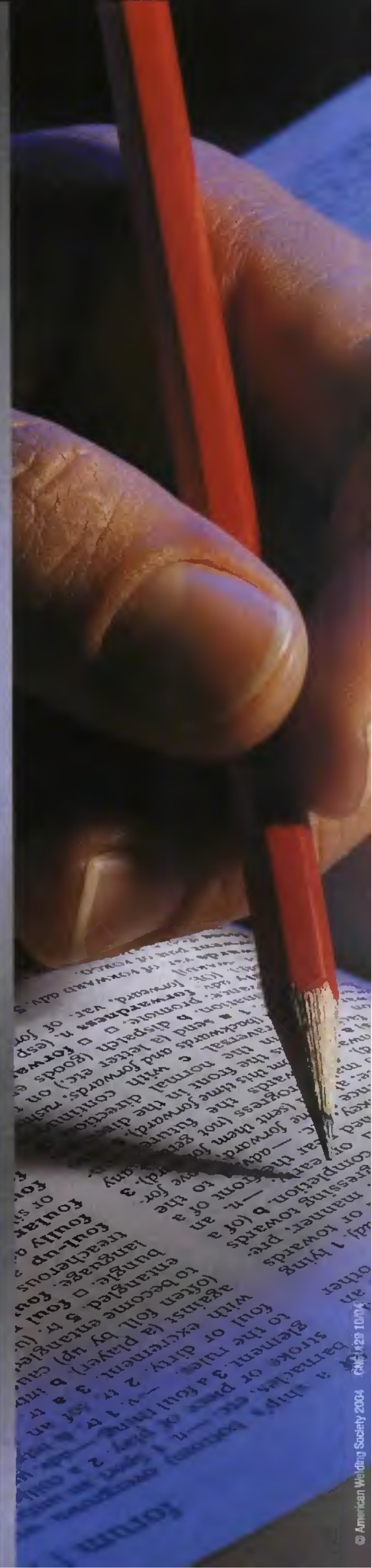

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Fig. 1 — On display are myriad components bright brazed in controlled atmosphere furnaces.

Controlled Atmospheres for Bright Brazing

Furnace brazing is often the best option for medium and large production runs

BY P. F. STRATTON AND A. McCRACKEN

One way to control the formation of oxides during brazing and also reduce oxides present after precleaning is to surround the braze area with an appropriate controlled atmosphere in a furnace. Controlled atmospheres do not perform any primary cleaning but can reduce surface oxides and promote wetting in the same way as fluxes (Ref. 1). Oxides, coatings, grease, oil, dirt, and other contaminants must be properly removed before brazing.

Kepston Ltd. of Wednesbury, U.K., has more than 25 years' experience in furnace brazing a wide variety of parts (Fig. 1).

Brazing Furnace Atmospheres

The atmospheres used at Wednesbury include pure dry hydrogen (H_2), exothermic or endothermic gas in continuous furnaces, and wet or dry H_2 in batch furnaces. This flexibility gives Kepston the ability to braze components as small as a few grams to more than 100 kg, in a variety of metals from mild steel to stainless steel, in batches from prototypes to very large production runs.

Furnace brazing is particularly applicable for high-production fabrication in continuous conveyor-type furnaces. For medium-production work, batch-type furnaces are preferable. In both types, heating is usually by electrical resistance, although other types of fuel can be used in muffle-type furnaces. The parts should be self-jigging or fixtured and assembled with filler metals preplaced near or in the joint. The preplaced filler metal may be in the form of wire, foil, powder, paste, slugs, or preformed shapes.

A Typical Brazing Application

An example of a jigged part is the fuel distributor A-pipe, manufactured for General Motors by Shalibane Engineering — Fig. 2. These AISI 304 stainless steel assemblies are brazed in a pure H_2 atmosphere in a humpback furnace. The assemblies are jigged on small stainless steel brackets to keep the joints away from the belt. In addition, a graphite sheet is sometimes placed between the assembly and the belt to prevent possible contamination of the belt from the copper brazing alloy — in paste form in this example.

Fig. 2 — These AISI 304 stainless steel jigged fuel distributor A-pipes are brazed in pure hydrogen in a humpback furnace.

The Furnace Temperature Zones

In continuous-type furnaces, several different temperature zones are advisable to provide the proper preheat, brazing, and cooling temperatures. For copper brazing, the hot zone temperatures would typically be set at 1922°, 1967°, and 1994°F, (1050°, 1075°, and 1090°C), although the final zone temperature may be raised to 2012°F (1100°C) for thicker sectioned parts.

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Based on a paper presented at the International Brazing & Soldering Conference, February 16–19, 2003, San Diego, Calif.

Fig. 3 — These self-jigging heavy elbow sections require a slow conveyor belt speed to braze properly.

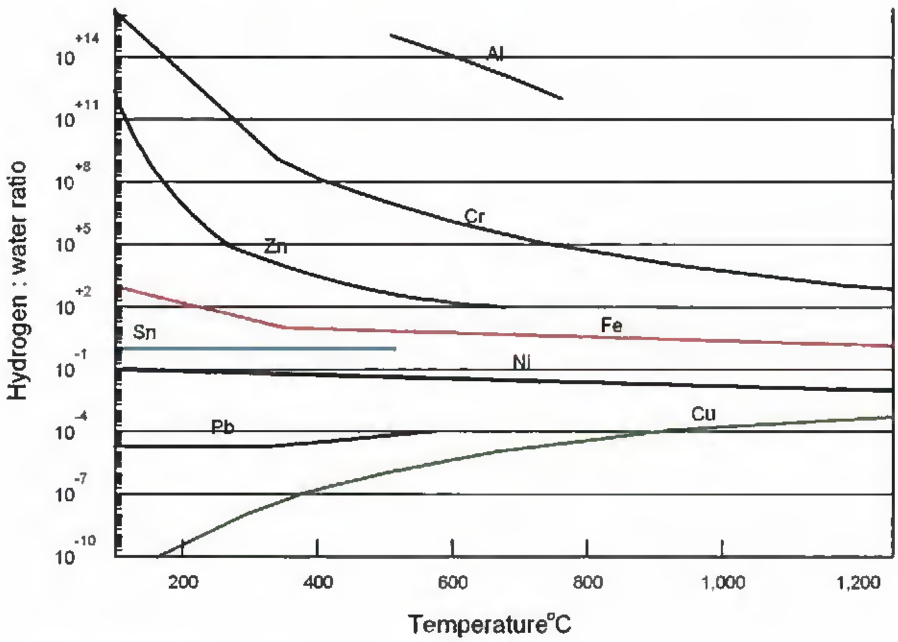

Fig. 4 — The oxidation boundaries of seven metals.

The atmosphere in each zone can be tailored to the function of that zone using BOC's Nitrazone technology (Ref. 2). The speed through a conveyor-type furnace must be controlled to allow the correct time at the brazing temperature. The speeds range from about 6 in./min (150 mm/min) for heavier sections, such as the elbows in Fig. 3, to about 20 in./min (500 mm/min) for thin-wall sections.

Critical Aspects of Furnace Loading

Furnace loading is critical for consistent results. Great care must be taken to ensure the loading is consistent, either by weighing each batch of small parts or specifying separations for larger ones. It is also necessary to support the brazing assembly properly so the part does not fall out of position while traveling through the furnace on the conveyor belt. This may require special fixtures, but most brazements are designed to be self-supporting.

An example of self-jigging parts is the mild steel hydraulic fitting brazed in a flat bed furnace using an endothermic atmosphere shown in Fig. 3. This component is often pressure tested after brazing to verify the joints are sound before shipping them back to the customer.

Induction Brazing

Controlled atmospheres are most commonly used in furnace brazing, but may also be appropriate in induction or resistance brazing. Furnace brazing requires an atmosphere to protect the assemblies from oxidation and, in the case of steels, from decarburization during brazing and also during cooling, which takes place in chambers close to, or contiguous with, the brazing furnace.

Benefits of Controlled Atmospheres

Controlled atmospheres have several advantages over the use of flux. If the job can be done without flux, there is no need for a postbraze cleaning to remove residues. A controlled atmosphere will also prevent the formation of oxides and scale on the part. Therefore, in many applications, parts can be machine-finished prior to brazing, and then go directly to a coating or plating operation without an intermediate cleaning step. Finally, the use of protective atmospheres is the only way to prevent damage from flux contamination produced by some techniques.

Effects of the Gases on Brazed Parts

All components of a controlled atmosphere make contributions to the brazing process. Hydrogen is an active agent for the reduction of most metal oxides at elevated temperatures. Hydrogen can cause embrittlement in some materials but is not usually a problem in slow-cooled products such as brazements. Carbon monoxide (CO) is an active reducing agent for some metal oxides such as those of iron, nickel, cobalt, and copper at elevated temperatures, but CO is toxic and must be handled with care (Ref. 3). This gas can serve as a source of carbon through cracking in the cooling zone of the furnace to form free carbon on the surface of the brazement. This may be useful in brazing some carbon steels but is undesirable in other applications.

Carbon dioxide (CO_2) is both an oxidant and a decarburizing agent for steels. It will oxidize iron, and some alloying elements such as chromium, manganese, and vanadium.

Nitrogen used as a diluent in the brazing section of a furnace allows the proportion of H_2 in the mixture to be kept below the explosive level. As a straight atmosphere, nitrogen does not react with most metals and will therefore prevent oxidation during cooling. At high temperatures, nitrides may be formed in susceptible materials such as stainless steels.

Water vapor is both an oxidant and a decarburizing agent for steels. The reducing ability of an atmosphere containing H_2 depends primarily on the H_2 to H_2O ratio, which must exceed 10 to 1 if the atmosphere is to be reducing to steels, and must be even higher for other elements such as chromium — Fig. 4. The amount of water in any atmosphere is given by its dew point, i.e., the temperature at which the moisture in the gas will condense.

Oxygen in the brazing atmosphere is always undesirable.

Methane may come from the atmosphere gas as generated or from organic materials left on the part by inadequate cleaning. It can serve as a source of carbon and hydrogen.

Sulfur or sulfur compounds may be an unintentional contaminant in the atmosphere and can react with the base metal to inhibit wetting. They usually come from contaminated fuel gases.

Inorganic vapors such as zinc, cadmium, lithium, and fluorine compounds can serve to reduce metal oxides and scavenge oxygen from the atmosphere. They are useful to replace constituents of alloys that are formed during brazing. Such vapors are also toxic, and proper safety precautions should be taken.

Inert gases such as helium and argon form no compounds with metals. They inhibit the evaporation of volatile components and permit the use of weaker retorts than are required for vacuum processes.

Vacuum Brazing Is Most Expensive

A vacuum process removes essentially all gases from the brazing area and therefore eliminates the need for purifying the supplied atmosphere. It is, however, the most expensive option. Certain base metals, such as stainless steels, superalloys, and aluminum alloys, have oxides that will dissociate in the vacuum at brazing temperatures. A vacuum also prevents difficulties sometimes experienced when gases given off by the base metal contaminate the joint interface. The low pressure also removes volatile impurities from the base and filler metals. Vacuum brazing is particularly useful in the aerospace, electronics, and nuclear fields, which may use metals that react chemically with reducing atmospheres or cannot tolerate entrapped fluxes or gases (Ref. 4).

Some Conclusions

The only components of the usual brazing atmosphere that act as fluxes or reducing agents are H_2 and CO. All other constituents are either neutral or may even promote reactions potentially harmful to the service life of the brazement.

Even more significant is the fact that the absolute levels of H_2 and CO are not critical. What counts is the ratio of H_2 to H_2O and the ratio of CO to CO_2 (Ref. 5). These two ratios alone determine the reducing capacity of the atmosphere. Of the two gases, H_2 is more reactive than CO, and the H_2 to H_2O vapor ratio is most critical as far as the fluxing capability of an atmosphere is concerned.

Fig. 5 — Shown is a copper-brazed mild steel select lever assembly.

Fig. 6 — Copper-brazed piston assemblies.

Fig. 7 — Bright-brazed AISI 304 stainless steel water pressure assemblies.

The ability of an H_2-containing atmosphere to reduce metal oxides depends on the temperature, the oxygen content (measured as dew point), and the pressure of the gas. Since most furnaces operate at atmospheric pressure, only temperature and dew point play a part. For the more reactive metals, the higher the processing temperature, the higher the dew point (or oxygen content) that can be used — Fig. 4. In other words, the higher the brazing temperature, the lower the H_2 to H_2O ratio can be for any given metal. Or, to put it yet another way, the reducing capacity of a given amount of H_2 increases with temperature.

The selection of the H_2 to H_2O ratio depends on which oxide is to be removed. If copper is to be brazed to stainless steel, for example, then a ratio suitable for reducing chromium oxide must be selected. Also, sufficient time must be allowed for the reducing action to take place. Even when brazing steels, high-H_2 exothermic atmospheres are required, particularly when the dew point of the atmosphere is high.

Exothermically Generated Atmospheres

Many brazing atmospheres are produced from the products of combustion of a hydrocarbon fuel. The most common are exothermic atmospheres where the burning of metered mixtures of hydrocarbon fuel gas and air generates sufficient heat to maintain the reaction. An exothermic atmosphere containing small quantities of H_2 and CO is the least expensive of the generated atmospheres. It reduces adequately for many applications, has a relatively low sooting potential, and requires a minimum of generator maintenance. Because the gas usually has a high dew point (water vapor content), it reacts with residues from brazing pastes and eliminates the small amounts of soot that

Fig. 8 — Copper-brazed solenoid guide tubes.

Fig. 9 — Nitrogen-hydrogen-brazed power steering subassemblies.

might otherwise be formed. The majority of brazing atmospheres are exothermic, and they are generally used to braze mild steel or low-carbon steel.

Exothermically generated atmospheres have certain drawbacks. They are flammable, and they are toxic due to the CO content. They are also decarburizing to medium- and high-carbon steels, and cannot be used where decarburizing must be avoided.

Endothermically Generated Atmospheres

If the ratio of fuel gas to air is high enough, the reaction becomes endothermic and requires the addition of heat and a catalyst for combustion to occur. Endothermically generated atmospheres are more reducing than exothermically generated ones but are more expensive to produce. They have a high CO content and can therefore be carbon neutral to medium- and high-carbon steels although they can also be used for mild steels. Their high reducing capability makes them suitable for a fairly wide range of metals and alloys.

Take, for example, the select lever assembly manufactured by West Bromwich Spring for Ford — Fig. 5. This mild steel assembly is brazed using a copper paste at three different joints in an endothermic atmosphere. Because the metal is mild steel, the carbon content of the atmosphere and the component are in balance and no additions are needed to control carbon potential. There are big variations in cross-sectional area, so this part would be difficult to process in a single-zone furnace. A three-zone furnace, with the first two zones set below the melting point of the copper to act as a preheat can be used. The parts then enter the third zone, which is only 18°–27°F (10°–15°C) above the melting point of copper. This means the time at final temperature is minimized, giving excellent control over the flow of the copper.

Another example is the mild steel piston assembly brazed for Jebron Door Closures. In this assembly, shown in Fig. 6, the rack has a copper shim under it and copper paste is placed on the end plates. Care must be taken when processing components with such wide variations in cross section. The braze alloy can melt, a fillet can form, but capillary flow can be limited because the thicker section has not reached the brazing temperature.

High-H_2 Atmospheres

Dissociated ammonia has a high H content and is therefore a very reducing atmosphere. It is used mostly in brazing stainless steel or other nickel alloys. However, ammonia is extremely toxic and its use is discouraged by legislation in many countries. Mixtures of nitrogen and H_2 or 100% H_2, depending on the reducing power required, have largely supplanted the use of dissociated ammonia.

Hydrogen is relatively expensive, so everything is done to reduce the quantity consumed. A humpback furnace can reduce the total flow of H_2 needed (Ref. 6), requiring some 30% less gas flow than a conventional flat bed furnace. BOC Nitrazone technology also reduces the proportion of H_2 used, with high H_2 used in the hot zone only, and high nitrogen at the ends of the furnace.

One of the components treated in such a furnace at Kepston is a water pressure assembly manufactured by Shalibane Engineering Ltd. for Audi AG. The AISI 304 stainless steel components are brazed in a 100% dry H_2 atmosphere using an internal copper ring. It can clearly be seen from Fig. 7 that the result is a bright, well-brazed part. These assemblies are jigged on stands to ensure consistency of throughput and assist with the flow direction of the internal copper ring. The stands also make inspection easier.

Pure H_2 atmospheres are equally suitable for brazing steels other than stainless steels. In the example shown in Fig. 8, the solenoid guide tube assembly, destined for an off-highway application, consists of both AISI 304 stainless steel and mild steel. The surfaces are so bright that is difficult to tell the steels apart.

Nitrogen-based Atmospheres

A nitrogen-based atmosphere is applicable in furnace brazing whenever exothermic gas, endothermic gas, or dissociated ammonia can be used as the reducing agent. There are several advantages to a nitrogen-based atmosphere. First, cryogenic nitrogen has a very low dew point. In other words, it is a very dry gas, and when H_2 (from a liquid or compressed gas supply) is added, the resulting H_2 to H_2O ratio is relatively high. That makes for a high reducing capacity or good fluxing. Furthermore, if a nitrogen-based atmosphere is used, the amount of H_2 required is usually below the explosive limit of the mixture (4.9%).

One example of the use of such an atmosphere, in this case nitrogen-5% H_2, is the brazing of power steering subassemblies, shown in Fig. 9. These mild steel assemblies, manufactured by Roulunds Codan for Renault, are brazed using a copper paste. In this case, the valve is assembled onto the tube using a dedicated assembly tool just prior to brazing, thus avoiding any problems associated with the transport of preassembled brazements.

Another advantage of a nitrogen-based atmosphere is that no chemical flux is needed if its main purpose would have been to reduce oxides in atmospheres with low reducing power such as exothermically generated gas. The use of fluxes requires larger joint clearance, to allow flux to escape and be displaced by the filler metal. This may produce a weaker joint. There is also the additional task of removing flux residue after brazing.

A particular advantage of a nitrogen-based atmosphere is that it can be tailored to provide just the right level of reduction, depending on the metal being processed or the stage within the brazing cycle. For example, it may be desirable to have a slightly oxidizing atmosphere in the preheating section of a furnace to help burn off organic compounds in paste-type filler metals. The brazing section of the furnace may need a strong reducing atmosphere; one may want the CO to CO_2 ratio to change with temperature changes at different points of the furnace to maintain a neutral atmosphere. Also, the type of atmosphere can have a detrimental effect on furnace components by, for example, carburizing the metal belts. Accordingly, BOC provides for adjustments in furnace atmosphere composition either by introducing different compositions at different points in the cycle or, in the case of continuous furnaces, in the different zones.

Summary

Controlled atmosphere furnace brazing is the optimum technique to process large volumes of assemblies. The atmosphere performs many functions, and the choice of atmosphere requires a knowledge of the entire brazing process. The use of pure gases, particularly where atmosphere zoning is applied, often gives the best results, as can be seen from the excellent results obtained by Kepston in partnership with BOC.

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Modern Brazing of Stainless Steel

BY STEPHEN L. FELDBAUER

Brazing stainless steel becomes more economical and efficient with the use of advanced furnace design and control

STEPHEN L. FELDBAUER (sfeldbauer@abbottfurnace.com) *is with Abbott Furnace Co., St. Marys, Pa.*

Atmosphere integrity and control are key to the successful brazing of stainless steel components. Due to the very high affinity that stainless has for oxygen at high temperatures, the presence of oxygen or moisture in the furnace will oxidize the surfaces to be brazed and result in a defective braze. Vacuum furnaces and humpback furnaces have been the traditional systems used to braze stainless steel because of their ability to ensure a very low oxygen partial pressure in the atmosphere. However, both furnace technologies bring with them issues that result in higher operational costs, increased maintenance costs, and other process-related costs that can be avoided by using straight through, continuous belt furnace technology. Recent advances in furnace design and atmosphere control have made it possible for stainless steel to be brazed in straight through, continuous belt furnaces. This step forward in technology now permits continuous processing at lower operational costs, less maintenance, and higher yields than realized with traditional brazing systems. Oxygen levels of less than 10 ppm and dew points as low as –85°F are common in a state-of-the-art straight through, continuous belt brazing furnace. The adoption of this technology by some of the leading producers of brazed components has allowed the industry to move forward in becoming more competitive.

Surface Cleanliness

A brazed joint is formed by the filler metal melting and flowing via a capillary effect into the pores of the closely fitted surfaces of the joint to form an alloy of the metals upon solidification — Fig. 1.

The key to successfully achieving a good brazed connection is surface preparation. The presence of contaminants or oxides prevents the filler metal from coming into contact with one of the surfaces to be brazed. In the case of minor oxidation, the pores of the surfaces to be brazed will be sealed by the oxide. As illustrated in Fig. 2, this prevents the capillary action and, ultimately, the brazing from occurring. Hence, the initial cleanliness of the surfaces to be brazed is extremely important, but it is equally important that the cleanliness of these surfaces be maintained during the brazing process.

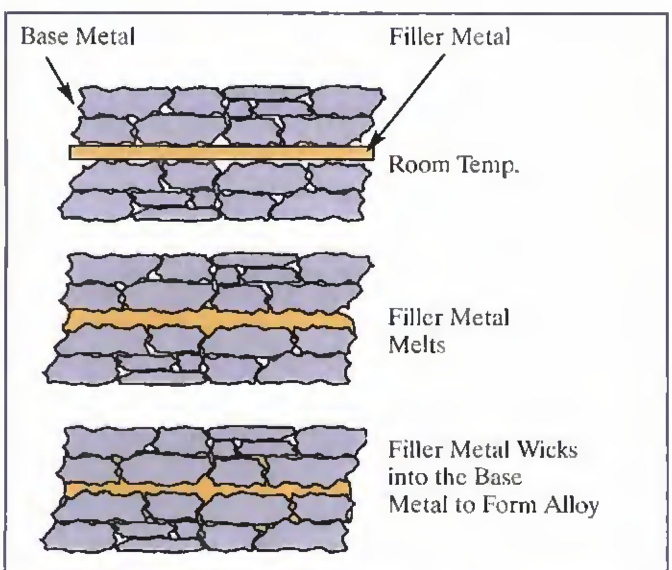


Fig. 1 — Schematic of brazing process.

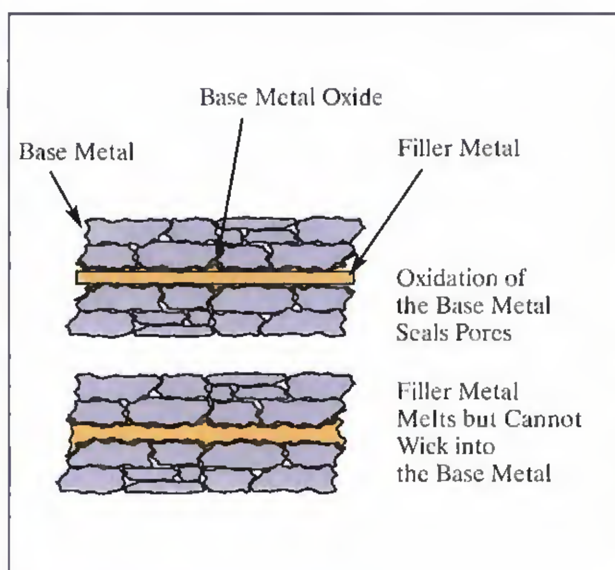


Fig. 2 — Effect of oxidation on brazing.

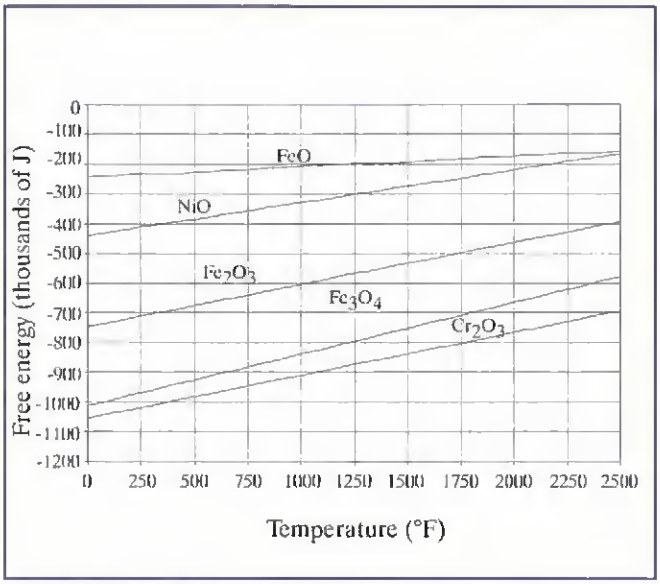


Fig. 3 — Oxide stability.

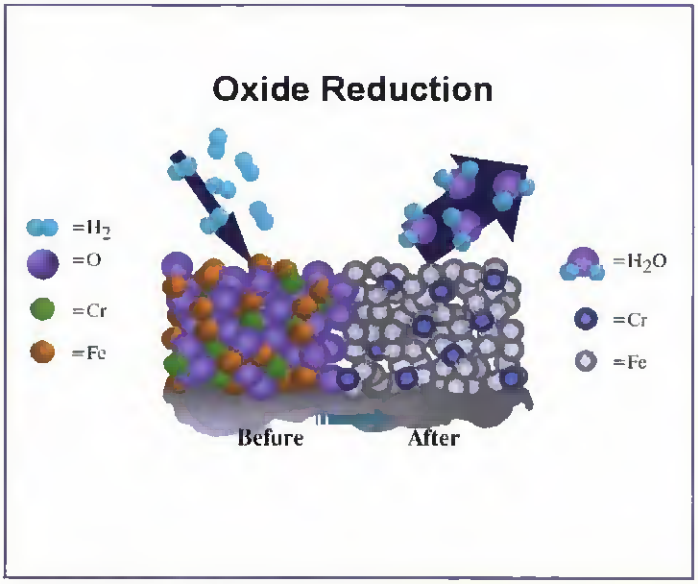


Fig. 4 — Oxide reduction mechanism.

Cleaning Stainless Steel

Achieving and maintaining the necessary level of cleanliness is much more difficult for brazing stainless steel components than brazing steel components. The chromium in the stainless steel forms a much more stable oxide at a much lower oxygen level than iron. The free energy of various oxides is shown as a function of temperature in Fig. 3. The lower the free energy, the more stable the oxide is and more difficult it is to reduce.

The oxides present on the surface must be reduced prior to the part reaching the melting temperature of the filler metal. In a vacuum system, the reduction is achieved by reducing the partial pressure of oxygen at an elevated temperature.

$$Cr_2O_{3\,(s)} \rightarrow 2Cr_{(s)} + \tfrac{3}{2}O_{2\,(g)}$$

The partial pressure of oxygen must be below 10^{-21} atmospheres for the oxide to be reduced at 1900°F. In a humpback furnace and a straight through brazing furnace, the reduction is typically achieved through a reaction of hydrogen with the oxygen present in the oxide to form water vapor — Fig. 4.

The presence of too much water vapor or oxygen in the system will prevent the reaction from proceeding. The dew point is used to determine the amount of water vapor in the system at given conditions. The dew point is the temperature at which an amount of water vapor in the system will saturate the atmosphere. Figure 5 shows the equilibrium dew point as a function of temperature for carbon steel and stainless steel. An atmosphere that has a dew point below the equilibrium dew point for a given temperature will result in the reduction of the oxide.

The typical dew point required for brazing stainless steel joints in hydrogen is –50° to –55°F. Although the temperature at which most stainless steel brazing furnaces are set is ~2070°F, the time at which the oxides must be reduced is when the parts are approaching the maximum temperature. Hence, the dew point must be below the equilibrium value at ~2000°F.

Equipment

The equipment used to braze stainless steel has changed over the years. These changes have been a result of technological advancements in the areas of atmosphere control and furnace design.

The traditional method of brazing was to use a vacuum furnace. The low oxygen level was achieved by removing the atmosphere from the furnace while heating up the components to be brazed. The lack of atmosphere eliminated the opportunity for oxidation of the stainless steel and reduced any oxides that were already present on the surface of the base metal.

Although effective, this method of brazing has a number of disadvantages. The capital cost of a vacuum furnace is two to four times that of competing technologies. The process is a batch process. The furnace must be heated and cooled with each batch of product. The result is wasted time and energy due to the large mass of the vacuum furnace. The reduced volume of production and the significantly higher capital cost for such a system make it more applicable to high-value niche products.

To braze larger volumes of products, the continuous belt furnace is used with a reducing atmosphere. The most common gas used in these atmospheres is hydrogen. If the amount of oxygen that is entering the furnace is small, the hydrogen can react with it and prevent the oxidation of the base metal.

Furnace Types

There are two types of continuous belt furnaces: the humpback furnace and the straight through, continuous belt furnace.

In the past, the humpback furnace was the most common method of continuous stainless steel brazing because the arched form of the muffle took advantage of the very low density of the hydrogen in relation to that of oxygen. The stratification of the atmosphere inside the furnace provided a very low dew point for the control of the oxides and effective brazing — Fig. 6.

The humpback furnace affords the producer the ability to braze larger volumes of product with equivalent quality, higher production rates, and higher thermal efficiency than the vacuum furnace.

The disadvantages of the humpback furnace are twofold. The height of the product must be restricted to ensure that the hump is effective in maintaining the seal through the stratification of the atmosphere. As well, the hump presents many problems with respect to product tipping and general furnace maintenance.

A straight through, continuous belt furnace (Fig. 7) avoids many of the issues presented by the hump in the humpback furnace. The belt rides on a horizontal surface throughout the furnace. Product stability and height issues are minimized

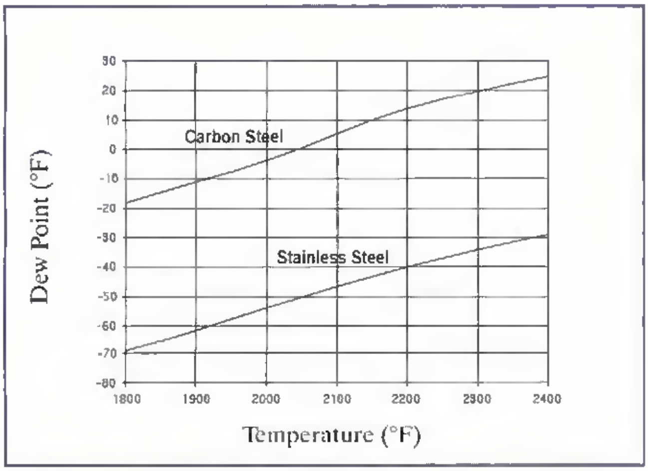


Fig. 5 — Dew point requirements.

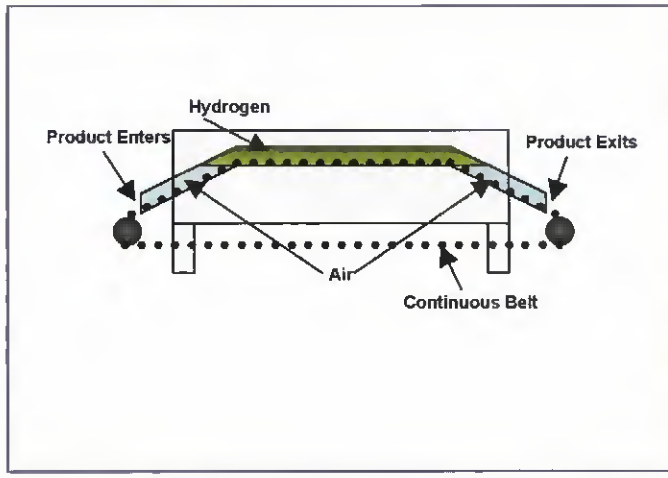


Fig. 6 — Schematic of humpback furnace.

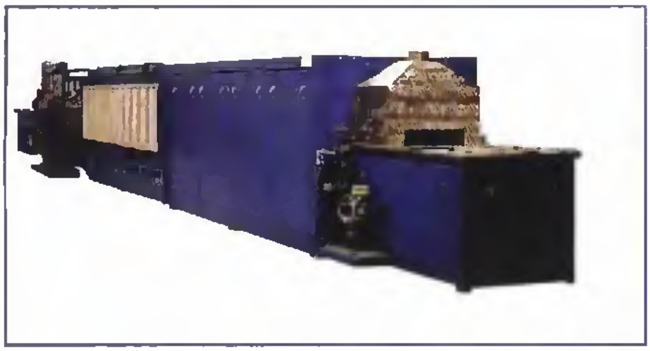


Fig. 7 — Straight through, continuous belt furnace from Abbott Furnace Co.

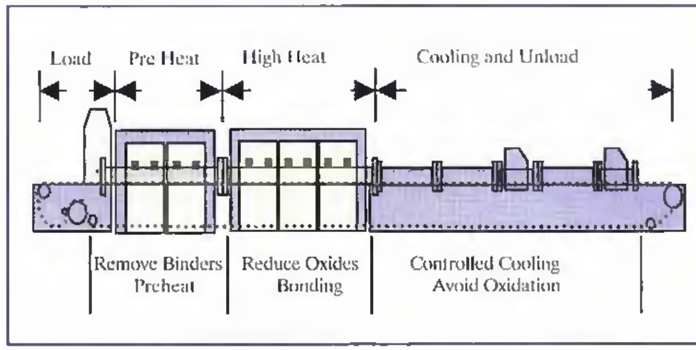


Fig. 8 — Schematic of a straight through, continuous belt furnace.

along with the added maintenance that is seen in the humpback furnace.

Until recent years, it was thought that the atmosphere and dew point could not be controlled to a level sufficient to braze stainless steel in a continuous belt furnace without the use of a flux. Due to advances in atmosphere technology and furnace design, this is now a very common approach to brazing stainless steel without a flux.

Successful Control of the Process

Controlling the time, temperature, and atmosphere relationship that is experienced by the product is the ultimate key to this process. Figure 8 illustrates the various zones and the function of each zone of the straight through furnace. The preheat section brings the product to the brazing temperature while removing any binders in the paste. The high heat section is where the oxides on the surface of the base metal are reduced and the filler metal melts to form the braze joint. Finally, the cooling must be done in such a way that there is no distortion or oxidation of the product.

Due to the many zones of control in this type of furnace, the temperature and the atmosphere may be varied throughout the furnace to optimize the brazing process. Each step of the brazing process is dealt with separately. The temperature and atmosphere needed for each of these steps are provided for the appropriate amount of time to reach completion.

Optimal atmosphere control is achieved through zoning, composition, multiple injection points throughout the furnace, flow rate, and overall directionality of the atmosphere flow in the furnace. Approximately 80 to 90% of the total atmosphere that is introduced into the furnace should flow toward the front of the furnace. Forward atmosphere flow provides optimal heating and a minimization of atmosphere usage to flush any volatiles from the product.

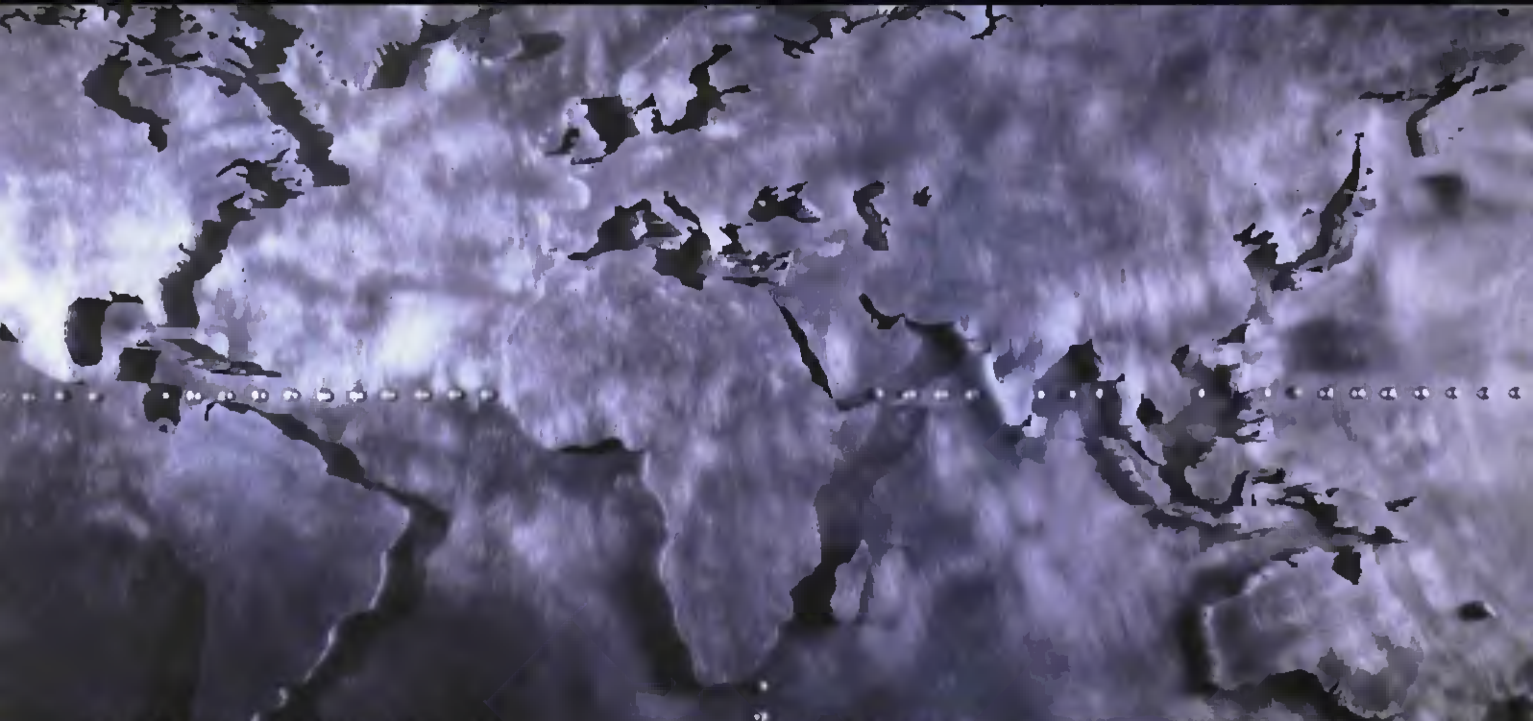
Understand the Variables

Important variables that must be considered in making such a system are quality of the construction, selection of the appropriate sealing materials, and incoming atmosphere integrity. Once a very pure atmosphere has been delivered to the furnace, the purity of the atmosphere must be maintained throughout its use. Mechanical additions to the furnace in the form of curtains and uniquely designed stacking aid in this control.

Advancements in the area of muffle design and muffle composition have greatly improved the performance of these systems. No longer are designers restricted to steel as the primary material for muffles. Advanced ceramics, with their many desirable properties of thermal stability and wear, are now common materials for muffles.

Summary

Advancements in materials, manufacturing techniques, furnace designs, and a better understanding of the stainless steel brazing process have made it possible to take advantage of the lower cost and higher throughput of a straight through, continuous belt furnace, providing brazing houses with another tool to become more competitive. ◆



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Postweld Heat Treatment Is Critical to Refurbishing a Wellhead Housing

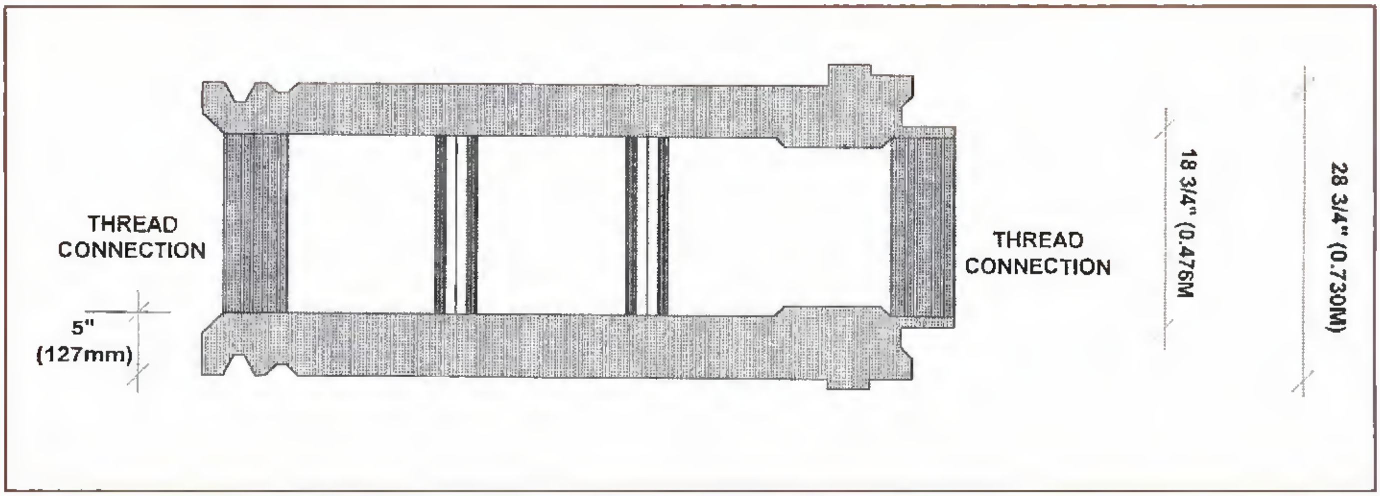

Fig. 1 — Schematic of high-pressure wellhead housing.

The cumulative effect of stress relieving and PWHT cycles proves detrimental to the required material properties

BY J. R. STILL and V. BLACKWOOD

Owing to the costs involved in manufacturing equipment for subsea production sites, it is common practice for operators to remove equipment from abandoned wells for reuse. This involves removing and examining each item to establish the work required for refurbishing. Depending on the damage sustained during production, this may warrant repair by buttering and machining, although the capacity of the wellhead would be downgraded. One process within the refurbishing program considered critical to the integrity of the wellhead is the practice of postweld heat treatment (PWHT).

To establish that the properties after PWHT and buttering would meet the downgraded requirements, a contractor proposed to carry out bead-on-plate weld procedure trials, heat-treated at selective temperatures. Depending on the results of this initial trial, weld procedures would also be carried out to verify that the mechanical properties of the refurbished wellhead housing were not impaired. However, the manufacturer involved in refurbishing the wellhead housing failed to realize the cumulative effect that the combined stress relieving and PWHT cycles would have on the material properties. In this instance, attempts to restore a wellhead housing by buttering and subsequent PWHT failed to achieve the minimum yield strength, resulting in the unit being scrapped.

Wellhead Housing History

A wellhead housing was removed from an abandoned subsea well, which on examination revealed extensive damage due to corrosion and erosion to the internal surface. The equipment in question was an 18¾-in.-diameter wellhead body rated at 15,000 lb/in.^{2} and manufactured from AISI 8630 (Ref. 1), an example of which is illustrated in Fig. 1. Owing to the damage caused by corrosion during production, the inside surfaces of the wellhead contained areas that were under the minimum wall thickness. The practice adopted by the operator was to either scrap or refurbish the wellhead housing, which involved downgrading the unit to 10,000

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Table 1 — Chemical Analyses of Forged Wellheads

Cast No.	C	Si	S	P	Mn	Ni	Cr	Mo	V	Al	Cu	CEV	Heat Treatment	Steelmaking
A See Note 1	0.28	0.24	0.012	0.012	0.87	0.74	0.73	0.42	0.04	0.17	0.05	0.725	Normalize 899°C 7 h air cooled Quench 871°C 5 h water cooled Stress Relieve 690°C 9.5 h air cooled	Electric arc and vacuum degassed
B (See Note 2)	0.28	0.27	0.006	0.013	0.83	0.69	0.93	0.39	0.02	0.03	0.24	0.748	Normalize 900°C 7 h air cooled Quench 880°C 9 h water cooled Tempered 680°C 10 h air cooled	Electric arc and vacuum degassed

Note 1: A — Original wellhead material.
Note 2: B — Forged material for weld procedure trials.

lb/in.[2]. However, the manufacturer claimed that a procedure was available to restore the wellhead housing to its original integrity of 15,000 lb/in.[2]. A decision was taken by the operator to allow the manufacturer to proceed at its risk and cost to demonstrate that its proposals would reestablish the original integrity of 15,000 lb/in.[2] yield.

An example of a new 18¾-in.-diameter wellhead housing attached by welding to a conductor structure is illustrated in Fig. 2. Figure 2 also illustrates the complex threading arrangement within the bore of the wellhead housing. Thickness of wellhead housing ranged from 5 to 7 in., depending on the service conditions.

Weld Procedure Trials

The manufacturer's proposals involved two stages. The first stage concerned bead-on-plate trials to establish the mechanical properties at specified PWHT temperatures and times. Depending on the results of the first stage, the second stage would involve qualifying butt joint weld procedures for repairing the internal damage to the wellhead housing.

Material selected for the first stage involved removing a 12-in. section from a wellhead forging. Details of the bead-on-plate trials are illustrated in Fig. 3. The forged material selected for the first stage trials was of similar composition, heat treatment, and mechanical properties as outlined in Tables 1 and 2, respectively. Welding processes used for the bead-on-plate trials involved shield metal arc welding (SMAW), submerged arc welding (SAW), and gas tungsten arc welding (GTAW). Procedures to be used for the bead-on-plate trials were based on the parameters selected for welding the full penetration butt joint weld procedures for qualifying the buttering technique.

Table 2 — Mechanical Properties of Forged Wellheads

Wellhead Material	Yield Strength (N/mm²)	Tensile Strength (N/mm²)	Charpy Impact Test Temperature (°C)	Location of Charpy Impact Test	Absorbed Energy (joules)
A	625	758	–30	¼t	43—52–38
B	591	746	–30	¼t	67—75–74

t = thickness

Buttering Welding Procedures

The following weld procedures were qualified in accordance with ASME IX (Ref. 2):

WP 01 — Welding process: SMAW and SAW

WP 02 — Welding process: GTAW and SAW

Details of weld consumables, welding parameters, and run sequence are listed in Fig. 4. Preheat temperature was controlled at 250°C and interpass temperature was 350°C. All welding consumables were stored and handled in accordance with the manufacturer's recommendations.

The Effect of Postweld Heat Treatment on Bead-on-Plate Trials

The segment removed from the wellhead forging was split into four test blocks identified as A, B, C, and D. Each test block was PWHT at the following temperatures with the exception of block A, which was retained to verify the mechanical properties in the supplied conditions.

Segment B 677°C 6 h
Segment C 670°C 7 h
Segment D 670°C 10 h

In order to compare the effect that PWHT had on the properties of Segments B, C, and D with the properties of the supplied forging, Segment A was subjected to mechanical tests as outlined on Fig. 3. The results achieved from Segment A recorded yield strengths of 82,500 and 82,900 lb/in.[2], whereas Segment C, which produced the highest mechanical proper-

Fig. 2 — Wellhead housing.

Table 3 — Weld Procedure Mechanical Properties

Weld Procedure Number	PWHT	Tensile Properties All Weld 0.2% PS N/mm²	All Weld UTS N/mm²	Cross Weld UTS N/mm²	Cross Weld UTS N/mm²	Charpy Impacts Location	Temp °C	Joules	Hardness Survey (Rockwell C) Cap	Middle	Root
WP 01	Temperature	619	697	643	595	Weld Center	–30	96-98-96	20	<18	<18
	670°C							Av. 97	20	19	21
	Time					Weld Interface	–30	89-126-163	<18	<18	<18
	4 h							Av. 126	18	<18	21
		lb/in.²	lb/in.²	lb/in.²	lb/in.²	WI + 2 mm	–30	155-162-144	18	19.5	<18
								Av. 155	20	<18	
		89,775	101,087	93,255	86,294			20			
						WI + 5 mm	–30	156-152-144			
								Av. 151			
WP 02	Temperature	729	879	818	802	Weld Center	–30	46-48-52	19.5	<18	<18
	670°C							Av. 49	20	19	20
	Time					Weld Interface	–30	59-54-40	<18	<18	<18
	4 h							Av. 51	<18	<18	18
		lb/in.²	lb/in.²	k lb/in.²	lb/in.²	WI + 2 mm	–30	134-140-143	<18	19.5	<18
								Av. 139	20.5	18	
		104,892	127,483	118,636	116,316	WI + 5 mm	–30	139-139-140			
								Av. 140			

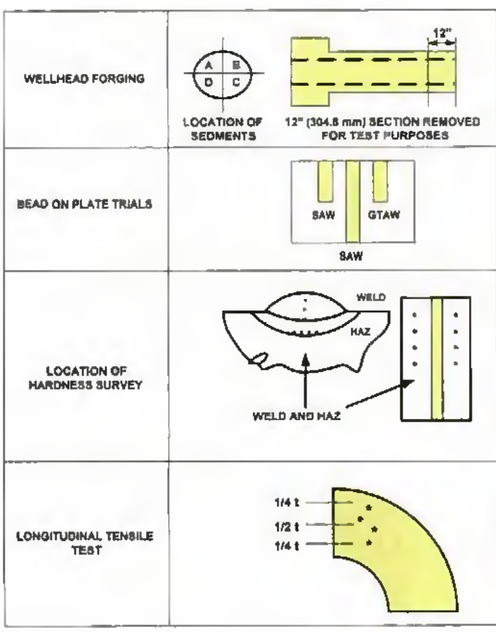

Fig. 3 — Location of tensile test and weld, HAZ, and forging hardness survey.

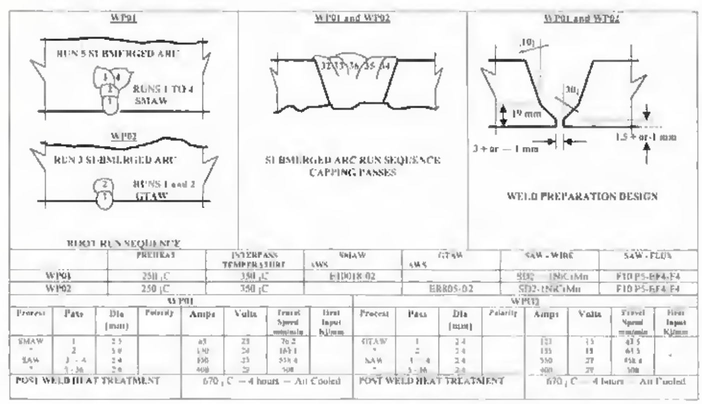

Fig. 4 — Welding procedures.

ties after PWHT, recorded yield strengths of 80,100 and 81,800 lb/in.², respectively. Brinell tests recorded a value of 228 for Segment A, whereas Segment C recorded a value of 217. Concern was expressed to the manufacturer that the yield strengths recorded for both Segments B and C were significantly lower than the 85,000 lb/in.² minimum yield strength requirement.

Postweld Heat Treatment of Butt Joint Weld Procedures

The manufacturer was confident that the material properties and PWHT applied for the weld procedures WP 01 and WP 02 would be sufficient to achieve the 85,000 lb/in.² minimum yield strength. The applied PWHT was based on Segment C PWHT, i.e., 670°C for 7 h, air cooled. The mechanical properties achieved are outlined on Table 3. The results in this instance for both joint and weld metal tensile were well above 85,000 lb/in.². Based on the results of the procedure test, the manufacturer proposed to refurbish the wellhead housing. However, the operator insisted, prior to repair, that the PWHT applied during manufacture of the wellhead housing must be verified from the manufacturing records.

Review of Stress Relieving and PWHT Records

To determine that the heat treatment applied during manufacture of the wellhead forging and the subsequent PWHT of the wellhead housing was correct, a review of the manufacturing records was carried out. It was identified that weld repairs to the ring groove inlays and a nozzle attachment had been carried out but not reported to the operator. The manufacturer could not substantiate that the repairs had been PWHT, which is required

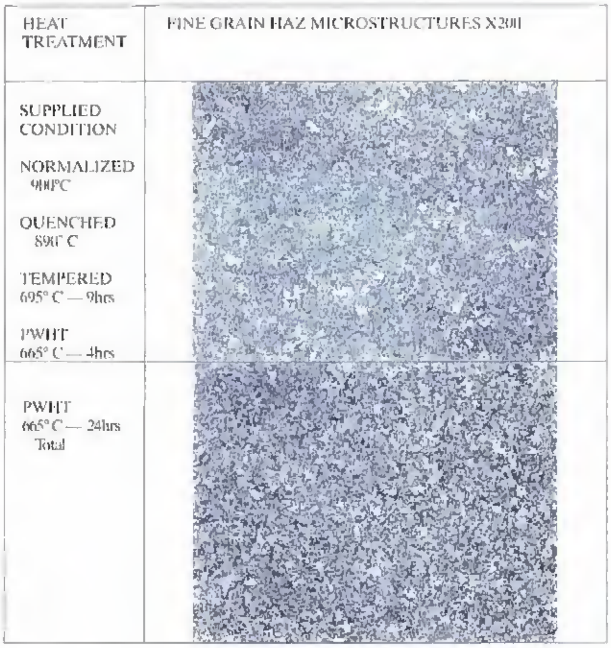

Fig. 9 — Microstructure of fine-grained HAZ in the supplied condition and prolonged PWHT condition.

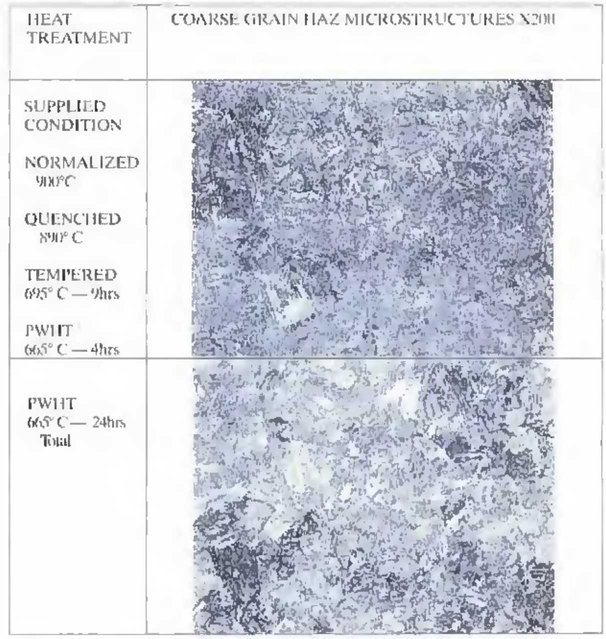

Fig. 10 — Microstructure of coarse-grained HAZ in the supplied condition and prolonged PWHT condition.

housing material metallography, carried out at the following locations, revealed extensive carbide precipitation after PWHT — Figs. 6–10.

Lessons Learned

Based on this experience, it is recommended that tighter control be applied for recording both stress relieving and PWHT; also that the operator engage a third-party inspection organization to witness and record the critical manufacturing stages, one of which involves the PWHT cycles.

Acknowledgment

The authors would like to thank David Baillie for commenting on the preparation of this paper.

References

1. AISI 8630 (UNS Designation G86300). American Iron and Steel Institute.

2. ASME *Boiler and Pressure Vessel Code*, Section IX — Welding and Brazing Qualifications.

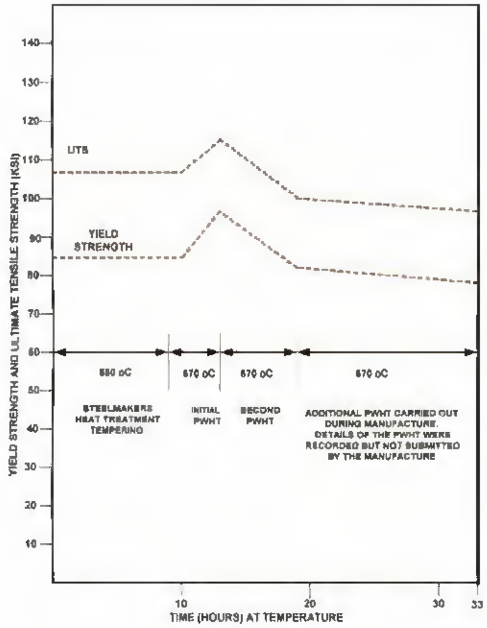

Fig. 5 — Postweld heat treatment trials carried out on wellhead segment.

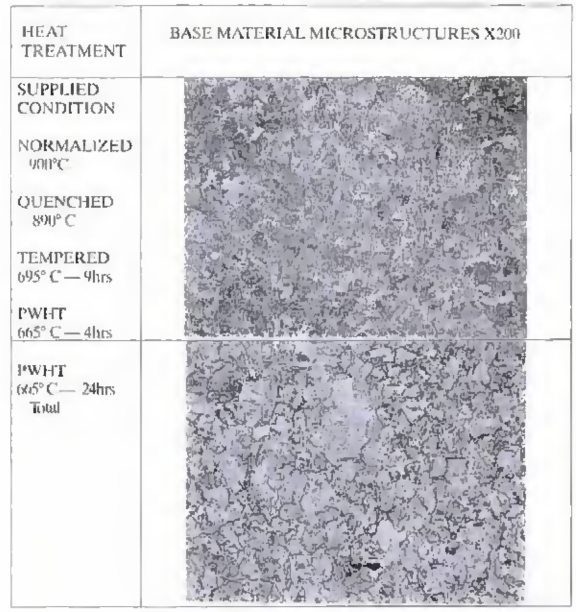

Fig. 6 — Microstructure of base metal in the supplied condition and prolonged PWHT condition.

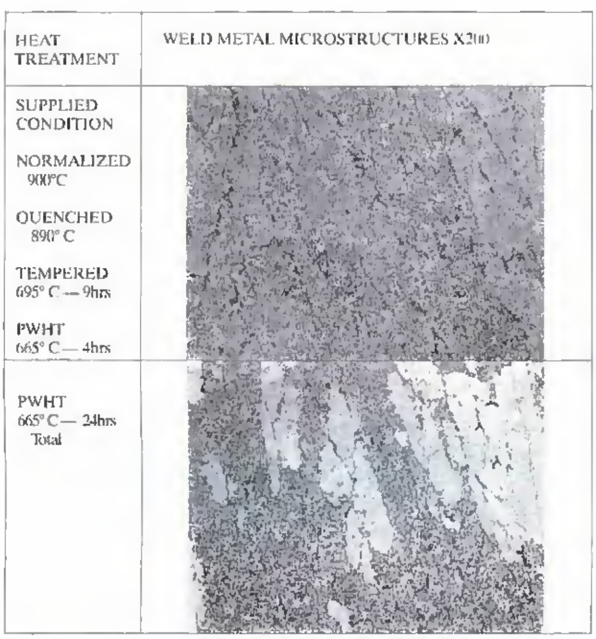

Fig. 7 — Microstructure of weld metal in the supplied condition and prolonged PWHT condition.

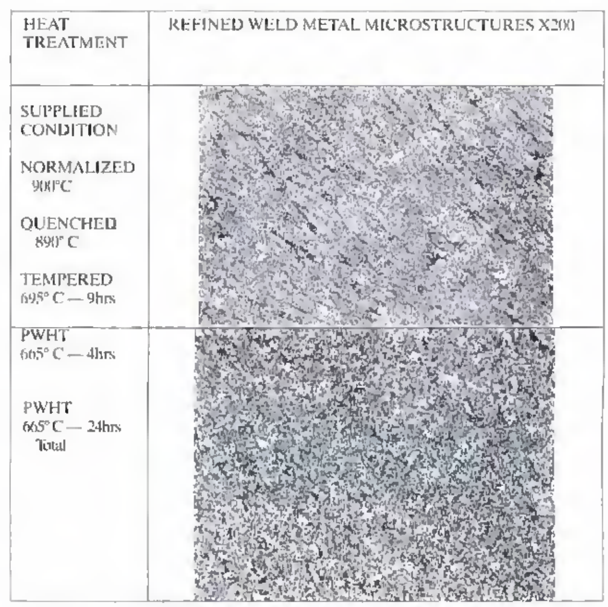

Fig. 8 — Microstructure of refined weld metal in the supplied condition and prolonged PWHT condition.

by ASME IX. This irregularity cast doubt over the length of time the wellhead housing had been PWHT. The total PWHT time identified was 33 h, which included the stress relief treatment applied during manufacture of the wellhead forging and PWHT after cladding and repairs.

Using the surplus material from weld procedure WP 02, which had originally been stress-relieved/PWHT for 13 h (tempered for 9 h at 680°C and PWHT at 670°C for 4 h), an additional PWHT of 20 h, i.e., 1.0 in./h (25 mm/h), was applied. Further mechanical tests involving joint tensile specimens taken at various stages revealed that after an additional 6 h the yield strength dropped to 81,000 lb/in.^{2}. However, after PWHT for an additional 14 h, the yield strength dropped to 77,400 lb/in.^{2}. Figure 5 illustrates the drop in tensile and yield strength due to the prolonged PWHT time. Based on these findings, the proposed repair was considered not practical for restoring the original integrity of 85,000 lb/in.^{2} yield strength.

Metallography: Supplied and PWHT Condition

Subsequent weld metal and wellhead

Manufacture of Braze and Solder Alloy Powders by Atomization

A key component in the success of brazed or soldered joints is how the alloy is made and the quality it brings to the process

BY DIENTJE FORTUNA

Fig. 1 — Spherical, gas-atomized nickel braze alloy particles.

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Based on a paper presented at the 34th International Brazing and Soldering Symposium, 2004 AWS Annual Meeting, April 6–8, Chicago, Ill.

Most brazing and soldering operations start with the application of an alloy powder to the parts. This can be in the form of a paste, slurry, spray, tape, or preform, all of which begin as a powder. How the powders are manufactured can impact the cost, quality, and success of soldered and brazed components. Understanding how the powders are manufactured and sized can help one make decisions on the alloy powder to use and how best to apply it to the parts to be soldered or brazed.

A number of manufacturing processes are used to produce metal powders. These processes include sintering, crushing, spray drying, cladding, and atomization. While all of these methods produce excellent forms of powder, atomization produces powders that meet the extensive requirements of the brazing and soldering processes — Fig. 1.

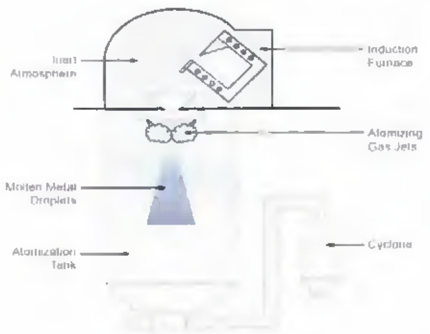

Fig. 2 — Schematic of a gas-atomizing induction furnace.

Table 1 — Types of Atomization Used to Produce Metal Alloy Powders

Types of Metal Alloys	Oil	Water	Types of Atomization Argon gas	Nitrogen gas	Vacuum/Gas	Air
Cobalt			X	X		
Copper		X				X
Iron base		X			X	X
Nickel base				X	X	
Aluminum			X			X
Precious metals			X	X	X	

Defining the Atomization Process

Atomization of molten metal is similar to the atomization of perfume. A liquid stream of perfume is hit with air to break up the liquid into millions of tiny drops that deposit on the skin as a fine mist. With metal powder production, the process is essentially the same. The molten metal stream is hit by a jet stream of air or other material and broken up into tiny drops, each of which contains all of the elements of the molten metal. The droplets cool and shrink to form powder particles.

The jet of air, as the way to break up the stream of liquid metal, can be replaced with other materials such as oil, water, or gases like argon, nitrogen, or helium. The powder manufacturing process itself can be accomplished in air, under vacuum, or under cover of a shielding gas such as those mentioned above. In every case, a high-quality braze or solder alloy powder is produced.

Choosing the method to manufacture a solder or braze alloy powder depends on the type of metals that make up the alloy powder. As you can imagine, the process to make a titanium-beryllium braze alloy is different than that for making a palladium-nickel braze alloy or a copper-tin-lead solder alloy. The temperatures required to melt the metals and the oxidation levels or properties of the finished powders are examples of some of the reasons one process is chosen over another to make these powders.

Table 1 shows the base metal alloy powders and the various atomization processes used to manufacture them.

How Does It All Start?

It begins with a recipe.

The recipe, which is actually the processing or job card, is based on internal or external chemistry and size specifications for the solder or braze alloy powder. It details the exact amount of each raw material component needed to produce the powder. An example of chemistry for a recipe might be something like the following:

- 60% Nickel
- 14% Nickel Boron
- 10% Ferrochrome
- 8% Silicon
- 5% Iron
- 3% Chromium

Of course, the quality of the powder actually starts with the purchase of raw materials. Knowing the reliability of the supplier and the quality level of the raw materials will provide consistent product realization and ensure the braze and solder metal powders function as expected and meet the requirements of the industry specifications. As added insurance, most raw materials are retested prior to use in the production of the alloy powders.

Atomization Process

The atomization process is controlled from start to finish through detailed job instructions, control checks at each step in the process, and extensively trained operators. Production controls can include accurate weights on the raw materials and monitoring of the melting temperature, gas pressures, water temperatures, pour time, and gas levels. Also important is the training and skill level of the production operators. Effective training can take 6 to 12 months for a new operator to become proficient at the melting/atomizing process. Essential to the success of the atomization of powder alloys is the documentation of the processes and practices of production.

Step one of the atomization process is the melting of the raw materials or melt stock. If using raw material, the exact amount of each component is weighed and combined in a container that will hold the total weight. This is referred to as a "furnace charge." It is possible, and sometimes desirable, to purchase melt stock that is premelted and contains most or all of the elements of a braze or solder alloy. This becomes the furnace charge that is melted and turned into alloy powder. A refractory furnace is used because it can withstand the heat required to melt metal alloys. The melt temperature can vary from 71°C (160°F) for low-temperature solder alloys to almost 1650°C (3000°F) for high-temperature braze alloys. The heat source for melting can be induction (electric) or gas and is introduced so that the entire furnace charge is heated uniformly. The furnace operator carefully monitors the melting process using temperature measurements and visual exams until the furnace charge has become completely molten and the temperature necessary for all the elements to become homogeneous has been achieved. Often, reactive elements such as rhenium, hafnium, yttrium, zirconium, and rare earths are added very late in the melting process to keep them from being dissolved rather than melted.

Figure 2 is a schematic of a typical induction furnace used for gas atomization of nickel-, cobalt-, and copper-based alloy powders. Similar furnaces are used for all types of alloy powders.

Once the metals are liquified and ready to pour, the furnace is tipped and the molten stream is poured into a chamber where the atomization takes place — Fig. 3. This is a rather dramatic operation as the hot liquid metal is hit with a stream of air, oil, or gas and broken up into millions of tiny droplets — Fig. 4. The droplets are then cooled in air, gas, or water to form powder particles.

Screening of Powders

The specialization of the atomizing equipment can help to optimize the range of the droplet sizes that are formed from the exploded metal stream of alloy. But, even under the best conditions, the sizes of the powder particles created from this process range from 5 to 600 microns (0.0002 to 0.023 in.). From this wide range of particle sizes, the desired particles, defined by internal and external specifications, must be separated and collected to create the end product that will be delivered to the brazing and soldering customers. The "product" could be as little as 20% or as much as 50% of the pow-

Fig. 3 — Refractory-lined furnace starting to pour the liquid metal for atomization.

Fig. 4 — Hot droplets of liquid metal formed during the atomization process.

der produced in the atomizing process. This is determined by how tight the particle size specifications are for the powder, and will be discussed later. Sizing of powders is accomplished by screening, and various types of screening equipment are employed. It is not unusual for two different types of equipment to be used to produce one braze or solder powder.

Screening is a method utilized to separate powders into size fractions in order to collect and deliver the product as defined by the specifications. Just as the name suggests, the process uses screens similar to those on windows and doors. They are made of steel or nylon materials woven to have a specific size hole and are based on a specific number of holes per square inch — Fig. 5. For efficiency, the screening process is designed to size the powder with the least amount of screening time. The powders are passed over the screens with a rotating or vibrating motion and, depending on the sizes of the particles, they go through the holes of the screen or stay on top (too big to pass through). The powders are then collected based on where they stayed during the process.

Powder Sizing

The screens used in the sizing process are tightly controlled by the number of holes per square inch. The number of holes corresponds with the powder size described in the powder specification. For example, to achieve a 140-mesh powder, a screen with 140 holes per square inch is used. If the powder is to be a 325 mesh, a screen with 325 holes per square inch would be the correct size to separate the powder and collect the product. As previously described, the powder from the furnaces would be passed over the 140-hole screen and all the powder that passed through would be collected as product. The powder that stayed on top of the screen would be removed from further processing, as it does not meet the size requirement.

When the powder size is defined by two or more sizes, the screening setup becomes more complex. As an example, a powder that is identified as –140 +325 will have to be screened over two screens. The top screen contains 140 holes per square inch, the bottom one will have 325 holes per square inch. Now as the powder is vibrated over the top screen, the powder too big to go through the top screen is removed. The powder that passes through the top screen will then pass over the bottom 325-hole screen. The powder that stays on the bottom screen is the product. It is the –140 (went through the 140-hole screen), +325 (stayed on top of the 325-hole screen) powder.

The process would be the same for a fine powder. If the powder is described as –325 +22 micron, the powder between the two screen sizes would be collected and finish processed as the product.

Finishing the Process

There are several steps that must still be accomplished before the powders are ready for delivery to a customer or for a subsequent process such as paste or tape manufacturing.

At the screening process, a sieve analysis is performed. This is a function of the quality process where several screens with different size holes are used at one time. By measuring the amount of powder that is retained on each screen it is possible to determine if the finished lot of powder meets all of the requirements of the various external specifications for the powder. This analysis will eventually be reported on a material certification issued by the manufacturer. If the sieve analysis shows the powder meets the manufacturing specifications, it is moved on for further processing. If it does not meet the requirements, it is reprocessed through the screens until the requirements are met.

The next step in processing the powder is blending of the "lot" of finished powder. This is done to ensure the powder particle sizes are homogeneous. There are many types of blenders, but those most often used are V-blenders, cone blenders, and double-cone blenders, so named because of their shapes. To ensure the best mix of the particle sizes, tumbling the powder from the narrow end of a V or cone into the wide end of these shapes is essential. Blending is accomplished in 30 to 60 minutes, depending on the weight of material in the blender. It is generally accepted that less than 30 minutes is insufficient time to get a well-blended, homogeneous mix of the powder particles, and more than 60 minutes can actually begin to overblend the powder, causing it to segregate. As a further note about blending, most manufacturers recommend the purchaser reblend the solder and braze powders prior to their use. It is possible for the powders to segregate somewhat during shipping in their containers, so each should be blended in a small V or cone blender before being applied to the components to be brazed or soldered.

To complete the powder manufacturing process, it is necessary to analyze the chemistry and size of the powder and issue material certifications based on the analysis. There are many pieces of equipment that can be used to perform the over-checks. For analysis of the chemistry, there are various spectroscopy methods including ICP or AA analysis machines. There are wet and dry methods for checking the powder size; oxygen, nitrogen, or helium analyzers for measuring the levels of gases; and furnaces for testing the melting and flow characteristics of the braze and solder alloys. All of these tests are completed to ensure the quality of the braze and solder alloy powders before they leave the manufacturer.

The last operation prior to shipment is to package the powders in containers that keep them clean and dry. The proper identification of the powder should be on the labels, and other information might include specification number, lot number, product warnings, and storage information. Containers vary from manufacturer to manufacturer, but all are designed to keep the braze and solder alloy powders at the same quality level as when manufactured.

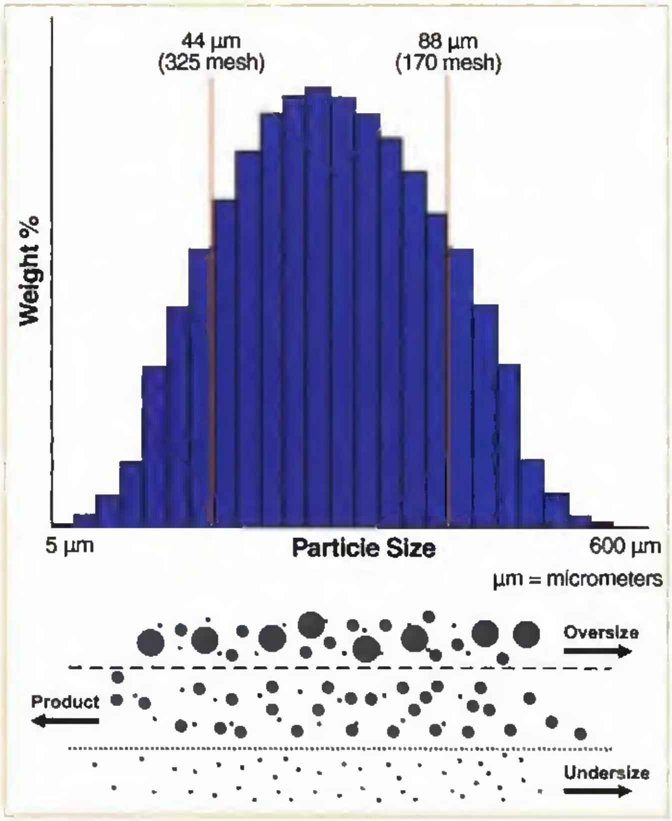

Fig. 5 — The screens are set up so that the powder that falls through the first screen but not through the second screen is the desired powder size. The oversize and undersize particles are collected for reprocessing.

Alloy Compositions

Braze and solder alloys start with a base metal to which other metals are added to improve or change the properties of the starting material. The original braze and solder metals of copper, silver, and gold were used as early as 4400 B.C.[1] The metals were readily available and could be melted in charcoal furnaces — the technology of the day. Today, there is a wider range of metals used for the basis of braze and solder alloy powders. These include copper, gold, nickel, iron, silver, and tin. To these base metals, additional metal components are added depending on what is needed to meet service conditions of the brazed or solder components, or for functionality of the braze or solder joint design. The materials listed in Table 2 represent some of the metals currently found in braze or solder alloy powders.

At present, there are hundreds of braze and solder alloys available. Also, alloys can be designed to meet the special requirements of a component to be joined by working with a manufacturer of alloy powders. The only limit is the imagination.

Interpreting Powder Mesh Analysis

It can be of great advantage to the success of a brazing or solder operation to understand the mesh size of the powder as stated on the material certification issued by the manufacturer.

Powder sizing is simple if you remember that either the powder particles fall through the holes of a screen or they stay on top. The size designations on certifications or specifications are based on screens having a specific number of holes per square inch, so no conversion is needed to understand the analysis received with a delivery of powder. Dissection of an example of a typical mesh size will help to demystify alloy powder sizing.

A specification that reads:

0.0% minimum	+120
90% minimum	–140
55% maximum	–325
5% maximum	22 micron

1. Mark E. Sapp, History of Thermal Joining, *http://weldinghistory.org*.

Table 2 — Ingredients of Braze or Solder Alloy Powders

Base Metal	Additions	
Alloys start with a base metal such as	For specific alloy characteristics or as temperature suppressants	For corrosion or oxidation resistance
Aluminum	Boron	Boron
Bismuth	Gallium	Chromium
Cobalt	Gold	Molybdenum
Copper	Hafnium	Nickel
Gold	Manganese	Silver
Iron	Phosphorus	Titanium
Lead	Silicon	Tungsten
Nickel	Silver	
Silver	Zinc	
Tin		
Titanium		
Zinc		

Is interpreted as the following:

- 0.0% means that all the powder particles must be small enough to pass through a screen with 120 holes per square inch. No powder is to remain on top of the screen
- Ninety percent of the powder has to be small enough to fall through a screen with 140 holes per square inch, or only 10% of particles large enough to stay on top of the screen are allowed.
- The powder is further identified by the amount of fine powder that can be included in the coarse mesh powder. In the example, only 55% of particles small enough to pass through the 325-hole screen are allowed in the product. The balance of the powder must be larger or remain on top of the 325 screen.
- The last size controls how fine the powder can be. Of the 55% allowed to be smaller than the 325 screen, only 5% can be smaller than 22 microns. Unlike the other sizes that are based on the holes per square inch, very fine powders are described based on the actual measured size of the particles, which, in this case, is 22 microns or 0.0008 in.

In general, if the mesh specification has a plus (+) sign, it is referring to powder that is larger than the screen size. A minus (–) sign refers to powder smaller than the screen size. Don't let the pluses and minuses cause confusion in understanding the powder size. Just think of the powder as staying on or falling through a screen. Then, whether the powder size is listed as 90% minimum –140 or 10% maximum +140, there won't be any confusion about the actual size of the powder.

Using This Knowledge

From a cost standpoint, there are several ways to capitalize on the understanding of powder production and the resulting alloy powders. One area to review would be how the method of manufacturing the alloy powders impacts the cost of these materials. As an example, when using a copper-based braze alloy, look for a manufacturer that atomizes in air or water, as these are lower cost processes. Most copper brazing applications do not require the higher cost, gas atomization process, so there is no reason to pay extra for a lower oxide copper powder. On the other hand, if the brazing process involves a base metal that oxidizes readily, such as those that contain aluminum or titanium, it may be more cost effective to use a gas-atomized copper powder even though the initial cost is higher. The dollars that could be saved in the processing of these difficult-to-braze components will more than make up for the higher purchase price.

Another cost consideration is with the mesh size of the alloy powders. When manufacturing powders, the greater the yield, or the more of the "as-atomized" powder that can be used to produce the final product, the lower the cost. For many brazing and soldering applications, no other consideration is necessary beyond that of the lowest cost filler metal. However, there are other applications where the method to apply the filler metal makes it impossible to use the "optimized yield" alloy mesh size. As an example, applications where the powder is sprayed or dusted onto the component could be negatively impacted by a powder that has a high percentage of fine particles as it will tend to clump or clog during these types of applications. The use of the lower priced powder could cost more in lost production time than the upfront cost of the higher priced, restricted mesh size powder.

Understanding the powder size used in a paste can help select the right application equipment for applying the alloy paste. If a coarser powder is used to manufacture the paste, there could be particles as large as 0.006 in. (0.15 mm). But, if the part to be alloyed needs a fine bead of alloy, a typical way to achieve this would be to use a small-diameter needle so only a thin bead of alloy paste is applied. The small-diameter needles measuring from 0.004 to 0.010 in. (0.1 to 0.25 mm) would exclude a lot of the powder particles from passing through. Most often, the larger particles will clog up the entrance to the needle, causing a reaction on the part of the application technician to increase the pressure. The larger particles will yield under the pressure and move aside, resulting in a messy burst of paste from the needle that must be cleaned up. Time and alloy paste are wasted. As if this waste is not bad enough, the larger particles become stuck in the syringe or cartridge and pile up as the smaller particles are extruded. Eventually the syringe or cartridge and the remaining braze or solder material are discarded when no more alloy paste can be pushed from the container.

In a similar situation where a paste or slurry is mixed by the end user, knowing the powder mesh size can help to make the right decision on the amount of binder to add. If a process has been established based on a certain ratio of binder and powder that results in an acceptable viscosity, the process can be upset when the mesh size of a new powder lot is not examined prior to use. To engineering, the most important issue is the ratio by weight between the binder and the alloy powder in order to ensure a specific amount of solder or braze alloy in the joint. Unfortunately, in the real world, the operator has to have a paste viscosity that will extrude through the needle onto the part. When a new powder lot has a higher percentage of fine powder, more binder may be necessary to achieve an acceptable viscosity. The additional surface area of the finer powder particles will yield a thicker, more viscous paste if the same amount of binder is used, which won't go through the needle. This situation is usually fixed by adding enough additional binder so the viscosity is the same as usual. What is rarely measured, unfortunately, is the drop in powder weight this new mix of paste or slurry has. The risk is voids and rework because of the lower alloy weight in the joint.

Using the information provided with each powder certification can help control costs and make it easier to achieve processing goals. Be proactive and talk to the braze and solder manufacturers about specific processes and alternatives they may have to offer that will not only meet the specifications required, but might offer lower costs or higher yields in the brazing or soldering process. There is nothing to loose and a lot to gain with just a little education about the alloy powders being used. ◆

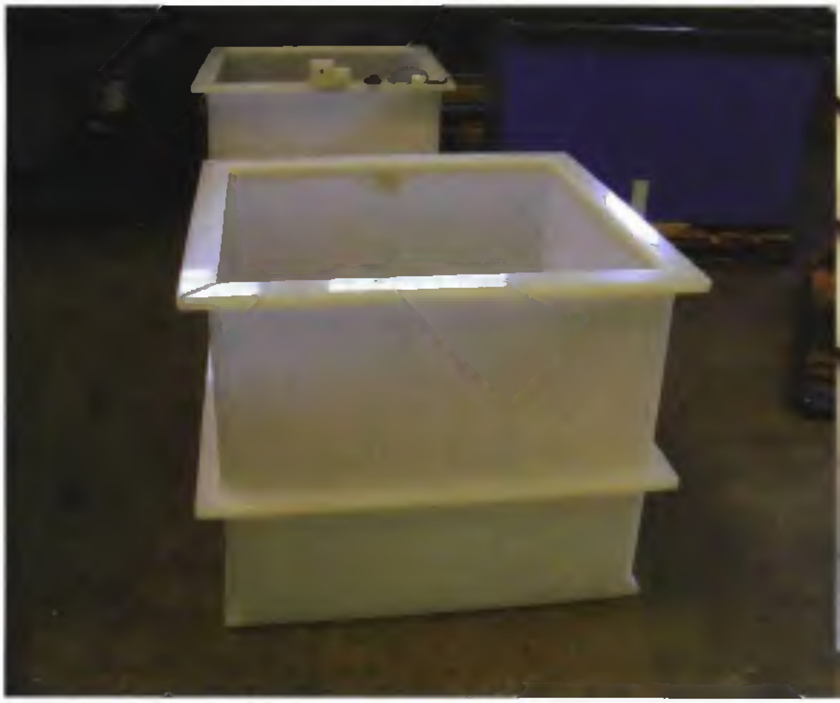

Fig. 1 — A plating tank built from thermoplastic material.

Fig. 2 — A thermoplastic fume scrubber.

Welding of Thermoplastics

The use of thermoplastic materials is growing, and welding is the technology of choice for joining them

BY DAGMAR ZIEGLER

Thermoplastic materials are not extensively used in the world of fabricated products, yet they could present excellent alternatives to metals due to their inherent characteristics. Depending on the application, thermoplastics may far outlast metals with regard to corrosion, resistance to chemicals, or resistance to abrasion. Thermoplastics, however, may have limitations with regard to the operating temperature or operating pressure of a fabricated structure.

One area in which use of thermoplastics is growing rapidly is piping systems for water, sewer, drainage, irrigation, natural gas, chemicals, and pharmaceuticals. Rotationally molded containers and tanks are also increasing in popularity. Few of us realize that landfills today are lined and covered with welded thermoplastic membranes to prevent groundwater contamination and air pollution.

Not widely known is that plastic sheet stock can be used to fabricate custom-built structures to satisfy demanding requirements. Structures made out of fabricated thermoplastic sheet are found in the plating and galvanizing industry (Fig. 1); air pollution control systems (Fig. 2); wastewater treatment systems; emergency vehicles; chemical, biochemical, and pharmaceutical process systems; and semiconductor components, just to name a few. In addition to structural design and selection of the appropriate material, the joining technology evolves as the key factor in the fabrication of a successful structure.

DAGMAR ZIEGLER (dagmar@wegenerwelding.com) is Business Manager, Wegener North America, Inc., Burr Ridge, Ill.

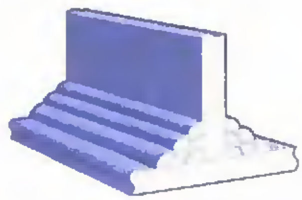

Fig. 3 — Multiple passes may be required when welding heavier gauge sheet using hot gas (air) hand welding.

Fig. 4 — Welding gun with tacking tip.

Types of Thermoplastic Materials

Industry offers many different thermoplastic resins. The most commonly used are polypropylene (PP), polyethylene (PE), and polyvinylchloride (PVC). With the addition of additives or changes in the manufacturing processes of these resins, subgroups were developed to meet specific criteria. These include copolymer polypropylene (PP Type II) and PVC Type II or CPVC, which is PVC with a higher chlorination content. In the PE family, the material density or molecular weight provides for numerous classifications such as low-density polyethylene (LDPE), linear low-density polyethylene (LLDPE), high-density polyethylene (HDPE), high molecular weight polyethylene (HMWPE), and ultrahigh molecular weight polyethylene (UHMWPE). New materials are continually being developed to meet particular application requirements.

If these materials do not satisfy particular requirements, a group of higher engineered materials is available. These include polyvinylidene fluoride (PVDF), ethylene chlortrifluoroethylene (ECTFE), tetrafluorethylene perfluormethyl vinylether copolymer (FEP), tetrafluorethylene perfluormethyl vinylether (MFA), or perfluoralkoxy copolymer (PFA). These materials typically have better chemical and temperature resistance but carry a higher cost. With the exception of PVDF and ECTFE, these materials are mostly used as linings in FRP constructions and require special expertise with respect to welding and fabrication.

Welding

A quality thermoplastic weld requires that execution of the weld be performed under the proper conditions and parameters. Welding means the heating of the materials to their specific welding temperature (thermoplastic state), applying a certain amount of pressure for the molecules to intermingle, and allowing the material to cool down under pressure. The following criteria need to be met:

- Material compatibility
- Suitable weld type and weld configuration
- Correct welding parameters
- Clean welding surfaces

Welding parameters are material and process specific. Following are typical welding processes:

- Hot gas (air) hand welding
- Hot gas (air) extrusion welding
- Heated tool butt welding
- Bending

Hot gas (air) hand welding and hot gas (air) extrusion welding are manual processes; therefore, the quality of the weld is highly dependent on the skill and attention level of the operator. Both methods use a filler material to perform the weld. The gas (air) is required to simultaneously transmit heat into the base materials and the welding rod to allow the molecular interlocking to take place. The primary difference between the two methods is the size of the weld generated.

Standard welding rod sizes in hot gas (air) hand welding are round rod ⅛, 5/32, and 3/16 in. in diameter. Some industries prefer to use a triangular-shaped rod, especially for cosmetic reasons. Due to the poor heat conductivity of thermoplastics, there is a limit as to the size of welding rod that can be used. Welding of heavier gauge sheet, therefore, requires multiple passes to obtain adequate weld size, a time-consuming task — Fig. 3. Multiple passes also create undesired stresses in the base material due to the multiple heating and cooling sequences. Provided there are no physical or material constraints, extrusion welding is the preferred method for replacing multipass welds.

A hot gas (air) hand welding system consists of a welding gun, a clean air supply, and a welding nozzle (tip). A dedicated pyrometer with a needle-style probe should also be on hand to provide accurate verification of the welding temperature. Additional tools are material scrapers and cleaning brushes for the tips. The design of the welding gun should provide for electronic adjustment of the welding temperature. The air supply must be clean — oil and moisture free — to prevent contamination of the weld. A constant air volume is required to keep the set temperature in the correct range.

After lining up the materials, the first step is to tack them together — Fig. 4. Tack welding is performed without a welding rod by moving a pointed tacking tip along the area to be welded. The tack weld assures that all parts are in place and that the materials stay in position when the actual welding operation is performed. After tack welding, the weld area should be scraped to remove the oxidation layer created by the hot air during the tacking process.

The most common form of hot gas (air) welding is called high-speed welding — Fig. 5. The high-speed welding tip is designed to guide the welding rod into the weld zone while simultaneously heating up the rod and the base material. The shoe at the end of the rod orifice allows the operator to apply the welding pressure. The welding pressure is dependent on material type and rod size. Key to quality hot gas welding is the correlation of constant temperature at constant speed, constant pressure, and constant air volume.

Hot Gas (Air) Extrusion Welding

The technology for manufacturing plastic sheet, pipe, rod, and tubing is used on a miniature scale in the hot gas (air) extrusion welding process. An extrusion screw inside a melting chamber processes 5/32- or 3/16-in.-diameter welding rod coming off a spool and supplies a fully molten, plasticized strand of material in a larger diameter — Fig. 6. The design and size of the weld is determined by a PTFE shoe, which is mounted to the end of the melting chamber. PTFE is the material of choice because it has a very low coefficient of friction and is easily machined. To preheat the base material, a hot air system is mounted on the side of the machine with the outlet right in front of the PTFE shoe. Depending on the application, these systems may be self-contained with an internal air supply, or may require connection to an external air supply.

Both hot gas (air) hand and hot gas (air) extrusion welding are manual operations. The quality of the weld is highly dependent on operator knowledge and skill.

Heated Tool Butt Welding

Very popular in the PP, HDPE, and PVDF piping industry, heated tool butt-welding can also be performed with sheet materials — Fig. 7. The process does not

Fig. 5 — High-speed welding.

Fig. 6 — A hot air extrusion welding machine.

Fig. 7 — A sheet butt welding machine.

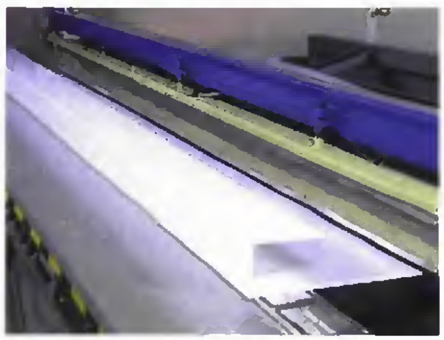

Fig. 8 — A sheet bending machine.

use filler material, but involves instead a heated bar located between two moving tables. The sheet is clamped onto the tables against a setting bar. Once set, a heating bar moves into place against which the two sheets are held. The machine then goes through a three-stage cycle of heating the material under two different pressures, moving the heating bar out of the way and pressing the sheet together under a higher pressure. Temperatures, times, pressures, and pressure ramps are dependent on the type of material and the overall surface to be welded.

Most machines are microprocessor-equipped to facilitate setting of the machine and to ensure full repeatability. Provided the machine is designed and constructed correctly, heated tool butt welds are rated higher quality welds due to the minimization of the human error factor, the comparatively small thermal influence in the weld zone, and possibility of documenting each weld.

Bending

Industrial thermoplastic sheet benders work much like a metal sheet brake — Fig. 8. In addition to the breaking function, the material needs to be heated across the bending line to avoid breakage. Similar to butt-joint welding, the heat and time settings are material-specific. For sheet gauges greater than ¼-in., a bottom as well as a top heating bar need to be used to adequately heat the bending zone. The bending of PP and PE requires a V-shaped bar to penetrate about two-thirds into the sheet and to remove the excess material out of the corner. Polyvinylchloride is bent with a flat bar.

Heated tool sheet butt welding machines and bending machines carry a higher initial capital cost but provide for a rapid return on investment due to their time-saving capabilities while offering the highest quality of the fabricated product.

Conclusion

People outside the thermoplastics fabrication industry may not take welding of plastics seriously or might consider it more of an art than a science. Some countries outside the United States have long recognized the importance of research in this field and have created sound fundamentals. These include specifications for equipment, welding and testing procedures, welder education, and certification and design criteria, just to name a few. In the United States, American Welding Society committees are in the process of establishing similar documentation for the benefit of fabricators and end users.◆

American Welding Society

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

(please type or print in black ink)

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

American Welding Society

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

Fabtech Comes to Cleveland

Major metalworking exposition to be held Oct. 26–29

Fabtech International, North America's largest annual metalforming and fabricating exposition, is coming to the I-X Center in Cleveland, Ohio, this month. Every year, Fabtech brings buyers and sellers together in a venue that facilitates networking and education.

Fabtech is cosponsored by the Society of Manufacturing Engineers (SME) and the Fabricators & Manufacturers Association (FMA). The event will feature more than 400 companies displaying their latest products and technical advances in metalforming and fabricating technology, welding, stamping, robotics, punching, bending, safety, hydroforming, lasers, finishing, cutting, controls, coil processing, software, tooling, and material handling.

The Fabtech conference will feature more than 100 presenters. In addition to conference sessions, product displays and demonstrations will be held on the exposition floor, including technologies of interest to attendees from industries such as architecture, engineering, and construction; aerospace; agriculture; appliances; automotive; chemical; construction products and materials; defense; electronics and electrical products; food service and processing; furniture and fixtures; heating, ventilating, and air conditioning; heavy equipment; job shop/contract manufacturing; medical; metalworking; mining; recreational equipment; transportation; and utilities.

Show Hours and Special Events

Fabtech will operate from 9 a.m. to 5 p.m. on Oct. 26 and 27, and from 9 a.m. to 4 p.m. on Oct. 28.

The keynote speaker will be Grant Aldonas, Under Secretary for International Trade, U.S. Dept. of Commerce. At 8 a.m., Oct. 27, his presentation will provide insight into issues such as international trade agreements, U.S. trade laws, and fair trade practices. He will also provide a progress report on the status of a variety of initiatives undertaken by the government in the past two years to "reenergize" the manufacturing segment of the economy. Over the past year, Aldonas has been highly involved in the nationwide manufacturing roundtable programs conducted by the Dept. of Commerce. As a result, he has a clear picture of the needs and concerns of the metal fabricating industry.

Every day at noon, free one-hour business seminars will be presented, with tools for taking a business to higher levels of success, including how to expand a business, competing successfully for government contracts, and developing innovative new products.

In addition, more than 30 conference sessions will be presented.

Conference Schedule

Tues., Oct. 26
9:30 to 11:30 a.m.

- Productivity Enhancements for Tube and Pipe Mills
- High-Strength, Low-Alloy Materials
- Machine Safeguarding
- Profit Growth Management
- Understanding Lubricants
- Demand Pull in the Fabrication Job Shop

12:00 to 1:00 p.m.

- Free Business Seminar: From Your Shop Floor to the Playing Field — Growing Your Business Systematically

1:30 to 3:30 p.m.

- Laser Cutting Technology
- Creating Integrated Roll Forming Systems
- Automated Robotic Welding
- Press Tooling and Productivity Improvement
- Total Productive Maintenance (TPM) for the Fabrication Job Shop

Wed., Oct. 27
8:00 to 9:00 a.m.

- Keynote: Grant Aldonas, Under Secretary for International Trade, U.S. Dept. of Commerce.

9:30 to 11:30 a.m.

- Forming and Fabricating of Stainless Steel
- Improving Roll-Forming Quality and Productivity
- Tube Cutting
- Water Jet Cutting
- Hot Metal Gas Forming: Tooling and Material Capabilities
- Lean 101 — Principles of Lean Manufacturing

12:00 to 1:00 p.m.

- Free Business Seminar: Ten Simple Steps to Winning Federal Government Contracts

1:30 to 3:30 p.m.

- Sheet Metal Punching
- Developments in Hydroforming
- Plasma Plate and Structural Cutting
- Coil Slitting Applications
- Data Collection: From Bar Codes to Touchscreens
- Creating a Press Room Preventive Maintenance Program
- Lean 202 — Value Stream Mapping

Thurs., Oct. 28
9:30 to 11:30 a.m.

- Press Brakes and Increased Productivity
- Lean 203 — Setup Time Reduction Using SMED in a Kaizen Blitz Mode
- Tube Bending
- Coil Cut-to-Length and Leveling Applications
- Surface Finishing
- Safety Issues for Better Employee Performance
- Aluminum Welding

12:00 to 1:00 p.m.

- Free Business Seminar: Product Development and Innovation for Manufacturers

Get All the Information

To learn more about Fabtech or to register, call FMA at (800) 432-2832, or visit *www.fmafabtech.com*; or contact the SME Resource Center at (800) 733-4763, or log onto *www.SME.org/fabtech*. ◆

General Guidelines for Cleaning after Soldering

By F. M. Hosking and E. P. Lopez

If flux residues are to remain on workpieces after soldering, next assembly or service operations generally require that they be electrically nonconductive and noncorrosive. However, even when these conditions are met, some applications will further require their complete removal to meet cosmetic, visual, or other performance requirements. Whatever the application, it is very important that postsoldering cleanliness be considered when the soldering process is specified. This includes removal of flux residues, excess solder such as icicles, and other soldering process materials, such as solder stop-off and organic inhibitor coatings.

Cosmetic blemishes and corrosion (Fig. 1) can hinder the application of other coatings afterward, whether metallic or organic. Environmental compatibility is particularly problematic, since it can be difficult to accurately determine corrosion rates under varying service conditions or to take into account the effects of other applied mechanical, thermal, or electrical loads on lifetime predictions. Because of these potential contributions to premature solder joint failure, the conservative approach is to remove all flux residues and related undesirable surface contaminants from the workpiece after soldering prior to next assembly, storage, or service.

When hand soldering, the resulting flux residues can be based on organic or inorganic chemistries. These residues are often hygroscopic, discolor with time, and cause fit-up problems for closely toleranced or moving parts.

Loose solder particles can cause several performance problems. If these features break off or interfere during subsequent processing or service, the function of the soldered assembly can be compromised by jamming of critical moving parts, blocked passages, or electrical shorts. The consequence is costly rework or catastrophic system failures.

The presence of solder particles or splatter provides evidence of inadequate process parameters. For example, solder particles can be caused by insufficient preheating or an overly high heating rate. The result is uncontrolled or incomplete vaporization of the water- (or alcohol-) based carrier in the flux prior to solder melting. This is particularly problematic when hand soldering where the heating profile is generally difficult to accurately control. Flux residues can encapsulate solder particles and bind them to the assembly. Postcleaning of the residue should release the solder splatter and similar debris. If the particles remain on the base metal surface, abrasive techniques can be used to remove the particles. If the particles are metallurgically bonded to the workpiece surface, more aggressive mechanical or chemical techniques will be needed to completely remove them. However, care should be observed to prevent damage to the base materials and workpiece functionality.

Solder stop-off coatings, which are intended to restrict solder wetting and flow over selected areas of the base metal, are usually easily removed. The powder slurry vehicle of the stop-off is formulated to vaporize before or during soldering. The remaining inorganic particles in the stop-off restrict solder flow and the remaining powder material can be removed by light burnishing or rinsing in a cleaning solution recommended by the stop-off supplier.

There are many approved commercially available cleaning solutions and associated equipment for postcleaning of soldered assemblies. They range from simple rags soaked in solvent, spray bottles or wire brushes to vapor degreasers and ultrasonic cleaners, to more automated batch-type and in-line cleaning equipment. In some cases, dry-cleaning processes such as RF plasma cleaners can be used after solvent or aqueous cleaning to rid the last atomistic layer of organic contamination. The selected technique depends on the type of flux residues or other surface contaminant(s) that must be removed. Materials compatibility between cleaning chemicals and the product materials (particularly with thermoplastic materials), accessibility of the cleaning equipment to the soldered assembly, and compliance with environmental, safety, and health regulations are other issues that require consideration when selecting a cleaning procedure. Once the cleaning method has been chosen, it is important to remember that the sooner the cleaning operation is performed, the easier it is to remove the targeted surface residues and contaminants.

Postprocess Cleaning

Postprocess cleaning has three stages. The first step uses a cleaning agent to release the desired contaminants from the selected workpiece surfaces. This includes the use of abrasive media. The second stage is removal or rinsing of the cleaning agent and residues from the workpiece. The final stage is drying of the cleaned assembly to remove any remaining rinsing agents. During these steps, care must be taken to not modify surface conditions or other properties that could affect product performance.

Common cleaning agents for organic residues are based on organic solvents, semi-aqueous cleaners, and water-containing saponifiers. Ionic residues require more polar solvents to effectively remove the contaminants. Generally speaking, "like dissolves like." With increasing international, federal, state, and local regulations on chemicals that harm the environment, newly formulated cleaners have been developed to comply with these more restrictive regulations. Environmentally responsible alternatives, which have been approved by the Environmental Protection Agency (EPA), can be found on the Significant New Alternatives Policy (SNAP) program list. The approved cleaners may not have the same effectiveness as the older formulations or may pose other safety concerns, such as low flash points and a potential fire hazard. Material safety data sheets should be consulted before using these alternative cleaners to ensure proper use. More de-

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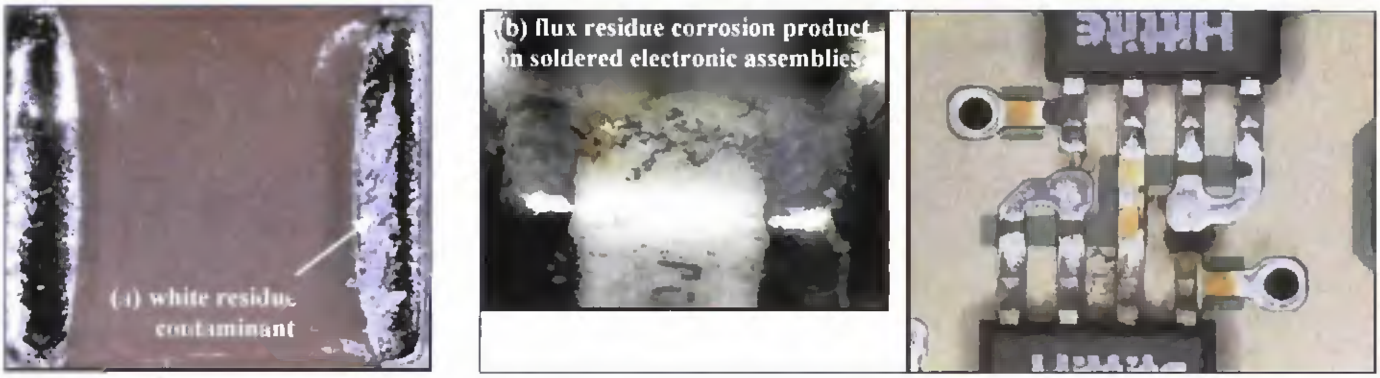


Fig. 1 — Ionic flux residues left on soldered assemblies can cause visual blemishes and potential sites for corrosion: A — white flux residue on soldered surface; B — residue corrosion product on soldered electronic assembly.

in the *Handbook for Critical Cleaning* (edited by B. and E. Kanegsberg, CRC Press, 2001). Although the reference is intended for the electronics industry, the information is pertinent to all postsolder cleaning operations.

Similar information and planning should be used when selecting the rinsing agent. A common rinsing practice is to first clean with an organic solvent, such as trichloroethylene, and then rinse with a polar solvent, such as ethyl alcohol or isopropyl alcohol, to effectively displace all nonpolar and polar contaminants, respectively. If an aqueous cleaning method is preferred, the simplest polar rinsing agent that can be used is deionized or distilled water. Deionized water is preferred, since it is less likely to recontaminate the cleaned surfaces. Tap water is not recommended since it can leave organic and inorganic contaminants behind that usually require an alcohol rinse to remove them. Agitation or heating during the rinse cycle can further assist the process. There are also commercially available rinsing solutions that contain surfactants, which lower the solution surface tension and are more effective when rinsing restricted and blind passages.

The final cleaning step is the drying stage. It can occur by natural evaporation, heat lamps, forced displacement by a dry gas, or forced evaporation by heating in a controlled environment (e.g., drying chamber). Most hand soldering operations use one of the first three drying options. Baking and/or vacuum-assisted drying may be necessary to completely remove absorbed or entrapped residual rinsing materials from blind or tight passages and porous materials. Care must be taken also in the type of drying gas selected. A common choice is electronic-grade dry nitrogen or an approved environmentally safe duster propellant. Compressed air should be avoided since it can contain oil particulate from the compressor unit and condensed water from the gas line.

Once the workpiece has been properly postcleaned, caution is still necessary to prevent recontamination of the cleaned surfaces, which could affect processing at the next assembly level. Proper handling and storage procedures should be developed to satisfy these requirements.

Finally, the cleaned parts should be inspected to confirm the effectiveness of the cleaning process. For hand soldering, this typically involves a visual inspection either at 1× or 10× magnification. Portable ultraviolet (UV) or black light units can also be used to fluoresce for dust particles and flux residues. If the cleaning operation requires quantification, the area of interest can be rinsed with a known volume of liquid, extracted, and then analyzed by ion chromatography and liquid chromatography for residue concentration per unit of rinsed area. Ionic residues are especially problematic in corrosive environments. As such, the Ionograph or Omega Meter® method is used to determine the ionic concentration of the rinsed solution by its electrical conductivity. The conductivity measurement is calibrated against a known ionic species concentration, such as sodium chloride. Other analytical techniques, such as surface insulation resistance (SIR) and Fourier-transform infrared spectroscopy (FT-IR), have been successfully used to determine the identity and quantity of flux residues.

The product application should dictate what the required level of postprocess cleaning pass-fail inspection criteria will be. As the reliability of the application increases, more rigorous cleaning criterion is necessary. For most hand soldering operations, qualitative, visual inspection is adequate. The AWS *Soldering Handbook* (3rd edition) should be consulted for more detailed information on these soldering and related cleaning processes.◆

NOTE: A DIAMOND (♦) DENOTES AN AWS-SPONSORED EVENT.

Advanced Energy & Fuel Cell Technologies Conference & Expo. Oct. 11–13, Laurel Manor, Livonia, Mich. Sponsored by the Society of Manufacturing Engineers (SME). Contact: (800) 733-4763; *www.sme.org/aet*.

16th Annual National Robot Safety Conference. Oct. 18–21, Ypsilanti, Mich. Sponsored by Robotic Industries Association. For information, call (734) 994-6088; or visit *www.roboticsonline.com*.

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*.

14th Annual METALCON International Conference and Exhibition. Oct. 20–22, Las Vegas Convention Center, Las Vegas, Nev. Sponsored by The Metal Construction Assn., (800) 537-7765; *www.metalcon.com*.

26th Annual Industrial Ventilation Conferences. Oct. 20–23, Birmingham, Ala. Sponsored by the University of Alabama at Birmingham, and University of Nevada at Las Vegas. Contact (205) 934-8994; *www.eng.uab.edu/epd*.

7th Annual Nanomaterials 2004. Oct. 25–27, Stamford, Conn. Conferences to focus on bridging the gap between emerging technologies and commercialization. Visit Business Communications Co., Inc., Web site *www.buscom.com/conference_pages/nano_conferences.html*.

Tube China 2004. Oct. 25–28, Shanghai New International Expo Center, Shanghai, China. Contact: Messe Düsseldorf North America, 150 N. Michigan Ave., Ste. 2920, Chicago, IL 60601; (312) 781-5180; *info@mdna.com*, or *www.mdna.com*.

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*.

Metalform-Mexico Exposition. Nov. 9–11, Santa Fe Exposition Center, Mexico City. Sponsored by the Precision Metalforming Association. Targeted at the metal stamping, fabricating, and assembly industries in Mexico. Contact: Precision Metalforming Assn., 6363 Oak Tree Blvd., Independence, OH 44131; (216) 901-8800; *www.metalforming.com*.

9th Beijing Essen Welding & Cutting Fair. Nov. 10–13, China International Exhibition Center, Beijing, China. Cosponsored by the German Welding Society (DVS) and the Chinese Mechanical Engineering Society (CMES). Contact: *suxy@cmes.org*, or *www.cmes.org/gjzhanlan/aisen/eindex/aisen1.htm*.

30th International Symposium for Testing and Failure Analysis. Nov. 14–18, Worcester, Mass. Contact: ASM International, *www.asminternational.org/events*.

ASNT Fall Conference & Quality Testing Show 2004. Nov. 15–19, Las Vegas, Nev. Sponsored by the American Society for Nondestructive Testing (ASNT). Admission to the show is free. Contact: *www.asnt.org/events/conferences/fc04/fc04.htm*.

♦Welding & Joining 2005, Frontiers of Materials Joining. Jan. 25–28, 2005, David Inter-Continental Hotel, Tel Aviv, Israel. Sponsored by AWS Israeli International Section, Israeli National Welding Committee, and Association of Engineers and Architects in Israel. Cosponsored by AWS, IIW, and DVS. Contact: *www.bgu.ac.il/me/convention/welding/welding2005.html*.

♦ 5th Weld Cracking Conference. Feb. 15–16, 2005, Monteleone Hotel, New Orleans, La. Sixteen experts will discuss the elements of hot and cold cracking, weld repair, lamellar tearing, stress corrosion cracking, toughness testing, and heat treating. Contact American Welding Society, *www.aws.org/conferences*; (800/305) 443-9353, ext. 449.

HOUSTEX® APEX (Advanced Productivity Exposition). March 1–3, 2005, George R. Brown Convention Center, Houston, Tex. Contact Society of Manufacturing Engineers, (313) 425-3155; *www.sme.org/events*.

International Laser Safety Conference. March 7–10, 2005, Marriott Hotel, Marina Del Rey, Calif. Sponsored by the Laser Institute of America. Contact: (407) 380-1553; *www.laserinstitute.org*; *ilsc@laserinstitute.org*.

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

Metalform 2005 Symposium. March 20–23, 2005, Donald E. Stephens Convention Center, Rosemont, Ill. Sponsored by the Precision Metalforming Association. Contact Precision Metalforming Assn., 6363 Oak Tree Blvd., Independence, OH 44131; (216) 901-8800; *www.metalforming.com*.

WESTEC® APEX (Advanced Productivity Exposition). April 4–7, 2005, Los Angeles Convention Center, Los Angeles, Calif. Contact Society of Manufacturing Engineers, (313) 425-3155; *www.sme.org/events*.

Twin Cities APEX (Advanced Productivity Exposition). May 3–5, 2005, Minneapolis Convention Center, Minneapolis, Minn. Contact Society of Manufacturing Engineers, (313) 425-3155; *www.sme.org/events*.

Rapid Prototyping & Manufacturing. May 10–12, 2005, Hyatt Regency Dearborn, Dearborn, Mich. Contact Society of Manufacturing Engineers, (313) 425-3155; *www.sme.org/events*.

EASTEC® APEX (Advanced Productivity Exposition). May 24–25, 2005, Eastern States Exposition Grounds, West Springfield, Mass. Contact Society of Manufacturing Engineers, (313) 425-3155; *www.sme.org/events*.

Cleveland APEX (Advanced Productivity Exposition). June 7–9, 2005, I-X Center, Cleveland, Ohio. Contact Society of Manufacturing Engineers, (313) 425-3155; *www.sme.org/events*.

EMO Hannover: The World of Machine Tools & Metalworking. Sept. 14–21, 2005, Fairgrounds, Hannover, Germany. Contacts: *www.emo-hannover.de*; Hannover Fairs USA, Angela Dessables, at *adessables@hfusa.com*.

FABTECH International 2005. Nov. 13–16, 2005, McCormick Place South, Chicago, Ill. Contact Society of Manufacturing Engineers, (313) 425-3155; *www.sme.org/events*.

FabForm 2005. Dec. 6–8, 2005. Exhibition Center, Nuremberg, Germany. Encompasses key sectors of sheet metal forming and fabricating technologies. Contact *www.fabform.de*.

Educational Opportunities

ASME International — Section IX Seminars. Oct. 4–6, Pittsburgh, Pa. This three-day seminar covers writing, qualifying welding procedures, and qualifying welders. Emphasis is on meeting Code requirements economically while providing useful direction to welders. Impact tested qualification and brazing are also covered. For information, visit *www.asme.org/pro_dev*.

Basic Motorsports Welding School. Oct. 11–15, Nov. 1–5, Dec. 13–17. Includes GTAW, GMAW, and PAC for steel, chrome-moly, stainless steels, and aluminum. Advanced Welding School, Nov. 8–12. Contact: The Lincoln Electric Co., (216) 383-2461; *www.lincolnelectric.com*.

Safety at Work Training. 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*.

Engineering Effective Team Management & Practice Seminar. Feb. 16–18, Aug. 15–17, 2005. Troy, Mich. Designed for managers at all levels, including those preparing to take on management responsibilities for the first time. Fees, including lunch and refreshments, are $1235, $1135 for members of the Society of Automotive Engineers (SAE). Contact: SAE International, (877) 606-7323; *www.sae.org*.

Lincoln Electric Professional Seminars. Blodgett's Welding Design, Oct. 12–14; Fracture and Fatigue Control in Structures, Oct. 26–28. Welding Technology Center, The Lincoln Electric Co., 22801 St. Clair Ave., Cleveland, Ohio. (216) 383-2240; *www.lincolnelectric.com/knowledge/training/seminars/*.

Welding for the Non-Welder. Oct. 11. 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*.

CWI/CWE Course and Exam. This 10-day program designed to prepare students for taking the AWS-certified CWI/CWE exam is presented in Troy, Ohio. The exam is presented on the last day. For schedule and entry requirements contact, Hobart Institute of Welding Technology (800) 332-9448; *www.welding.org*; *hiwt@welding.org*.

T.E.S.T. NDT, Inc., Courses. CWI preparation, ultrasonic, eddy current, radiography, dye penetrant, magnetic particle, and visual at Levels 1, 2, and 3. Meet SNT-TC-1A and NAS-410 requirements. On-site training available. T.E.S.T. NDT, Inc., 193 Viking Ave., Brea, CA 92821; (714) 255-1500; FAX (714) 255-1580; e-mail: *ndtguru@aol.com*; *www.testndt.com*.

Boiler and Pressure Vessel Inspectors Training Courses and Seminars. Courses and seminars cover such topics as ASME Code Sections I, IV, V, VIII (Division 1), IX, and B31.1; Writing Welding Procedures; Repairing Pressure Relief Valves; Understanding How Boilers and Pressure Vessels Are Constructed and Inspected; and others. To obtain the 2004 schedule of training courses and seminars offered by the National Board of Boiler and Pressure Vessel Inspectors at its Training and Conference Center in Columbus, Ohio, contact: Richard McGuire, Manager of Training, (614) 888-8320, e-mail: *rmcguire@nationalboard.org*; *www.nationalboard.org*.

Welding Introduction for Robot Operators and Programmers. This one-week course is offered at the Troy, Ohio, facility; or presented at a corporate location tailored to specific needs. Contact Hobart Institute of Welding Technology, (800) 332-9448, ext. 5603; Web site: *www.welding.org*.

Unitek Miyachi Corp. Training Services. Unitek Miyachi's Applications Lab offers personalized training services on resistance and laser beam welding and laser marking. For information, contact (626) 303-5676 or e-mail *info@unitek miyachi.com*; *www.unitekmiyachi.com*.

CWI Preparatory and Visual Weld Inspection Courses. Classes presented in Pascagoula, Miss., Houston, Tex., Houma, La., and Sulphur, La. Course lengths range from 40 to 80 hours. Contact Real Educational Services, Inc., (800) 489-2890; or e-mail to *info@realeducational.com*.

EPRI NDE Training Seminars. EPRI offers NDE technical skills training in Visual Examination, Ultrasonic Examination, ASME Section XI, and UT Operator Training. For information, contact Sherryl Stogner, (704) 547-6174, e-mail: *sstogner@epri.com*.

Free Home Study Internet-based GTAW Training Course for Welding Engineers and Beginners. This three-month-long certificate course requires 2–3 h study/week. Presented by Huntingdon Fusion Techniques. For complete details, send an e-mail to *hft@huntingdonfusion.com*.

Victor 2004 Training Seminars. Victor Equipment Co. offers training programs for gas apparatus and service repair technicians, end users, and sales personnel. For the 2004 schedule, contact Aaron Flippen, (940) 381-1217; *www.victorequip.com*.

The Fabricators & Manufacturers Association, International (FMA), and the Tube and Pipe Association, International (TPA), Courses. For the course schedule, call (815) 399-8775; e-mail: *info@fmametalfab.org*; *www.fmametalfab.org*.

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

Hellier NDT Courses. The 2004 schedule of courses in nondestructive testing is available from Hellier, 277 W. Main St., Ste. 2, Niantic, CT 06357, (860) 739-8950, FAX: (860) 739-6732.

NACE International Training and Certification Courses. Course description, dates, and registration forms are available from NACE Membership Services, (281) 228-6223, FAX: (281) 228-6329, e-mail: *msd@mail.nace.org*; *www.nace.org*.

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

Tool and Die Welding Course. The Hobart Institute of Welding Technology (HIWT) offers tool and die welding courses tailored to meet specific employer needs, presented on site or at the institute. Typical topics include surface prep, pretreat, preheat, quenching, postheat, etc. Contact: HIWT, 400 Trade Square East, Troy, OH 45373; (800) 332-9448; FAX: (937) 332-5300; *www.welding.org*.

Welding Skills Training Courses. Courses include weldability of ferrous and nonferrous metals, arc welding inspection and quality control, preparation for recertification of CWIs, and others. For complete schedule, contact: Hobart Institute of Welding Technology, 400 Trade Square East, Troy, OH 45373, (800) 332-9448 or, outside the U.S., (937) 332-5000, FAX: (937) 332-5200; *www.welding.org*.

Structural Welding: Design and Specification Seminars. Conducted by the Steel Structures Technology Center (SSTC). For 2004 schedule and locations, contact: SSTC, (248) 344-2910, FAX: (248) 344-2911; *www.steelstructures.com*.

Machine Safeguarding Seminars. Conducted by Rockford Systems, Inc. For more information, contact Rockford Systems, P.O. Box 5525, Rockford, IL 61125, (800) 922-7533; FAX: (815) 874-6144; *www.rockfordsystems.com*.

ASME International — Section IX Welding Guide. Course #ZCD996. Introduction and review of Section IX welding information including welding documentation forms, review of Articles I and IV, sample WPS and review; sample POR and review; testing and examination requirements for performance qualification; and other issues relating to Section IX. For information, visit *www.asme.org/pro_dev*.

Call for Papers

The Laser Institute of America has issued a call for papers for its International Laser Safety Conference to be held March 7–10, 2005, Marina Del Rey, Calif. Topics of interest include worldwide safety standards, operational policies and practices of lasers, bio-effects, laser light shows and displays, non-beam hazards, hazard and risk analysis, training programs, laser safety in health care facilities, and regulatory, mandatory, and voluntary safety standards. October 15, 2004, is the deadline for submitting abstracts of papers. Submit abstracts online at *www.liaregistration.org*.

Educational Opportunities

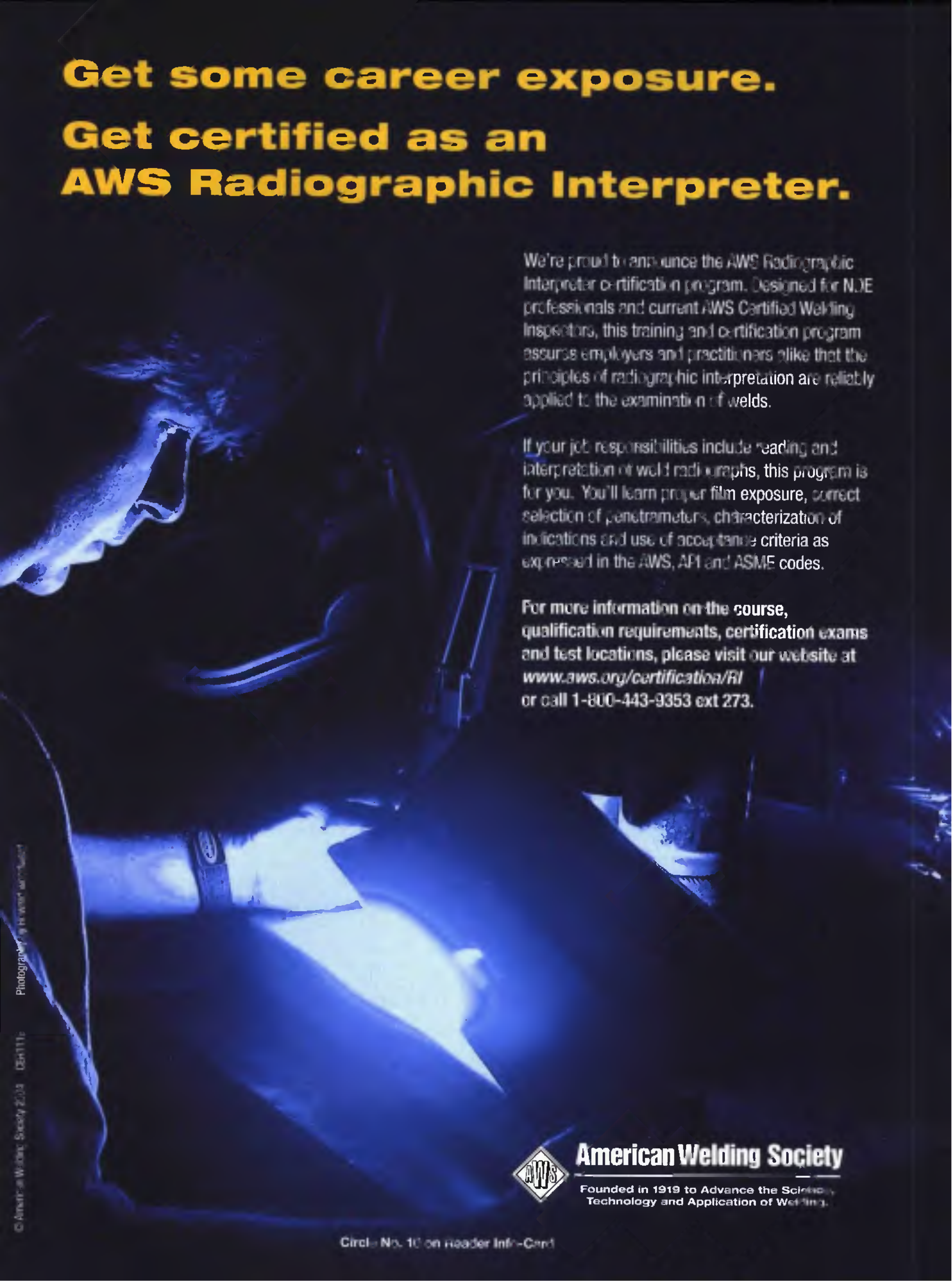
AWS 2004 Schedule
CWI/CWE Prep Courses and Exams

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.

City	Exam Prep Course	CWI/CWE Exam
Atlanta, Ga.	Oct. 24–29 (API 1104 Clinic also offered)	Oct. 30
Baltimore, Md.	Oct. 31–Nov. 5 (API 1104 Clinic also offered)	Nov. 6
Beaumont, Tex.	Nov. 7–12 (API 1104 Clinic also offered)	Nov. 13
Chicago, Ill.	Oct. 24–29 (API 1104 Clinic also offered)	Oct. 30
Denver, Colo.	Oct. 3–8 (API 1104 Clinic also offered)	Oct. 9
Long Beach, Calif.	Nov. 7–12 (API 1104 Clinic also offered)	Nov. 13
Louisville, Ky.	Nov. 14–19 (API 1104 Clinic also offered)	Nov. 20
Miami, Fla.	EXAM ONLY	Oct. 14
Miami, Fla.	Dec. 5–10 (API 1104 Clinic also offered)	Dec. 11
Orlando, Fla.	Nov. 15–20 9-Year Recertificatiom Course	No Test
Phoenix, Ariz.	Oct. 3–8 (API 1104 Clinic also offered)	Oct. 9
Pittsburgh, Pa.	Oct. 17–22 (API 1104 Clinic also offered)	Oct. 23
Portland, Oreg.	Nov. 7–12 (API 1104 Clinic also offered)	Nov. 13
Reno, Nev.	Oct. 31–Nov. 5 (API 1104 Clinic also offered)	Nov. 6
Rochester, N.Y.	EXAM ONLY	Aug. 21
Sacramento, Calif.	Oct. 4–9 9-Year-Recertification Course	No Test
St. Louis, Mo.	EXAM ONLY	Dec. 4
San Antonio, Tex.	Oct. 17–22 (API 1104 Clinic also offered)	Oct. 23
San Juan, P.R.	Dec. 5–10 (API 1104 Clinic also offered)	Dec. 11
Sioux Falls, S.Dak.	Nov. 14–19 (API 1104 Clinic also offered)	Nov. 20
Tulsa, Okla.	Oct. 17–22 (API 1104 Clinic also offered)	Oct. 23

An Important Event on Its Way?

Send information on upcoming events to the Welding Journal Dept., 550 NW LeJeune Rd., Miami, FL 33126. Items can also be sent via FAX to (305) 443-7404 or by e-mail to campbell@aws.org.


Get some career exposure.
Get certified as an
AWS Radiographic Interpreter.
We're proud to announce the AWS Radiographic Interpreter certification program. Designed for NDE professionals and current AWS Certified Welding Inspectors, this training and certification program assures employers and practitioners alike that the principles of radiographic interpretation are reliably applied to the examination of welds.
If your job responsibilities include reading and interpretation of weld radiographs, this program is for you. You'll learn proper film exposure, correct selection of penetrameters, characterization of indications and use of acceptance criteria as expressed in the AWS, API and ASME codes.
For more information on the course, qualification requirements, certification exams and test locations, please visit our website at
www.aws.org/certification/RI
or call 1-800-443-9353 ext 273.
American Welding Society
Founded in 1919 to Advance the Science, Technology and Application of Welding.
Circle No. 10 on Reader Info-Card

Precautions with Fumes and Gases

Many welding, cutting, and allied processes produce fumes and gases that may be harmful to your health.

Definition

- Fumes are solid particles that originate from welding consumables, the base metal, and any coatings present on the base metal.
- In addition to shielding gases that may be used, gases are produced during the welding process or may be produced by the effects of process radiation on the surrounding environment.
- Acquaint yourself with the effects of these fumes and gases by reading the Material Safety Data Sheets (MSDSs) for all materials used (consumables, base metals, coatings, and cleaners).
- For help, consult a recognized specialist in industrial hygiene or environmental services.
- The amount and composition of these fumes and gases depend upon the composition of the filler metal and base material, welding process, current level, arc length, and other factors.

Possible Effects of Overexposure

Depending on the material involved, the effects may range from irritation of the eyes, skin, or respiratory system to more severe complications. Effects may occur immediately or at some later time.

- Fumes can cause symptoms such as nausea, headaches, dizziness, and metal fume fever.
- The possibility of more serious health effects exists when highly toxic materials are involved. For example, manganese overexposure can affect the central nervous system resulting in impaired speech and movement.
- In confined spaces, the gases might displace breathing air and cause asphyxiation.

How to Avoid Overexposure

- Keep your head out of the fumes.
- Do not breathe the fumes.
- Use enough ventilation or exhaust at the arc, or both, to keep fumes and gases from your breathing zone and general area.
- In some cases, natural air movement provides enough ventilation and fresh air.
- Where ventilation is questionable, use air sampling to determine the need for corrective measures.
- Use mechanical ventilation to improve air quality.
- If engineering controls are not feasible, use an approved respirator.
- Work in a confined space only if it is well ventilated, or while wearing an air-supplied respirator. Fumes from welding or cutting and oxygen depletion can alter air quality, causing injury or death. Be sure the breathing air is safe.
- Follow OSHA guidelines for permissible exposure limits (PEL) for various fumes.
- Follow the American Conference of Governmental Industrial Hygienists, recommendations for threshold limit values (TLV)* for fumes and gases.
- Have a recognized specialist in industrial hygiene or environmental services check the operation and air quality and make recommendations for the specific welding or cutting situation.

Information Sources

Occupational Safety and Health Administration (OSHA). *Code of Federal Regulations*, Title 29 Labor, Parts 1910.1 to 1910.1450, available from the U.S. Government Printing Office, Superintendent of Documents, P.O. Box 371954, Pittsburgh, PA 15250-7954 (telephone: (800) 321-6742, Web site: *www.osha.gov*).

American Conference of Governmental Industrial Hygienists (ACGIH). *Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices*, available from ACGIH, 1330 Kemper Meadow Dr., Cincinnati, OH 45240-1634 (telephone: 513-742-2020; Web site: *www.acgih.org*).

American Welding Society (AWS). *Fumes and Gases in the Welding Environment* and other welding related safety and health publications, available from Global Engineering Documents, 15 Inverness Way East, Englewood, CO 80112-5776 (telephone: 800-854-7179; Web site: *www.global.ihs.com*).

Mine Safety and Health Administration (MSHA). *Code of Federal Regulations*, Title 30 Mineral Resources, Parts 1 to 199, available from the U.S. Government Printing Office, Superintendent of Documents, P.O. Box 371954, Pittsburgh, PA 15250-7954 (telephone: 202-693-9400; Web site: *www.msha.gov*).

For specific information, refer to the applicable Material Safety Data Sheet available from the manufacturer, distributor, or supplier.

Source: AWS Safety and Health Fact Sheet No. 1.

*TLV is a registered trademark of the ACGIH.

AWS Foundation Grants Additional Scholarships

THE SECTION NAMED SCHOLARSHIP PROGRAM

Scholarships sponsored by AWS Sections to support students in their communities.

Congratulations to Jeremy Olszowy, 2004-2005 recipient of the Amos and Marilyn Winsand – Detroit Section Named Scholarship.

"I would like to thank the American Welding Society for supporting me in my educational studies of welding engineering. I really enjoy learning and expanding my background in the field."

Jeremy Olszowy
Ferris State University, Welding Engineering Technology

THE NATIONAL SCHOLARSHIP PROGRAM

Scholarships available to students pursuing a minimum four-year degree in a specific field at an accredited four-year university.

Congratulations to Joshua W. Sleigh, 2004-2005 recipient of the Jerry Robinson – Inweld Corporation Scholarship.

"What a blessing it is to receive the Jerry Robinson-Inweld Scholarship to pursue my dream of becoming a welding engineer and to seek higher quality production in industries."

Joshua W. Sleigh
LeTourneau University, Welding/Materials Joining Engineering

THE INTERNATIONAL SCHOLARSHIP PROGRAM

International Scholarships are awarded to full-time international students pursuing undergraduate or graduate studies in joining sciences.

Congratulations to Yong Chae Lim, 2004-2005 recipient of the AWS International Scholarship.

"I thank the American Welding Society for awarding me this scholarship. This will definitely help me financially in my studies allowing me to dedicate more of my time to expand my knowledge in welding engineering. Thank you."

Yong Chae Lim
The Ohio State University, Welding Engineering

For specific information on the Scholarship Programs, please visit our website at *www.aws.org/foundation*.

AWS Foundation, Inc.
Building Welding's Future through Education

NJC Investigates Adhesive Bonding Steel to Composites

As a part of the Navy's Surface Strike Affordability Initiative, the Navy Joining Center is leading a project team that is developing adhesive bonding technology for composites-to-steel structures for the next-generation surface combatants.

The initial focus of this technology is directed at the DD(X) Class land attack destroyers. The technology developed will have applications extending to other surface-combatant ships including aircraft carriers. The project is being performed by a team with participation from Bath Iron Works, Northrop Grumman Ship Systems, The Composites Manufacturing Technology Center of Excellence — South Carolina Research Authority, Penn State University/ARL, Boeing, and Edison Welding Institute.

The Navy Joining Center is developing technologies designed to reduce the topside weight of the next-generation surface combatants, beginning with the DD(X) Class pictured above.

New material systems are required as a result of advanced performance criteria identified in the DD(X) program and other Navy ships. These requirements call for reducing the weight of ships, especially topside structures that are above the waterline. Thus, there is an increased demand to use composite materials in the fabrication of structures such as helicopter hangars, superstructure, and mast enclosures. Composites are strong, lightweight, and not susceptible to corrosion. However, to take full advantage of the benefits offered by composite materials, industry must be provided with advanced joining methods to bond composite and steel structures for marine applications.

Currently, mechanical fasteners are used to join composites to steel and composites to composites on Navy ships. These fasteners are expensive, their installation procedures are labor intensive, and the joints require long-term maintenance. Adhesive bonding eliminates the labor costs associated with mechanical fasteners and permits the integration of composites into new surface-combatant vessel designs, meeting the functional requirements of structures, signatures, and longevity. Thus, the focus of this project is to develop and demonstrate a producible and cost-effective steel-to-composite adhesive joining technology that meets the DD(X)'s requirements .

Specifically, the project will target large composite-to-steel structural joints, where adhesive bonds must provide load continuity throughout the ship's structure. A concurrent engineering approach is being used to demonstrate through engineering analysis and physical testing that the functional and manufacturing requirements for adhesive bonded joints are attainable.

The goals of the project are as follows:

- An engineered steel-to-composite joint design that meets functional requirements for Navy surface combatants
- A selection of adhesives that meet manufacturing and performance requirments
- A robust manufacturing process that will work in the shipyard environment
- Nondestructive inspection methods for both manufacturing and fleet service use
- Repair techniques

The project team has selected an adhesive system and developed a design for bonded joints that meet performance requirements of the DD(X) program. This design has already been subjected to comprehensive finite element analysis and is currently being validated by mechanical testing of the bonded joints.

In addition, the manufacturing process has been demonstrated by bonding full-scale composite-to-steel structures in a shipyard environment. Adhesive bond joint characterization activities are currently under way to confirm the mechanical properties of the bonded joints.

The nondestructive testing of joints is under development using ultrasonic techniques. A number of structural integrity demonstrations are planned for the near future to further document the performance of the joints.

This Navy Manufacturing Technology project is well aligned with the DD(X) program office and Navy shipbuilders to support the implementation of the new processes. The procedures that will evolve from these studies will serve as vital building blocks for all future composite-to-steel ship designs — to meet the needs of the 21st century Navy.

For more information, contact Larry Brown at *larry_brown@ewi.org*, (614) 688-5080; or George Ritter at (614) 688-5199, *george_ritter@ewi.org*.

NJC Operated by EWi
The Navy Joining Center
1250 Arthur E. Adams Dr.
Columbus, OH 43221
Phone: (614) 688-5010
FAX: (614) 688-5001
e-mail: *NJC@ewi.org*
www: *http://www.ewi.org*
Contact: Larry Brown

By Howard M. Woodward

The 28 Leadership Symposium attendees posed for a class photo before going back to work in the classroom.

Lee Kvidahl's vision of an annual program to train AWS volunteers was fulfilled once again July 31 through August 3 when the Sixth Annual Leadership Symposium took place at AWS Headquarters in Miami, Fla.

Kvidahl's concept was to strengthen District representatives' leadership skills, offer them tips on planning activities, provide an opportunity to meet key AWS staff personnel, and expose them to AWS's supporting resources.

Numerous graduates of the previous leadership symposia have moved up to serve in District and Section posts, further supporting the program's value.

Rhenda Mayo, director, Member Services, and **Ray Shook**, executive director, provided Staff support to the symposium conducted by **Ron Gilbert**.

Gilbert, an outside facilitator, has been retained to host these symposia for his skillful ability to present diverse and fun-filled interactive programs.

The Symposium leaders included (from left) Ray Shook, AWS executive director; Rhenda Mayo, director, Member Services; Lee G. Kvidahl, AWS past president (1993–94); and Ron Gilbert, program facilitator.

Listed here are the representatives and their Section names with District numbers in parentheses: **Jim Shure**, *Boston (1);* **Brian Cassidy**, *Long Island (2);* **David Vinson**, *Philadelphia (2);* **John Ament**, *Lancaster (3);* **Jennifer Hurry**, *Washington, D.C. (3);* **Stewart Harris**, *Triangle (4);* **Michael Bannester**, *North Central Florida (5);* **Howard Johns**, *Niagara Frontier (6);* **Eric Johnson**, *Cincinnati (7);* **Bob Humphrey**, *Western Carolina (8);* **Glen Wade**, *Holston Valley (8);* **Paul C. Hebert**, *New Orleans (9);* **Lee Smith**, *Northwestern Pennsylvania (10);* **Dan Harrison**, *Cleveland (10);* **Scut Reitenour**, *Western Michigan (11);* **Mark Rotary**, *Detroit (11);* **Craig H. Wentzel**, *Milwaukee (12);* **Wayne Abarca**, *Illinois Valley (13);* **Steven Hoff**, *Sangamon Valley (14);* **Mace Harris**, *Northwest (15);* **Rick Hanny**, *Nebraska (16);* **Veronica Covey**, *Central Texas (17);* **John N. Husfeld**, *Houston (18);* **Chris Hobson**, *Olympic (19);* **Richard "Woody" Cook**, *Utah (20);* **Henry L. Jackson**, *L.A./Inland Empire (21);* **Mike Rabo**, *Sacramento (22);* **Dale Phillips**, *San Francisco (22).*

One representative from each District is selected annually to participate in the Leadership Symposium. Each Section may nominate a candidate by sending its recommendation to the District director. The ideal candidate is an effective communicator who can share the tips and skills learned at the symposium with their District director and other Section leaders.

To assure time for sharing this feedback, the Leadership Symposium will be a new standing agenda item at each District Conference. ♦

member-get-a-member campaign

Listed are the participants in the 2004–2005 AWS Member-Get-A-Member Campaign. For campaign rules and a prize list, see page 67 of this *Welding Journal*. If you have questions regarding your member proposer points, call the AWS Membership Dept., (800/305) 443-9353, ext. 480.

Winner's Circle

Members who have sponsored 20 or more new Individual Members, per year, since June 1, 1999.

J. Compton, *San Fernando Valley (4)*
E. H. Ezell, *Mobile (2)*
J. Merzthal, *Peru (2)*
G. Taylor, *Pascagoula (2)*
B. A. Mikeska, *Houston (1)*
R. L Peaslee, *Detroit (1)*
W. L. Shreve, *Fox Valley (1)*
S. McGill, *N.E. Tennessee (1)*
T. Weaver, *Johnstown/Altoona (1)*
G. Wuomer, *Johnstown/Altoona (1)*
R. Wray, *Nebraska (1)*

( ) Denotes the number of times the member achieved Winner's Circle status. Status is awarded at the close of each membership campaign year.

President's Honor Roll

Members who sponsor 1–5 new Individual Members between June 1, 2004, and May 31, 2005. Those sponsoring 2 or more AWS Individual Members are listed here.

J. Cantlin, *Southern Colorado — 2*
E. Ezell, *Mobile — 2*
G. Garner, *St. Louis — 2*
P. Harper, *Baton Rouge — 2*
D. Kensrue, *Long Beach/Orange Cty. — 2*
J. Krall, *Dayton — 2*
P. Layola, *International — 2*
S. Salamun, *New Jersey — 2*
G. Schrueter, *Puget Sound — 2*
T. Shirk, *Tidewater — 2*

Student Sponsors

AWS Members who sponsor 3 or more new AWS Student Members between June 1, 2004, and May 31, 2005.

D. Scott, *Peoria — 21*
N. Carlson, *E. Idaho/Montana — 11*
R. Collins, *New York — 11*
G. Euliano, *Northwestern Pa. — 10*
G. Seese, *Pittsburgh — 8*
J. Crosby, *Atlanta — 5*
R. Patovesik, *St. Louis — 3* ♦

new AWS supporters

New Affiliate Companies

CRM Fabrication & Repair, Inc.
2419 Old Thompson Bridge Rd., Ste. E-9
Gainesville, GA 30501

IPC, Inc.
211 N. Gear Ave.
West Burlington, IA 52655

Keco Industries
7375 Industrial Rd.
Florence, KY 41042

Operating Engineers Training Trust
2190 S. Pellisier Pl.
Whittier, CA 90601

Telic Corp.
P.O. Box 552
Valparaiso, IN 46380

Whitehead Construction, Inc.
P.O. Box 92
Elizabethton, TN 37644

New Supporting Companies

Oden Enterprises, Inc.
1110 Spruce St.
Wahoo, NE 68066

Thomas & Betts
8700 Fairbanks N.
Houston, TX 77064

New Distributor Member

AWESCO
20 Center St.
Alban, NY 12204

New Educational Institution

Eastern New Mexico University
P.O. Box 6000
Roswell, NM 88202

New Sustaining Companies

Southern Erectors, Inc.
6540 W Nine Mile Rd.
Pensacola, FL 32526
Representative: Thomas A. Jones Jr.

Southern Erectors, Inc., in business since 1973, is an industrial metal fabrication and erection and mechanical contractor specializing in paper machine hoods, hood air supplies, general machine room ventilation, boiler breeching, and air-pollution control systems. The systems include electrostatic precipitators, bag houses, wet and dry scrubbers, flue gas ducting, and ash hoppers.

Garrett Container Systems, Inc.
123 N. Industrial Park Ave.
Accident, MD 21520
Representative: James O. Kitzmiller

Garrett Container Systems designs, manufactures, and markets aluminum shipping and storage containers for government (primarily defense) and commercial markets. The company's commitment to quality as well as its employees has resulted in strong continuous growth in both sales and employment. The company is ISO 9001-2000 and FAA certified.

Kleinfelder
7802 Barton
Lenexa, KS 66214
Representative: Joseph M. Vincent

Kleinfelder is a full-service geotechnical, materials testing, environmental, and construction management firm.

It operates from about 60 offices and employs more than 1600 professionals including specialists in geotechnical engineering, environmental consulting, field construction monitoring, steel inspection, and geological and laboratory testing.

The firm provides technical engineering consultation tempered by years of experience in all project fields.

Fusion, Inc.
4658 E 355th St.
Willoughby, OH 44094
Representative: Rony Straniero

Fusion specializes in brazing and soldering automation, including the manufacture of several hundred varieties of brazing alloy pastes.

Fusion also offers feasibility testing, design, and specialty building of automation machines and applicators, and design expertise to provide customers with one reliable source for all of their brazing and soldering needs. ♦

Welding professionals convene for the Instructors Institute

Shown outside the welding laboratory at AWS Headquarters in Miami, Fla., are most of the professionals who participated in the recent Instructors Institute program held July 28–31. Chris Pollock, AWS director of education, is at the far right, and Paola Celis, administrative assistant, AWS Education Product Development, is seated at left.

Each of the 22 AWS Districts selected one professional welding educator to participate in the 2004 Instructors Institute, held July 28–31 at AWS Headquarters in Miami, Fla.

The program was an intensive mix of classroom study, discussion, and a lot of hands-on projects in the well-equipped AWS welding laboratory.

This year's presenters included facilitator **Ron Gilbert** (pictured on page 61), **Richard DePue**, and AWS President **Jim Greer**. Assisting in the AWS laboratory were **Dennis Klingman**; manufacturing representatives **Gary Flohr** and **Jon VanPelt**; and **Chris Pollock**, AWS education director; **Albert Hermida**, AWS welding lab manager; and U.S. Army Sgt. **Kerry P. Stinson**, on assignment at AWS.

The work days began at 7 a.m. and ended about 5 p.m., followed by dinner and planned recreation in the evenings. The key ingredient for the success of these programs is the camaraderie that develops among these educators from all parts of the United States, combined with the expertise of the professionals who conduct the institute's classes and direct the activities.

The participants are listed by District number, noted in parentheses. **Paul Mendez**, Fairhaven, Mass. (1); **Kenneth Messemer**, W. Babylon, N.Y. (2); **Steven Robeson**, Berryville, Va. (3); **Ed Dupree**, Hampton, Va. (4); **Michael Bannester**, Silver Springs, Fla. (5); **Bruce Lavallee**, Athens, N.Y. (6); **Jim Hannahs**, Piqua, Ohio (7); **Joe Livesay**, Crossville, Tenn. (8); **Anthony Blakeney**, Hammond, La. (9); **Dave Cook**, Concord Township, Ohio (10); **Richard Mathis**, Copemish, Mich. (11); **Mike Brown**, Pewaukee, Wis. (12); **Mike Spangler**, St. Anne, Ill. (13); **Gary Dugger**, Fairmount, Ill. (14); **Mark Harmon**, Grand Forks, N.Dak. (15); **Danny McCullock**, Lincoln, Neb. (16); **Carey Wesley**, Beaumont, Tex. (18); **Jeff Schwab**, Spokane, Wash. (19); **Randee Munns**, Logan, Utah (20); **Richard Samanich**, N. Las Vegas, Nev. (21); and **Dale Phillips**, Brentwood, Calif. (22). For details on the Instructors Institute, contact the AWS Education Dept., (800) 443-9353, ext. 229. •

Instructors learned new methods from each other in the lab sessions.

Dennis Klingman (right) and Sgt.Stinson (center-right) monitored the lab work.

Every assignment was intended to challenge the welder's skills.

A summary of changes in ASME Section IX, 2004 Edition

by Walter J. Sperko, P.E.

This is a summary of the changes that appear in the 2004 addenda to ASME Section IX. These changes and related discussions are the author's opinions and do not necessarily represent the official opinions of the Subcommittee IX.

Welding Procedure (QW-200)

Section IX has always permitted welding procedure specifications (WPSs) to specify more than one welding process and it has permitted test coupons to be welded with more than one process; however, previous rules in QW-200.4 covering this used the term "procedure" somewhat loosely, making its real meaning elusive. In these addenda, QW-200.2 has been changed to require that the approximate weld deposit thickness for each process, filler metal, and set of variables be recorded when a test coupon is welded and more than one process, filler metal, or other essential variable is used. For example, if a test coupon is welded using GMA and a portion is welded using short circuiting transfer and the remainder using spray transfer, the approximate deposit thickness for each transfer mode must be recorded.

The term "procedure" in QW-200.4 has been replaced with WPS, making it clear that multiple WPSs may be used to weld a single production joint. In addition, when a WPS specifies multiple welding processes or sets of variables, QW-200.4 permits individual welding processes and sets of variables be used independently provided one stays within the limits of the variables for that process. That is, for a WPS specifying GMAW in both the short circuiting and spray transfer modes, each transfer mode variation may be used independently provided the weld deposit limits, preheat, and interpass temperature limits, etc., for each variation are met during production welding.

Walter J. Sperko, president, Sperko Engineering, provides consulting services in welding, metallurgy, corrosion, and ASME code issues. Contacts: (336) 674-0600; www.sperkoengineering.com *or e-mail* sperkoeng@att.net.

QW-404.12 and QW-404.33 were the subject of an inquiry by a user who was unclear what an "SFA filler metal specification classification" was. This paragraph's first phrase now reads, "A change in the filler metal classification within an SFA specification." QW-404.12 always intended that the classification of the filler metal (e.g., E7018, ER70S-6, etc.) be specified in the WPS and, for impact-tested applications, QW-404.33 always intended that the filler metal in the WPS be limited to the classification that was used on the test coupon.

The biggest change in these addenda was the addition of QW-290 for writing and qualifying WPSs for temper bead welding. Development of these rules began in 1999.

Note: There is an error in Fig. QW-462.2, discovered after the addenda were published. The figure shows the radius along the edge of the specimen as $^1/_8$-in. *minimum*, it should read $^1/_8$-in. *maximum*.

Temper bead welding is a technique in which the properties of the heat-affected zone (HAZ) or the previously deposited weld metal are controlled (i.e., "tempered") by the manner in which subsequent layers of weld metal are deposited. The most common reason to use temper bead welding is as an alternative to postweld heat treatment when postweld heat treatment is impractical. Temper bead is permitted today mostly for maintenance and repair applications.

Subcommittee IX developed temper bead rules because various construction codes (i.e., Section III, Section VIII, B31.3, etc.) and the *National Board Inspection Code* had adopted a variety of rules for temper bead welding that were neither uniform nor consistent. The Section IX temper bead rules will correct this. In addition, Section IX's rules replace prescriptive requirements with the more traditional Section IX approach of making the manufacturer or contractor responsible for determining how to make a specific type of weld, then having them qualify their WPSs accordingly. This will provide more flexibility to users than the present prescriptive requirements allow.

Shown is the U.S. delegation to ISO TC 44 held July 20 and 21 in Osaka, Japan. From left are AWS Vice Presidents Gerry Uttrachi and Damian Kotecki, AWS Past President Tom Mustaleski, author Walter J. Sperko, and Andrew Davis, AWS managing director, Technical Services.

QW-290 requires bend testing of test coupons and provides for either hardness testing or impact testing to be specified by the Construction Code as well as acceptance criteria. In the event that they do not specify a test method, the default test method is hardness testing with hardness data recorded for information only. When qualification by impact testing is required, the Construction Codes will be responsible for specifying the extent of testing (i.e., weld metal, HAZ, and base metal) and location within each region as well as the test temperature.

Just as supplementary essential variables are "turned on" when a Construction Code requires that a WPS be qualified with impact testing, so too, use of temper bead welding in accordance with QW-290 must be specified by the Construction Code. Also paralleling impact testing rules, an existing WPS that is not qualified for temper bead welding may be upgraded simply by preparing a separate test coupon and performing the required testing for temper bead welding. If the basis for qualification for temper bead welding is impact testing, the

WPS being upgraded must be qualified with supplemental essential variables. Partial penetration welds (such as repair welds) may be qualified by making a partial penetration weld, but full-penetration groove welds must be qualified by making full-penetration groove welds. Partial or full-penetration groove welds qualify fillet welds.

All consumable electrode welding processes and machine GTAW are permitted to be used for temper bead welding. Manual GTAW is prohibited because, unlike consumable electrode welding, there is no correlation between the arc energy and the size of the weld bead associated with that energy. For machine GTAW, an advanced heat input formula that takes into account the ratio of heat input to the filler metal size and feed rate is specified. In-process repairs using manual GTAW are permitted, but a special WPS that is based on machine welding qualifications must be developed, and special welder qualification is required.

The variables for temper bead welding are covered in Table QW-290.4. This table has separate columns of essential variables for qualification by hardness testing and by impact testing. The test method specified by the Construction Code determines the column that applies to the qualification. If no test method is specified, the hardness testing column applies. The nonessential variables column always applies.

It is interesting to compare the requirements for temper bead qualification using hardness testing vs. impact testing as the basis for qualification. Since increased hardness is the result of faster cooling and loss of toughness is caused by slower cooling, the variables in each column are frequently opposites. For example, when hardness testing is the basis for acceptance, increasing the thickness of the base metal beyond the thickness qualified is not permitted, but when impact testing is the basis for acceptance, decreasing the thickness below the thickness qualified is not permitted.

The most novel concept in the temper bead rules is controlling the ratios of heat input between weld bead layers. In order to control properties, the heat input or bead size of the first layer of weld metal against the base metal in the test coupon is measured. Then the heat input or bead size of the second layer is measured, and so on. When doing production welding, the ratio of heat input or bead size between the weld metal that is against the base metal and the layer of weld metal on top of that layer must be controlled to within a percentage of the ratio qualified, and so on for each subsequent pair of layers until at least $^{3}/_{16}$ in. (5 mm) of weld metal has been deposited. At that point, the heat input or bead size is the maximum used on the test coupon if impact testing is the basis for qualification, and it is the minimum used on the test coupon if hardness testing is the basis for qualification.

Another interesting aspect of temper bead welding is the use of a surface temper bead reinforcing layer. This is weld metal that is added after welding is essentially complete. The function of this layer is to temper the final layer of weld metal, particularly the HAZ at the toe of the weld. Controlling the distance from the toe of the completed weld to the edge of the surface temper bead reinforcing layer is critical to tempering the HAZ. If the distance is too close, the HAZ will reharden on cooling; if it is too far, the desired tempering will not occur. The optimum distance depends on the heat input of the tempering bead, but is typically around $^{1}/_{8}$ in. (3 mm). Surface temper bead reinforcing layers are usually removed by grinding, but sometimes that is not necessary depending on the properties of the weld metal.

Anyone who performs qualification of WPSs for temper bead welding should document the following in addition to the variables in QW-290 since, due to early industry feedback, the Subcommittee is considering imposing them as essential variables in the next addenda:

1) Bead overlap

2) Grinding to remove a portion of beads (e.g., flat topping or half-bead grinding) prior to depositing the next layer

3) Surface temper weld bead placement relative to the toe of the weld.

QW-290 is not presently permitted by any Construction Codes, but a Section XI Code Case is being prepared to permit its use. Other sections and codes will follow. Long-term, the temper bead rules will offer a method for improving toughness and ductility of welds as an alternative to postweld heat treatment.

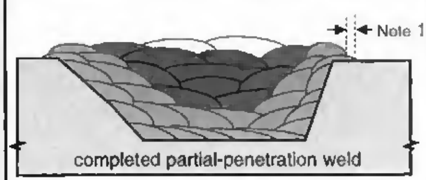
Welder Qualification (QW-300)

There are no changes for welder or welding operator qualifications.

Base Metals and Filler Metals

S-numbers have always been somewhat confusing to Code users, particularly occasional users. QW-420.2, for instance, stated that S-number materials were "optional." The fact is that S-number materials behave the same as P-numbers — except that they are different. S-numbers are assigned to materials that are found in ASME B31, *Code for Pressure Piping*, but are not recog-

Nomenclature for Temper Bead Welds



- weld beads against base metal
- first layer tempering beads
- second layer tempering beads
- fill weld beads
- surface temper weld reinforcing beads

Note 1: Distance from the edge of the surface temper beads to the toe of the weld.
Note 2: Beads near the finished surface may be both tempering beads and surface temper reinforcing beads.

nized materials in the *Boiler and Pressure Vessel Code*. ASME policy prohibits these materials from being assigned P-numbers.

P-numbers and S-numbers are assigned to materials on the same technical basis — weldability. From a welding viewpoint, materials that are assigned to the same P- or S-Number have equivalent weldability, i.e., all materials assigned S-3 require the same welding practices as materials assigned P-3.

QW-420.2 has been revised to simplify the rules regarding S-numbers and their restrictions and limitations. According to this paragraph, P-number materials are fully interchangeable with S-number materials for welder qualification. In contrast, if a WPS is qualified using P-number materials, equivalent S-number materials may also be welded; however, if the WPS is qualified using S-number materials, only S-number materials are qualified. With apologies to Dickens, 'tis a far, far better thing to weld test coupons using materials assigned P-numbers than to weld materials assigned S-numbers.

To take this clarification one step further, QW-423, which allows substitution of alternate base metals for welder qualification, has been revised to state that qualification with either P-number or S-number materials qualifies the welder for both P-number and S-number materials. QW-424, which controls qualification of base metals for procedure qualification, now says that when P-number materials are used for procedure qualification, such a qualification supports welding corresponding P-number and S-number materials. One still has to read QW-420.2 to find out tha procedures qualified with S-number materials only qualify corresponding S-

— Sperko continued on next page

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number materials.

A new family of alloys, UNS R31233, has been added to the P-number listing as P-49. This is a cobalt-based alloy with 26%Cr, 9%Ni, 5%Mb, Fe, and W. Nickel and Co are interchangeable from a weldability viewpoint, so this alloy fits into the general category of the other nickel alloys. Interestingly, the Subcommittee elected to skip P-numbers 47 and 48 to leave room for new "true" nickel alloys.

The P- or S-numbers of base metals can be found at *www.pnumbers.com*. This site is not ASME-sanctioned, but it contains a table of all the metals listed in QW/QB-422. This table can be sorted by any column in QW/QB-422, i.e., by specification, grade, P-number, product form, etc. The *www.fnumbers.com* site covers filler metals.

Standard Welding Procedure Specifications (SWPSs)

Five new SWPSs have been added to Appendix E. They cover P/S-1 to P/S-8 base metals from $^1/_8$ to $1^1/_2$ in. in thickness. Welding is permitted with SMAW and GTAW using Types 309 and 309L filler metals. Separate SWPSs using GTAW with and without consumable inserts are provided.

Brazing (QB)

The tensile test specimens used for brazing have been revised to allow use of specimens that are pinned to the tensile testing machine using a hole through the wide section of the specimen through which a dowel is inserted above the jaws of the tensile testing machine prior to loading. With a pinned specimen, the load into the specimen passes through the pin, eliminating deformation of the specimen due to the clamping action of the jaws. Clamping action of the jaws sometimes deforms the specimen so much that failure occurs at the edge of the deformation outside the reduced section — far from the weld. This test specimen is consistent with AWS B2.2 and C3.2 requirements.

Metrication

This edition will include metric units throughout all sections. Metric conversions in Section IX are rational conversions, not mathematical conversions. That is, we selected the metric units that we would have selected had we been working in metric all along. For example, if a test coupon was $1^1/_2$ in. (38 mm) thick, the base metal thickness range qualified used to be $^3/_{16}$ to 8 in. (4.8 to 203 mm). In these addenda, the metric range qualified is 5 to 200 mm, which makes more sense if one is working in the metric system.

The foreword states that the Code user must work in either U.S. Customary Units or in metric units and that one system must be used for all phases of construction (materials, design, fabrication, etc.) without mixing of units.

Appendix F permits conversion of U.S. Customary Units to metric using three significant figures where conversions are not provided by the Code. It would be reasonable to apply this practice to those values found on PQRs in the event that one is required to prepare metric WPSs. There is no intention to require requalification using metric-unit materials in order to write metric-version WPSs.

Coming Attractions

The committee has already received comments on the temper bead rules, and some new requirements will be added. There are changes being made to resistance welding, including changes to variables to bring them up to current technology and a new, more meaningful set of tests will be imposed.

ASME code committee meetings are open to the public. The schedule is available at *www.sperkoengineering.com* and *www.asme.org*. ♦

standards notices

technical committee meetings

AWS technical committee meetings are open to the public. To attend a meeting, contact the staff secretary of the committee as listed below at AWS, 550 NW LeJeune Rd., Miami, FL 33126; (305) 443-9353.

All of the following meetings are for standards preparation.

Oct. 4, D14B Subcommittee on General Design and Practices. Las Vegas, Nev. Contact: Peter Howe, ext. 309.

Oct. 4, D14E Subcommittee on Welding of Presses. Las Vegas, Nev. Contact: Peter Howe, ext. 309.

Oct. 5, D14C Subcommittee on Earthmoving and Construction Equipment. Las Vegas, Nev. Contact: Peter Howe, ext. 309.

Oct. 5, D14G Subcommittee on Welding of Rotating Equipment. Las Vegas, Nev. Contact: Peter Howe, ext. 309.

Oct. 5, C7C Subcommittee on Laser Beam Welding and Cutting. San Francisco, Calif. Contact: Harold Ellison, ext. 299.

Oct. 6, D14 Committee on Machinery and Equipment. Las Vegas, Nev . Contact: Peter Howe, ext. 309.

Oct. 7, C7B Subcommittee on Electron Beam Welding and Cutting. San Francisco, Calif. Contact: Harold Ellison, ext. 299.

Oct. 12, C1 Committee on Resistance Welding. Romulus, Mich. Contact: Harold Ellison, ext. 299.

Oct. 13, B2 Committee on Procedure and Performance Qualifications. Pittsburgh, Pa. Contact: Richard McGinnis, ext. 471.

Oct. 13, D8 AWS/SAE Joint Committee on Automotive Welding. Romulus, Mich. Contact: Harold Ellison, ext. 299.

Oct. 13, D8C AWS/SAE Subcommittee on Automotive Arc Welding. Romulus, Mich. Contact: Harold Ellison, ext. 299.

Oct. 13, D8D AWS/SAE Subcommittee on Automotive Resistance Spot Welding. Romulus, Mich. Contact: Harold Ellison, ext. 299.

Oct. 13, D8E AWS/SAE Subcommittee on Automotive Laser Welding. Romulus, Mich. Contact: Harold Ellison, ext. 299.

Oct. 13, D8F AWS/SAE Subcommit tee on Automotive Resistance Spot Welding of Aluminum Alloys. Romulus, Mich. Contact: Harold Ellison, ext. 299.

Oct. 13, D8G AWS/SAE Subcommittee on Automotive Arc Welding of Aluminum. Romulus, Mich. Contact: Harold Ellison, ext. 299.

Oct. 13–15, A2 Committee on Definitions and Symbols. Wheeling, W.Va. Contact: Cynthia Jenney, ext. 304.

Oct. 13–15, A2B Subcommittee on Definitions. Wheeling, W.Va. Contact: Cynthia Jenney, ext. 304.

Oct. 13–15, A2C Subcommittee on Symbols. Wheeling, W.Va. Contact: Cynthia Jenney, ext. 304.

Oct. 14, D15 Committee on Railroad Welding. St. Louis, Mo. Contact: Richard McGinnis, ext. 471.

Oct. 14, D15A Subcommittee on Freight Cars and Their Materials. St. Louis, Mo. Contact: Richard McGinnis, ext. 471.

Oct. 15, C4 Committee on Oxyfuel Gas Welding and Cutting. Clearwater, Fla. Contact: Harold Ellison, ext. 299.

standards for public review

A5.24/A5.254M:200X, *Specification for Zirconium and Zirconium-Alloy Welding Electrodes and Rods.* Revised standard — $8.00. ANSI public review expires 10/26/04.

B5.4:200X, *Specification for the Qualification of Welder Test Facilities.* New standard — $6.00. ANSI public review expires 10/26/04.

D14.6/D14.6M:200X, *Specification for Welding of Rotating Elements of Equipment.* Revised standard — $56.75. ANSI public review expires 10/19/04.

AWS was approved as an accredited standards-preparing organization by the American National Standards Institute (ANSI) in 1979.

AWS rules, as approved by ANSI, require that all standards be open to public review for comment during the approval process.

The above standards are submitted for public review.

A draft copy may be obtained from **Rosalinda O'Neill**, AWS Technical Services Business Unit, 550 NW LeJeune Rd., Miami, FL 33126; telephone (800/305) 443-9353, ext. 451, e-mail: *roneill@aws.org.*

ISO draft standard for public review

ISO/DIS 5172, *Gas Welding Equipment – Blowpipes for Gas Welding, Heating, and Cutting — Specifications and Tests.*

Copies of this draft international standard are available for review and comment through your national standards body, which in the United States is ANSI, 25 W 43rd St., Fourth Floor, New York, NY 10036; telephone (212) 642-4900.

Any comments regarding ISO documents should be sent to your national standards body.

In the United States, if you wish to participate in the development of international standards for welding, contact Andrew Davis at (305) 443-9353 ext. 466, e-mail: *adavis@aws.org.* ♦

technical inquiry

Subject: This inquiry relates to qualifying an aluminum procedure by AWS D15.1:2001, *Railroad Welding Specification — Cars and Locomotives.*

Question: Is it the intent of the D15.1 Code to utilize nondestructive testing (NDT), specifically radiographic testing (RT), for an aluminum welding procedure qualification or is aluminum exempt from this requirement?

Response: The intent of the D15.1 Code is that aluminum is not exempt from the procedure qualification requirement of Paragraph 17.6.1.3 to perform NDT prior to performing mechanical testing.

Note: The D15 Committee will take under advisement the exemption that is raised in this inquiry for the next revision of the AWS D15.1 standard. ♦

District director awards

The District Director Award provides a means for District directors to recognize individuals who have made outstanding contributions to their local Sections and/or Districts.

Alfred Fleury, District 2 director, has nominated the following for this award for 2003–2004.

Bill Miller, *New Jersey*

John Bruskotter, District 9 director, has nominated the following for this award for 2003–2004.

John Angers, *Acadiana*
George Fairbanks, *Baton Rouge*
Davis Rayborn, *Baton Rouge*
Rickye Messer, *Baton Rouge*
Charles Lewis, *Acadiana*
Lavon Mills, *Mobile*
Jackie Morris, *Mobile*
Gene Bickford, *Morgan City*
Bill New, *Morgan City*
Byron Landry, *New Orleans*
Paul Hebert, *New Orleans*
David Foster, *New Orleans*
Anthony Blakeney, *Southeastern Louisiana Univ. Student Chapter*
Ollie Myers, *Baton Rouge Capital Area Student Chapter*
Roy Ledford, Jr., *Birmingham Section* and *Bessemer State Technical College Student Chapter*

Michael Kersey, District 12 director, has nominated the following for this award for 2003–2004.

Francis Juckem, *Madison-Beloit*
Robert Schuster, *Milwaukee*

Jack D. Heikkinen, District 15 director, has nominated the following for this award for 2003–2004.

Loren Kantola, *Arrowhead*
Doug Mroz, *Arrowhead*
Marvin Anderson, *Arrowhead*
Tom Baldwin, *Arrowhead*
Mark Harmon, *Northern Plains*
Ralph Williams, *Northern Plains*
Joel Johnson, *Northern Plains*
Brent Smith, *Northern Plains*
Mace Harris, *Northwest*
Mike Henson, *Northwest*
Dale Szabla, *Northwest*
John R. Penaz, *Northwest*
Pam Lesemann, *Northwest*
Bob Sands, *Northwest*
Mark Sandvig, *Northwest*

Phil Zammit, District 19 Director, has nominated the following for this award for 2003–2004.

David Atteridge, *Inland Empire*
John Sisk, *Inland Empire*
Rick Henson, *Spokane*
Rich Irving, *Spokane*
Jerry Hope, *Puget Sound*
Chris Hobson, *Olympic*
Mike Yung, *Portland*
Sue Caldera, *Portland*
Steve Prost, *British Columbia*
Fred Stuewe, *Willamette Valley*

Jesse Grantham, District 20 director, has nominated the following for this award for 2003–2004.

John Cantlin, *Southern Colorado*
Patrick Mulville, *Southern Colorado*
Russell Rux, *Wyoming*
Rick Schneider, *Wyoming*
Jim Corbin, *Colorado*
Bob Teuscher, *Colorado*
Farren Elwood, *Colorado*
Richard "Woody" Cook, *Utah*
Bill Komlos, *Utah*
Danny MacCallum, *Albuquerque*
Pierrette Gorman, *Albuquerque*
Phil Fuerschbach, *Albuquerque*
Juan Martinez, *Southwest Idaho* ♦

District director data

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membership counts

member grades	as of 9/1/04
Sustaining companies	413
Supporting companies	203
Educational institutions	316
Affiliate companies	237
Welding distributor companies	52
Total corporate members	1,221
Individual members	43,104
Student & transitional members	4,136
Total members	**47,240**

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SECTION NEWS

DISTRICT 3

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

WASHINGTON, D.C.

JANUARY 4
Speaker: **John Abbitt**, district manager
Affiliation: Thermadyne Corp.
Topic: Cutting heavy metals using the exothermic process
Activity: Abbitt demonstrated slice cutting for the attendees. **Craig Meiser** and Chair **Becky Lorenz** were presented District Director Awards by **Alan Badeaux,** District 3 director.

FEBRUARY 11
Speaker: **Steve Collins**, president
Affiliation: Excel Mechanical
Topic: The challenges of operating a small welding business
Activity: This Washington, D.C., Section program was held in Fairfax, Va.

MARCH 10
Activity: The Washington, D.C., Section members toured the UDVAR-HAZY Center at the Smithsonian Air and Space Museum at Dulles Airport.

MAY 1
Activity: The Washington, D.C., Section members held their picnic at Carderock Pavilion, Md., including a hands-on opportunity to try their hands at blacksmithing, which was supervised by blacksmith **Les Lorenz**.

YORK CENTRAL PENNSYLVANIA

AUGUST 13
Activity: The Section hosted its annual golf outing at Cool Creek Country Club in Wrightsville, Pa. About 116 golfers participated in the event. **Jeff Hoffman** was honored for his expert chairing of the golf outing event for the past five years. The first general Section meeting will be held October 7 at the Four Points Sheraton Hotel in York, Pa., at 6:00 p.m. **Robert Blauser** of Harley Davidson is scheduled to speak on motorcycle frame fabrication.

Speaker John Abbitt is shown at the January Washington, D.C., Section program with Becky Lorenz.

Steve Collins accepts a speaker gift from Becky Lorenz, Washington, D.C., Section chair at the February program.

Washington, D.C., Section members pose for a group shot during their tour at Dulles Airport in March.

The Washington, D.C., Section members and guests pose during their picnic in May.

Jeff Hoffman (left) accepts an appreciation award from George Bottenfield, York Central Pennsylvania Section chair, at the August golf outing.

Alan Badeaux, District 3 director, presents Becky Lorenz with the District Director Award at the Washington, D.C., Section program in January.

Mark Skehan (left) and Joe Redding were two of the top-scoring golfers at the York Central Pennsylvania golf outing.

Of course Rick Forbey is smiling, he just won the $200 drawing at the Syracuse Section's April meeting.

Sgt. Alfonso Ash addressed the South Florida Section in April.

Shown at the Syracuse Section program last October are (from left) Chair Zane Keniston, Bob Davis, Vince Carnisax, and Vice Chair Ken Phy.

The Cleveland Section board members discuss the monthly program schedule at its August meeting.

DISTRICT 5

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

SOUTH FLORIDA

OCTOBER 23, 2003
Activity: The Section toured Exponent Failure Analysis Associates in Miami, Fla. The firm is engaged in investigations of engine and machinery failures, automotive component malfunctions, structural defects, and problems in boating and shipping. The dinner was held at Backyard Barbecue.

NOVEMBER 2, 2003
Activity: The South Florida Section hosted its annual Scramble Golf Tournament at Hollywood Beach Golf course for about 80 participants.

FEBRUARY 5
Speaker: **Thomas M. Mustaleski**, AWS president
Affiliation: BWXT Y12 L.L.C.
Topic: Plans to modify S.E.N.S.E., CWE, scholarship, and other AWS programs

APRIL 29
Speaker: **Alphonso L. Ash, Jr.**
Affiliation: Sergeant, U.S. Army
Topic: Training Army welders
Activity: As part of the Army's Training with Industry program, Sgt. Ash worked at AWS headquarters for a year, where he honed his technical skills, learned welding theory and inspection techniques, and studied for and passed his CWI exam. This South Florida Section meeting was held at McFatter Technical Center with many of its welding students in attendance.

DISTRICT 6

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

SYRACUSE

OCTOBER 8, 2003
Speakers: **Bill Davis**, president, and **Bob Davis**, vice president
Affiliation: Davis Inspection Service
Topic: Welder qualification test samples
Activity: The Section members had a hands-on demonstration of weld samples testing using both destructive and nondestructive techniques.

APRIL 14
Activity: The Syracuse Section members toured Ferris Industries in Munnsville, N.Y., to study the manufacture of commercial mowers. **Phil Wenzel**, president, discussed the company's history from its founding in 1909. The dinner was held at Joel's Front Yard Steak House in Vernon, N.Y. **Rick Forbey** of Liftech, Inc., the Section's newest member, was the winner of the $200 cash drawing.

DISTRICT 10

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

CLEVELAND

AUGUST 12

Activity: The Section's hoard met to plan the Section's program schedule. Present were **Paul Null, Harry Sadler, Bill Soltis, Dennis Klingman, Mark Demchak, Louis Verhass, John Gerken, Dan Harrison, Bob Gardner, Rich Harris,** and **Bob Henderson** (the photographer). The incoming officers are **Mark Demchak**, chair; **Larry Waller** and **Dan Harrison,** vice chairs; **Paul Null**, secretary; and **Harry Sadler,** treasurer.

MAHONING VALLEY

AUGUST 6

Activity: The 29th annual **Jim Best** golf outing was held at Tanglewood Golf Course in Pulaski, Pa. Volunteers included **Crystal Savage, John Brletich, Amy Sherwood, Spencer Hulett, David Dicciccio,** and **Tiffany Schafer.** Sponsors and hole donors were Airgas, Avesta, Brilex, City Machine Technologies, Crossley Economy, Columbiana Boiler, Girard Machine, Hobart, Kobelco, Lincoln Electric, Linde, Miller Electric, Northeast Fab., Norton, Praxair, Reichard Industries, Speciality Fab., Steel & Alloy Specialist, Spectrochemical Testing, Stoody, Timken Industrial, and Youngstown Oxygen & Welding.

Working at the Mahoning Valley Section's golf outing were (from left) Crystal Savage, John Brletich, Amy Sherwood, Spencer Hulett, David Dicciccio, and Tiffany Schafer.

Top team at the Mahoning Valley tournament included (from left) Nick Ambrosini, Bob Jackson, Phil Guerra, and Carl Ford.

NORTHWESTERN PA.

AUGUST 10

Speaker: **Chet Wesley, director**

Affiliation: Tri State Welding Lab

Topic: Attracting welding industries to the Erie, Pa., industry base

Activity: This program was held at Tri State Welding Lab for 35 attendees. **Matt Bonindi,** Student Chapter chair, and **Will Boozel,** welding instructor, presented Section Chair **Chet Wesley** with a speaker gift.

Chet Wesley (center) receives a speaker gift from Matt Bonindi (left) and Will Boozel at the Northwestern Pennsylvania Section program in August.

DISTRICT 11

Director: Eftihios Siradakis
Phone: (989) 894-4101

NORTHERN MICHIGAN

FEBRUARY 12

Speaker: **Chuck Hunt**

Affiliation: TBA Career Technical Center

Topic: Battery-powered GMA welding equipment

Activity: The program was held in Traverse City, Mich.

APRIL 22

Activity: The Northern Michigan Section members toured the Natural Gas Compression facility in Traverse City, Mich. **Bill Jenkins**, general manager, explained the processes used by the company to manufacture its line of reciprocal and rotary screw type compressors for natural gas.

MAY 25

Speaker: **Brent Williams**

Affiliation: Miller Electric Mfg. Co.

Topic: Innovations in GTA welding

Activity: **Art Hedges** accepted his Gold Membership Award for 50 years of membership in the Society, presented by Northern Michigan Chair **Bill Neil**

Art Hedges (center) receives his Gold Membership Award from Northern Michigan Chair Bill Neil (left) and Vice Chair Chuck Hunt.

AWS President Jim Greer (far right, rear) is shown with some of the area's outstanding welding students who attended the St. Louis Section program in February.

St. Louis Section members are shown at Metaltek International with Rick Suria as he receives a speaker's gift from Chairman Kevin Corgan in March.

Shown are the St. Louis Section members who worked at the Illinois State Vocational Welding Contest in April. From left to right: Garner Kimbrell, Brian Muenchau, Bob Palovcsik, Chuck Gulash, Gay Cornell, Paul Thompson, and District 14 Director Tully Parker.

Working at the St. Louis golf outing are (from left) Norm Helton, Hil Bax, Becky McDonald, Gay Cornell, Dave Payne, Tully Parker, and Don Koleson.

and Vice Chair **Chuck Hunt**. The program was held at Cottage Cafe Restaurant in Traverse City, Mich.

NORTHWEST OHIO

JULY 23
Activity: The Section held its annual scholarship golf outing at Whitford Valley Golf Club. **Don Leonharot, Terry Lowe**, and **Tony Duris** organized the event for the 20 participating teams. The dinner was held at the clubhouse. All of the proceeds raised went to benefit the Section's scholarship fund.

DISTRICT 14

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

INDIANA

AUGUST 14
Activity: The Section held a program planning session for the upcoming year at the Starweld facility in Rushville, Ind.

ST. LOUIS

FEBRUARY 19
Speaker: **James E. Greer**, AWS president
Affiliation: Moraine Valley Community College, professor
Topic: Welding education
Activity: More than 140 students and teachers were in attendance. The program was held at Elks Lodge, Granite City, Ill.

MARCH 18
Activity: The St. Louis Section toured the Metaltek International casting plant. **Rick Suria**, quality control manager, conducted the tour.

APRIL 23
Activity: The St. Louis Section members assisted with the Illinois State Vocational Welding Contest held at the Capital Area Vocational Center, Springfield, Ill.

MAY 22
Activity: The St. Louis Section held its May outing at Fairmount Park Racetrack in Collinsville, Ill.

JUNE 7
Activity: The St. Louis Section held its annual golf tournament at Fox Creek Golf Course. The organizers and coordinators included **Norm Helton, Hil Bax, Becky McDonald, Gay Cornell, Dave Payne, Tully Parker**, and **Don Koleson.**

Most of the participants in the Sacramento Valley Section-sponsored CWI exam are shown in this photograph taken August 15.

DISTRICT 18

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

SAN ANTONIO

AUGUST 14

Activity: The Section hosted its annual picnic and awards-presentation program at Braun Hall in San Antonio, Tex. **Hamp Drew** received the Educator of the Year Award, and **Matt Casanova** accepted the Dalton E. Hamilton Memorial CWI of the Year Award. District Director **John Mendoza** presented proclamations to Life Members **Lawrence Schenk** and **Al Marin** to dedicate two new scholarships to honor each man.

Shown at the San Antonio program are (from left) Matt Casanova, Lawrence Schenk, Al Marin, and Hamp Drew.

DISTRICT 19

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

OLYMPIC

New Student Chapter Organized. AWS welcomes the **South Sound Student Chapter**. It will be mentored by the Olympic Section members.

DISTRICT 22

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

SACRAMENTO VALLEY

AUGUST 15

Activity: The Section hosted a CWI exam for 40 participants.

Henry Rojas served as Part B supervisor, **Rob Purvis** and **Lorne Grimes** worked as proctors for the exam. Dale Flood, Section chair, worked as Part A and C supervisor.

Flood also took all of thethe photographs, so he missed out on being included in the pictures. ♦

Section secretaries take note . . .

The deadline for submitting news and Section meeting reports in Society News is the 20th of each month. For example, a report received at the *Welding Journal* office by November 20th will appear in the January issue. Reports received November 21st will appear in the February issue.

Many Section secretaries use the AWS online method for submitting Section Meeting Reports and the photos together using the AWS Web site: *www.aws.org/sections/SecEvent.html.*

You can type your info directly into this form, print out a copy for yourself, attach your photos, and send them directly to the *Welding Journal* office.

Or, you can fax your Section Meeting Reports to (305) 443-7404.

Or, you can call the editor, Howard Woodward, at (800) 443-9353, ext. 244, to discuss your special projects and how best to report them for publication in the *Journal*. ♦

Guide to AWS Services

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Identifies funding sources for welding education, research, and development. Monitors legislative and regulatory issues of importance to the industry.

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Mary Ellen Mills.. *memills@aws.org* ......(444)

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Exhibiting Information .... (242, 295)

Associate Executive Director/Sales Director
Jeff Weber.. *jweber@aws.org* ....(246)

Director of Convention & Expositions
John Ospina.. *jospina@aws.org*.............(462)

Organizes the annual AWS Welding Show and Convention. Regulates space assignments, registration materials, and other Expo activities.

PUBLICATION SERVICES
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National Sales Director
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Welding Handbook
Welding Handbook Editor
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Publishes the Society's monthly magazine, *Welding Journal*, which provides information on the state of the welding industry, its technology, and Society activities. Publishes *Inspection Trends*, the *Welding Handbook*, and books on general welding subjects.

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Educational Product Development
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Responsible for tracking the effectiveness of existing programs and for the orchestration of new product and service development. Coordinates in-plant seminars and workshops. Administers the S.E.N.S.E. program. Assists Government Liaison Committee with advocacy efforts. Works with Education Committees to disseminate information on careers, national education and training trends, and schools that offer welding training, certificates or degrees.

Conferences and Seminars
Director
Giselle I. Hufsey.. *giselle@aws.org* ....(278)

Responsible for conferences, exhibitions, and seminars on topics ranging from the basics to the leading edge of technology. Organizes CWI, SCWI, and 9-Year Renewal certification-driven seminars.

CERTIFICATION OPERATIONS
Director
Terry Perez.. *tperez@aws.org* ....(470)

Information and application materials on certifying welders, inspectors, and educators..(273)

INTERNATIONAL BUSINESS DEVELOPMENT
Director
Walter Herrera.. *walter@aws.org* ....(475)

AWS AWARDS, FELLOWS, and COUNSELORS
Managing Director
Wendy S. Reeve.. *wreeve@aws.org* ....(293)

Coordinates AWS awards and AWS Fellow and Counselor nominees.

TECHNICAL SERVICES
Department Information ....(340)

Managing Director
Andrew R. Davis.. *adavis@aws.org* ......(466)
International Standards Activities, American Council of the International Institute of Welding (IIW)

Director, National Standards Activities
Peter Howe.. *phowe@aws.org*................(309)
Machinery & Equipment Welding, Robotic & Automatic Welding, Computerization of Welding Information.

Manager, Safety and Health
Stephen P. Hedrick.. *steveh@aws.org* (305)
Metric Practice, Personnel & Facilities Qualification, Safety & Health, Joining of Plastics & Composites, ASC Committee on Safety, Plastic Welding Qualification

Technical Publications
Senior Manager,
Rosalinda O'Naill.. *roneill@aws.org* ....(451)

AWS publishes more than 200 technical standards and publications widely used in the welding industry.

Engineers
Harold P. Ellison.. *ellison@aws.org* .....(299)
Welding in Sanitary Applications, Automotive Welding, Resistance Welding, High-Energy Beam Welding, Aircraft and Aerospace, Oxyfuel Gas Welding & Cutting.

John L. Gayler.. *gayler@aws.org* ....(472)
Structural Welding, Welding Iron Castings

Rakesh Gupta.. *gupta@aws.org* ....(301)
Filler Metals & Allied Materials, International Filler Metals, Instrumentation for Welding.

Cynthia Jenney .. *cynthiaj@aws.org* ....(304)
Definitions & Symbols, Brazing & Soldering, Brazing Filler Metals & Fluxes, Technical Editing.

Richard McGinnis.. *richard@aws.org* ..(471)
Procedure & Performance Qualification, Railroad Welding, Mechanical Testing of Welds, Methods of Inspection.

Brian McGrath . *bmgrath@aws.org* ......(311)
Thermal Spraying, Arc Welding & Cutting, Welding in Marine Construction, Piping & Tubing, Friction Welding, Joining Metals & Alloys, Titanium and Zirconium Filler Metals.

Note: Official interpretations of AWS standards may be obtained only by sending a request in writing to the Managing Director, Technical Services. Oral opinions on AWS standards may be rendered. However, such opinions represent only the personal opinions of the particular individuals giving them. These individuals do not speak on behalf of AWS, nor do these oral opinions constitute official or unofficial opinions or interpretations of AWS. In addition, oral opinions are informal and should not be used as a substitute for an official interpretation.

WEB SITE ADMINISTRATION
Director
Keith Thompson.. *keiko@aws.org*........(414)

Nominees for National Office

Only AWS Sustaining Members, Members, Honorary Members, Life Members, or Retired Members who have been members for 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 devotion to the affairs of the Society, assistance in promoting cordial relations with industry and other organizations, and for the contribution of time and effort on behalf of the Society.

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

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

International Meritorious Certificate Award: This award is given in recognition of the candidate's significant contributions to the worldwide welding industry. This award 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. ♦

TeleWeld
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Reprints
Order quality custom reprints from Claudia Stachowiak, FosteReprints, telephone (866) 879-9144 ext. 121, or e-mail at *sales@fostereprints.com*.

AWS Mission Statement

The mission of the American Welding Society is to advance the science, technology, and application of welding and allied processes, including joining, brazing, soldering, cutting, and thermal spray.

It is the intent of the American Welding Society to build AWS to the highest quality standards possible. The Society welcomes your suggestions. Please contact any of the staff listed on the previous page or AWS President James E. Greer, Moraine Valley Community College, 248 Circlegate Rd., New Lenox, IL 60451.

AWS Foundation, Inc.

550 NW LeJeune Rd., Miami, FL 33126
(305) 445-6628; (800) 443-9353 ext. 293
e-mail: *vpinsky@aws.org*
general information
(800) 443-9353, ext. 689

Chairman, Board of Trustees
Ronald C. Pierce

Executive Director
Ray W. Shook

Managing Director
Wendy S. Reeve

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

Guide Displays Photos of Cleaned Steel Surfaces

The Society for Protective Coatings publication 04-07, SSPC-VIS 3, *Guide and Reference Photographs for Steel Surfaces Prepared by Hand and Power Tool Cleaning*, contains 43 full-color reference photographs to be used as a supplement to the SSPC standards for hand and power tool cleaned steel. Included are seven different steel surfaces, four uncoated and three previously coated, before and after tool cleaning. The document revises and expands on the previous edition published in 1993. Price is $165, $115.50 to SSPC members. For more information or to purchase, call (877) 281-7772, or visit the online book store at *www.sspc.org*.

High-Temperature Textiles Depicted in Literature

Textiles for extreme-temperature industrial operations are detailed in the company's latest product selection guide oriented toward educating buyers on ways to improve their productivity and efficiency. Products are illustrated for maintenance, repair, operations, and production applications. The various categories of products include welding equipment and supplies, fire-protection equipment, and safety equipment and supplies.

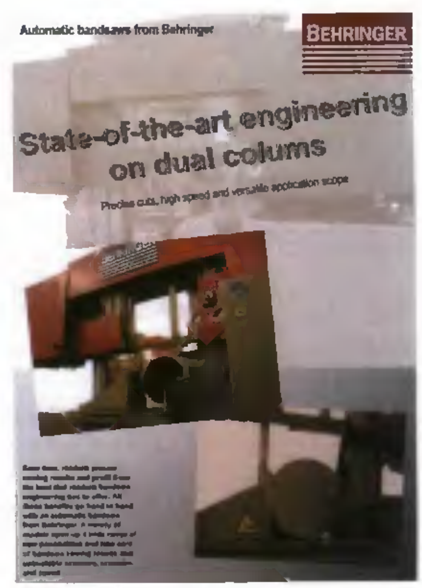
Auburn Manufacturing Inc. 112
P.O. Box 220, Mechanic Falls, ME 04256

Safety-Related Industrial Products Displayed

Industrial signs, label printers, printer software, safety signs, photoluminescent signs, pipe and valve markers, and numerous other safety-related industrial products are featured in a new catalog. One section is dedicated to the Prinzing Enterprises product lines, including lockout/tagout devices, training posters, safety dispensers, and compliance products.

Brady Corporation 113
6555 W Good Hope Rd., Milwaukee, WI 53223

Brochure Explains Features of Automatic Band Saws



An eight-page, full-color brochure describes the company's automatic band saws featuring large-diameter twin-column design to provide greater rigidity during cuts and more constant feed rates vs. the swing frame-type machines. Also covered is a discussion of the drive and control systems, saw blade operation, material handling, and cutting applications including bundle cuts. Specifications and cutting capacities for several automatic band saw machines are provided.

Behringer Saws, Inc. 114
Morgantown Business Pk., 721 Hemlock Rd.
Morgantown, PA 19543

Abrasive Blast Equipment and Accessories Pictured

This 120-page, color catalog features blast cabinets, blast cabinet wear parts, blast pots, valves and kits, blast pot wear parts, operator safety equipment, air blast accessories, industrial blast equipment, and blasting abrasives. Included are color photographs, product illustrations, and exploded parts diagrams to easily identify equipment, parts, and components.

International Surface Preparation 115
603 Park Point Dr., Ste. 200, Golden, CO 80401

AASHTO Releases New Publications Catalog

The latest American Association of State Highway and Transportation Officials (AASHTO) catalog includes descriptions of more than 200 titles. The literature covers a wide range of information on the design, construction, and maintenance of highways and transportation facilities.

AASHTO 116
P.O. Box 96716, Washington, DC 20078-7041

Plasma Arc Cutting System Illustrated in Literature

A 4-page, full-color brochure presents all features and specifications for the Cutmaster™ 51 air plasma cutting system for non-HF start automation applications. Detailed is the technology behind the 1Torch™ plasma torch, and how the machines can be used in combination with existing cutting tables for ¼-in. (6-mm) production cut capacity and ⅝-in. (15 mm) edge start capacity.

Thermal Dynamics Corp. 117
Ste. 300, 16052 Swingley Ridge Rd., Chesterfield, MO 63017

Catalog Features Four Abrasive Product Lines

The master catalog and price list illustrates and describes the company's lines of Power Brush, Anderlon® nylon filament abrasive brushes, abrasives, and maintenance products. Added in this edition are highlights depicting items available for 48-hour shipment. Other features include a new product index, additional technical information, and application visualizations.

Anderson Products 118
1040 Southbridge St., Worcester, MA 01610

— *continued on page 87*

Fifteen Advanced at FKI Logistex


Todd Ploudre


Kevin Brophy


Jill Raah


Chuck Waddle


Ken Buzek


Gary Cash

FKI Logistex Manufacturing Systems has named three members to new key positions. **Todd Ploudre** was promoted to controller; **Kevin Brophy** to manager, financial analysis; and **Jill Raah** to coordinator, marketing communications.

In FKI's Warehouse and Distribution North America group, customer operations, **Chuck Waddle** moved to executive VP, sales and systems engineering; **Ken Buzek** to executive VP, project management and installation; and **Gary Cash** to VP, product management. At the group's Cincinnati, Ohio, and Danville, Ky., units, **Bob Duplain** moved to senior VP and CFO; **Arlo Bromley** to VP, engineering; **Terry Wesley** to VP, manufacturing; **John Moore** to director, customer service and support; and **Pete Eschmeyer** to director, quality and ISO. In Emeryville and Napa, Calif., **Steve Downs** moves to general manager and CFO; **Farrokh Bhathena** to VP, operations; **Mark Hein** to VP, product development; and **Hazem Nashif** to chief technology officer.

Fibre-Metal Designates National Sales Manager


Scott Thorne

Scott Thorne has been promoted to national sales manager at The Fibre-Metal Products Co., Concordville, Pa. Previously, Thorne served the company as sales manager for its eastern zone and regional sales.

Praxair Surface Technologies Names Business Manager


Richard Thorpe

Praxair Surface Technologies, Indianapolis, Ind., a subsidiary of Praxair, Inc., has appointed **Richard Thorpe** as equipment and services business unit manager of TAFA Inc., Concord, N.H., the company's thermal spray equipment and consumables business. With the company for 23 years, Thorpe most recently served as business unit manager for standard equipment, and the product line manager for HVOF and powder feeders.

— continued on page 82

Will ISO welding standards include U.S. practices?

You decide.

ISO welding standards are important. In the long run, they will be used worldwide.
Within the next few years, the U.S. will begin using ISO filler metal standards. Thanks to U.S. volunteer efforts, those standards will contain U.S. standard practices and methods.

Without continuing U.S. volunteer participation — without being "at the table" when future ISO committee work is being done — additional ISO standards will be based on practices and methods other than those currently used in the U.S. Without U.S. volunteer participation, the industry will have to learn a whole new and expensive set of welding standards, rewrite thousands of WPSs, and requalify tens of thousands of welders.

ISO Welding committee meetings take place all over the world. U.S. volunteers donate considerable time to attend. AWS assists by providing up to $1,000 a year to defray travel expenses — but our support fund is low.

Your contribution is important and will make a difference.
To make contributing easy — and to provide you with advertising and recognition in return — we're selling ads in a special International Section of the *Welding Journal.* These ads will reach 50,000 readers, all potential buyers of your products. All proceeds will go directly to the ISO Participation fund, administered by the AWS International Standards Activities Committee.

Show your support for US participation in ISO.
A small, two-column inch ad in one *Welding Journal* issue is just $500. Discounts are available if you buy more than two months of advertising at a time.

Send your check, payable to AWS ISO Participation Fund, with 25 words of copy to:
AWS ISO Participation Fund
American Welding Society
550 NW LeJeune Road
Miami, FL 33126

These ads will appear in future issues of *Welding Journal*, beginning in the spring of 2005.

For more information on contributing,
call Bob Bishopric, Director of Marketing,
at 800-443-9353, ext. 213
or email *bbish@aws.org.*
To volunteer for work on ISO or other AWS standards,
call Andrew Davis at ext. 466
or email *adavis@aws.org.*

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

— continued from page 80

Dave Walters

Jerry Douglas

Great Lakes Air Systems Adds Two Employees

Great Lakes Air Systems, Clawson, Mich., a manufacturer of air filtration systems for robotic welding, has named **Dave Walters**, sales consultant to its staff, and **Jerry Douglas**, product manager. Walters previously was executive director, Advance Sign Group. Douglas previously served as plant manger, MSE Automation Guarding Systems.

Airgas Elects Board Member and Names Scott Melman Awardees

Airgas, Inc., Radnor, Pa., has elected **Richard C. Ill** to a three-year term on its board of directors. He fills the position vacated by **Frank B. Foster III**, who recently retired. Previously, Ill was president and CEO of Triumph Group, Inc., where he continues to serve as a director.

In another announcement, Airgas presented its annual Scott Melman Award to **Lee C. Cherry** and **Roger A. Robidas**. Cherry is CFO for Airgas Mid-America, based in Bowling Green, Ky. Robidas is special projects manager for Airgas East, based in Salem, N.H. Cherry and Robidas were cited for their long-term service to the company and their personal contributions to the integration of the BOC U.S. packaged gas business, which was completed on July 30.

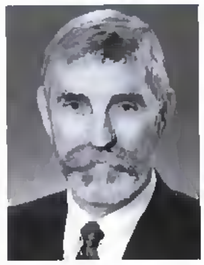
ESAB Fills Two Key Posts

Mark Elender

ESAB Welding & Cutting Products, Florence, S.C., has named **Mark Elender** as senior VP, sales, North America, and **Jon Rennie** as VP and general manager for all of its North American consumables business. Elender, with the company for 24 years, most recently served as VP, sales, for the United States. Rennie most recently served the company as VP, operations, for consumables.

MEMBER MILESTONE

Kotecki Elected VP of IIW



Damian J. Kotecki

Damian J. Kotecki, AWS vice president, was elected to serve as vice president of the International Institute of Welding (IIW) at the 2004 Annual Assembly held in Osaka, Japan, last July.

The IIW is a consortium of welding societies from about 46 countries worldwide. Since its inception in 1948, the IIW has directed its member societies in research and in communicating advances in welding materials, design, inspection, health and safety, education, training, and qualification standards. Dr. Kotecki said, "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. In my additional role as vice president of the American Welding Society, I expect to strengthen the relationship between IIW and the AWS."

Kotecki is technical director for stainless and high-alloy product development for The Lincoln Electric Co., Cleveland, Ohio. His column, Stainless Q&A, is a regular feature of the *Welding Journal*.

Obituaries

Richard H. LeTourneau

Richard H. LeTourneau

Richard H. LeTourneau, 79, died August 3 at his home in Longview, Tex.

Dr. LeTourneau was an author, industrialist, and president emeritus of LeTourneau University. He also served as president and CEO of his family's earthmoving machinery company, R. G. LeTourneau, Inc., based in Longview.

Since retiring in 1985, Dr. LeTourneau served as a computer literacy consultant to small colleges around the country, taught business courses, wrote several books on leadership, success, ethics, and business management, and served as interim dean of the School of Business at East Texas Baptist University. He also served on the boards of various business, political, civic, and church organizations.

Dr. LeTourneau is survived by his wife, Louise, four children, eight grandchildren, and eight great-grandchildren.

Marvin Moon

Marvin Moon

Marvin Moon died July 9 in Pacoima, Calif. Early in his career, Mr. Moon worked in manual welding operations at Rockwell Rocketdyne. His next position was at Astro Arc in Sun Valley, Idaho, where he worked for eight years in manual and automatic welding. In 1980, Mr. Moon joined Arc Machines, Inc., a manufacturer of orbital welding equipment, where he established its Welder Training Department. Mr. Moon remained manager of the department until his retirement in January 2002. He is credited with helping many welders make the transition from manual welding to orbital welding. He is survived by three sons.

Jerry L. Schuster

Jerry L. Schuster

Jerry L. Schuster, 63, died May 5 in Boston, Mass. An AWS Life Member and a member of ASM International, he held a master's degree in metallurgical engineering from the University of Illinois. For the past 14 years, Mr. Schuster was president of Omni Technologies Corp., Epping, N.H., where he was instrumental in the development of an aluminum flux cored brazing wire and rings, and other innovative processes for the aluminum brazing industry. Earlier, he worked for Hamilton Standard division of United Aircraft, ALCOA Research and Development, Alcoa Center, Pa., for 15 years; and Brazonics in Amesbury, Mass., Metal Bellows in Sharon, Mass., and EG&G in Salem, Mass. Mr. Schuster is survived by three sisters, two brothers, and many nieces, nephews, and great nieces and nephews.

American Welding Society

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

(please type or print in black ink)

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.____________

SUBMISSION DEADLINE FEBRUARY 1, 2005

American Welding Society

Nomination of AWS Counselor

I. HISTORY AND BACKGROUND

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

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

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

II. RULES

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

III. NUMBER OF COUNSELORS TO BE SELECTED

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

NEW PRODUCTS

— continued from page 23

Hollow Core Gouging Electrode Is Faster than Solid Rods

The Gouge Tech® Lightning Rod hollow core gouging electrode is made for any type of gouging torch connected to a DC power supply and compressed air source. The company says the product is faster than solid DC copper rods, with reduced smoke, reduced slag, and excellent arc stability on a variety of metals. Applications include gouging, cutting, piercing, creating grooves for weld joints, removing old welds, cleaning and repairing castings, rough machining, gouging out cracks, and other types of metal removal.

Flame Technologies, Inc. 109
703 Cypress Creek, Cedar Park, TX 78613

Infrared Camera Measures Up to 250°C

With thermal sensitivities of less than 0.10°C, the IR-InSight T250 provides clear images even when background hotspots are present. Featuring a 3.5-in. LCD display and a yellow ABS housing, the camera offers point-and-shoot, one-button operation. *SightView* image analysis and reporting software is included. The camera is suited for general predictive and preventive maintenance applications and inspections.

Infrared Solutions, Inc. 110
9600-T W. 54th Ave. N., Plymouth, MN 55447

Powered Pallet Truck Has 4400-lb Capacity

Included in the Advantage line of mobile material handling equipment, the Model ZEPWRPT44 is equipped with 43¼-in. forks and variable-speed drive. It incorporates a 2½-hp lift motor, a 1½-hp drive motor, and a 24-VDC battery operating system, along with a MOSFET controller for efficient battery use.

Advance Lifts, Inc. 110
701 Kirk Rd., St. Charles, IL 60174

Weld Seam Detector Handles Tubes from 5 to 500 mm in Diameter

Combining digital signal analysis and eddy current technology, the PC-based Model SND40 weld detector offers a graphical user interface with a touchscreen, as well as fieldbus and ethernet interfaces. It is suitable for tubes made of various metals and is largely independent of tube wall thickness. The detector handles difficult positioning tasks in tube bending machines, hydroforming presses, and other tube processing machines.

Roland Electronic GmbH 111
Otto-Maurer-Str. 17, Keltern DE 75210, Germany

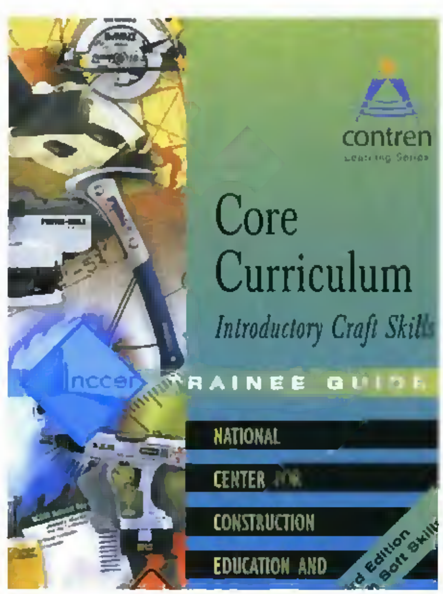
NEW LITERATURE

— continued from page 79

Patents and Trademarks Explained for Lay Persons

Patents and Trademarks Plain & Simple is intended to help inventors and small business owners determine what is and is not patentable, how to do patent searches on their own and avoid patent infringement problems, and how and when to consult an attorney. Included are guidelines on how to talk to an attorney, manage the budget, and choose, search, and register a trademark. Written by Michael H. Jester, a registered patent attorney, the volume is available in book stores, online, or from Career Press, 3 Tice Rd., P.O. Box 687, Franklin Lakes, NJ 07417; (800) 227-3371, price $16.99.

Craft Skills Covered in Text



Core Curriculum: Introductory Craft Skills, 3rd edition, a 490-page, full-color text, covers basic communication and employability skills, safety, construction math, hand tools, power tools, blueprints, and basic rigging. Published by Prentice Hall for the National Center for Construction Education and Research (NCCER), the volume is available in several formats priced at about $40 each, and as individual subject study modules at $14 each. For complete information contact NCCER Customer Service toll-free at (888) 622-3720.

CAREER OPPORTUNITIES

WANTED
Independent Sales Reps

to demonstrate welding alloys to end users.

-Consumables Market
-Repeat Customers
-Complements Industrial Rep's present line(s) of products.

Very unique opportunity.

Contact Christopher Biggar
Vulcan Systems, Inc.
(800) 642-9885

MIDWEST MARKETING COMMUNICATIONS PROFESSIONAL

with 10 years of experience in the welding industry for national and international companies. Bachelor of Arts in Communications with particular expertise in Marketing Strategy, Brand Building, Media Buying, Trade Shows & Event Planning. Willing to relocate.
Contact: Tracey Rettig (248) 336-2054 or tsr20042002@yahoo.com

GREAT WAGES PAID!

Located in Casper Wyoming, Westech/WOTCO manufactures large off road mining equipment. Must be able to weld with MIG - the normal weld wire we use is FCAW with 3/32 and 1/16; we also use GMAW with .045 weld wire. We offer many great benefits - incentive bonus, retirement plan, IRA contribution, heath, dental and life insurance, paid vacations and paid holidays. Visit our website at www.wstech.com, contact Linda at lakers@wotco.com or 307-235-1591 x124.

Pre-employment drug testing – EOE

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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.

	Professional	**Student** (in each of 3 levels)
First Place	Plaque	$200 + Plaque
Second Place	Ribbon	$100 + Ribbon
Third Place	Ribbon	$50 + Ribbon
Honorable Mention	Ribbon	Ribbon

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.

AWS Fellowships

To: Professors Engaged in Joining Research

Subject: Request for Proposals for AWS Fellowships for the 2005-06 Academic Year

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

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

Please note, there are important changes in the schedule which you must follow in order to enable the awards to be made in a timely fashion. Proposals must be received at American Welding Society by **January 10, 2005.** New AWS Fellowships will be announced at the AWS Annual Meeting, April 26-28, 2005.

THE AWARDS

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

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

DETAILS

The Proposal should include:

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

In addition, the proposal must include:

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

The technical portion of the Proposal should be about ten typewritten pages. Proposal should be sent electronically by **January 10, 2005,** to:

Gricelda Manalich (*gricelda@aws.org*)
Executive Assistant, Board Services/IIW
American Welding Society
550 N.W. LeJeune Rd., Miami, FL 33126

Yours sincerely,

Ray W. Shook
Executive Director
American Welding Society

WELDING RESEARCH

SUPPLEMENT TO THE *WELDING JOURNAL*, OCTOBER 2004
Sponsored by the American Welding Society and the Welding Research Council

Optimization of Shielded Metal Arc Weld Metal Composition for Charpy Toughness

Artificial neural network models can help formulate consumables

BY M. MURUGANANTH, S. S. BABU, AND S. A. DAVID

ABSTRACT. Artificial neural network models that predict the Charpy-impact toughness values as a function of composition, heat treatment, and shielded metal arc welding process parameters were coupled with multipurpose optimization software. This coupled model was used to optimize the carbon, nickel, and manganese concentrations in a weld to achieve a maximum toughness of 120 J at –60°C. The coupled model used linear and nonlinear techniques to explore the possible combinations of carbon, manganese, and nickel concentrations for a given set of welding process parameters. An optimum weld metal composition was achieved only with nonlinear methods. The number of iterations and the exploration of input parameter space varied depending upon the type of nonlinear technique. The predicted weld metal composition was in agreement with published results.

Introduction

The development of a new welding consumable for a weldment with good properties is often difficult due to complex interaction between alloying elements, welding process, process parameters, and the testing conditions. Among this wide range of variables, it is not possible to vary one variable without influencing the effect caused by the other. For example, Evans showed that, for a given shielded metal arc welding process and process parameters, increasing the titanium concentration from 7 to 30 parts per million (ppmw) led to a large increase in the toughness of Fe-C-Mn-based welds (Ref. 1). Though the concentration of titanium was varied, it influenced the effect of oxygen in the weld. In a similar manner, increasing nickel concentration in high-manganese (~2 wt-%) steel welds did not improve the toughness of the weld as would be expected otherwise. This phenomenon was explained with an increase in hardenability effect, i.e., increased nickel and manganese concentration led to the formation of martensite (Ref. 2). The above example illustrated the need for extensive trial and error experimentation guided by metallurgical principles. In the last three decades, extensive research has been done on welding consumable design and there exists a large set of experimental data relating the process, composition, and properties (Refs. 3–6). However, these welding consumable designs are not guaranteed to be the optimum, since it is not practical to explore all combinations of compositional and process variations due to the cost and time limitations.

M. MURUGANANTH, formerly at the Metals and Ceramics Division, Oak Ridge National Laboratory, Oak Ridge Tenn., is at the School of Material Engineering, Nanyang Technological University, Singapore. S. S. BABU and S. A. DAVID are with the Metals and Ceramics Division, Oak Ridge National Laboratory.

To arrive at an optimum composition and process parameters, an alternative approach is to use computational models that have been well tested and validated with already existing experimental data. Computational models relate the input parameters (e.g., voltage, current, weld metal composition, etc.) to the output parameters (strength, toughness, microstructure, etc.). These models can be empirical, phenomenological, or integrated models (may include empirical and phenomenological models). Empirical models are either based on analytical functions or artificial neural network models that have been fitted or trained, respectively, on already existing data. The empirical models in general have limited extendibility to the range of input data used in the development stage. The phenomenological models are based on well-established principles or equations that describe particular phenomena. Many parameters used in the development of these models are derived from experimental information. The integrated models can couple many such models to relate the complex interactions between different phenomena. By interrogation of these computational models over the wide range of compositional and process parameters, it is possible to arrive at optimum composition by repeated calculations.

KEY WORDS

Consumable Design
Neural Network Modeling
Optimization Methodologies
Nonlinear Programming
Sequential Quadratic Programming
Downhill Simplex Methods
Genetic Algorithms

Optimization of welding using computational models must consider two main issues. First, the models cannot be applicable to overall input space due to its limitation on applicability. This can be solved by limiting the scope of the input data used in the calculations. Second, even with limited scope of input variables, this approach may sometimes lead to insolvability conditions, depending on the input parameters space that needs to be considered for optimization. For example, in a case where n input parameters are varied over a range of m values independently, the number of combinations that need to be evaluated by this forward modeling would amount to m^n. In a steel weld metal, if the concentrations of nickel, silicon, and manganese are allowed to vary between 0 and 10 wt-% with increments of 0.1, then the number of combinations to find the optimum will be 10^6. The 10^6 evaluations can be easily performed for a simple model that requires resources of only a small desktop computer. For example, if a model takes 0.01 s for one calculation, it will take only 2.78 h. If the model takes 8 h to run a particular case, it will take 913 years! This problem of insolvability can be removed by extending the recent advances in optimization methodologies. The current paper pertains to the evaluation of optimization software toward weld design optimization.

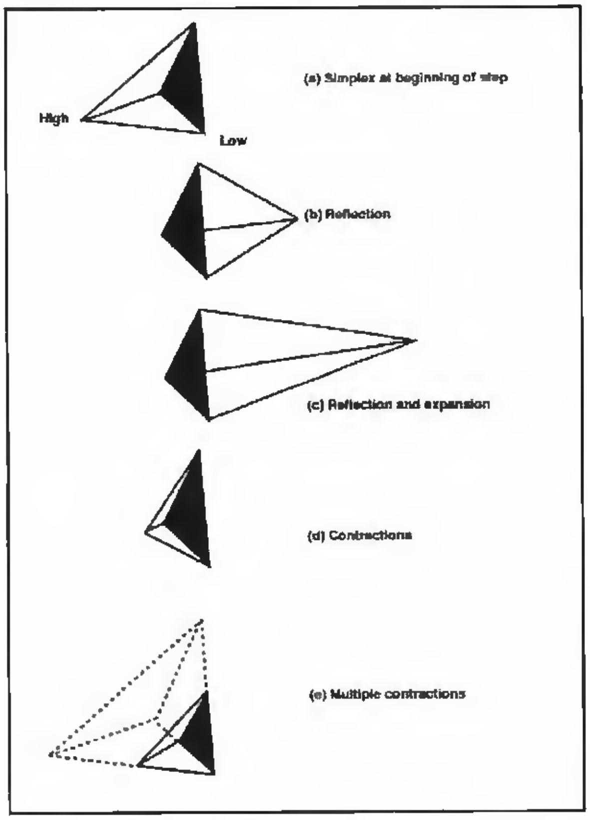

Fig. 1 — In this figure, each vertex corresponds to each dimension and the normalized value of minimum and maximum in each dimension correspond to size of these vertices. A — Simplex at the beginning of the step, here a tetrahedron. The simplex at the end of the step can be: B — a reflection away from high point (where the objective function is largest); C — a reflection and expansion away from high point; D — a contraction along one dimension from the high point; E — a contraction along all dimensions toward the low point. An appropriate sequence of such steps will always converge to a minimum of the objective function (Ref. 9).

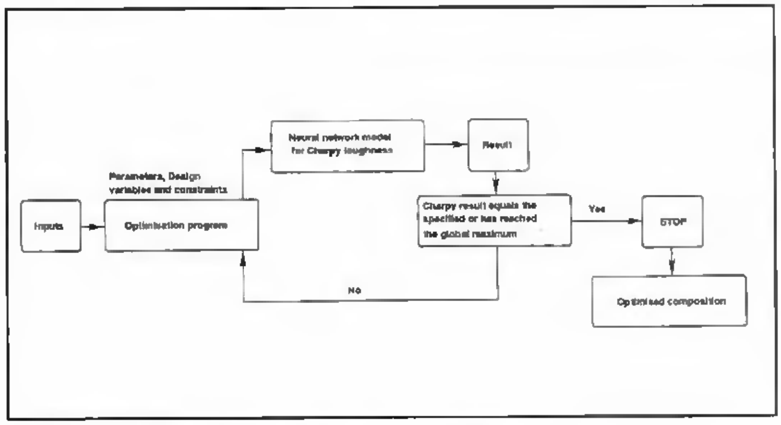

Fig. 2 — Flowchart showing the optimization procedure.

Optimization Methodologies

Optimization techniques can be broadly classified under linear and nonlinear programming methods. The linear programming methods can be used to determine the optimum when the variables are linearly related to the objective function and the constraints. An example is the relation between *c/a* ratio in a body-centered tetragonal structure of martensite and carbon concentration. But such ideal relations do not exist in the relation between alloying elements and mechanical properties. Under such complex relations between input and output parameters, the nonlinear programming methods, including sequential quadratic programming (SQP), downhill simplex methods, and genetic algorithms are commonly used (Ref. 7). Some of these nonlinear methods are briefly explained below.

In SQP, the objective function assumes a quadratic relationship with the variables (design) and parameters. Sequential quadratic programming can be used for both constrained and unconstrained optimization problems. A constrained optimization involves specification of constraints. In SQP, search for an optimum is made by finding a solution to a quadratic subproblem at each iteration. This method is used for problems with a smooth objective function.

Downhill simplex methods can be illustrated based on a geometric figure in N dimensions, consisting of $N + 1$ points (or vertices) and all their interconnecting line segments, polygonal faces, etc. Here, the notation N corresponds to the number of dimensions, which is related to the number of input parameters. In two dimensions, a simplex is a triangle. In three dimensions, it is a tetrahedron — not necessarily a regular tetrahedron. The downhill simplex method takes a series of steps, most steps just moving the point of the simplex where the objective function is largest through the opposite face of the simplex to a lower point (where the objective function becomes the minimum). These steps are called reflections, and they are constructed to conserve the volume of the simplex. The method also expands the simplex in one or another direction to take larger steps to expedite the speed of convergence. Conversely, the method also shrinks the simplex in all directions, allowing it to settle in a minimum. These are called contractions. This method is said to have the highest proba-

Table 1 — Input Variables Used to Train the Models for Establishing a Network of Composition, Heat Treatment, and Welding Parameters with Toughness (PWHT is Postweld Heat Treatment) (All elements in wt-% unless otherwise specified)

Input Variables	Minimum	Maximum	Mean	Std. Dev.
Carbon	0.02	0.19	0.07	0.021
Silicon	0.01	1.63	0.4	0.13
Manganese	0.23	2.31	1.2	0.42
Sulphur	0.002	0.14	0.0078	0.008
Phosphorus	0.003	0.25	0.01	0.014
Nickel	0	9.4	0.6	1.6
Chromium	0	11.78	0.5	1.4
Molybdenum	0	1.54	0.2	0.34
Vanadium	0	0.53	0.01	0.045
Copper	0	2.18	0.06	0.22
Cobalt	0	0.016	0.0007	0.0027
Tungsten	0	3.8	0.008	0.2
Oxygen (ppmw)	63	1535	406.2	112.3
Titanium (ppmw)	0	770	100.03	135.4
Nitrogen (ppmw)	21	1000	98.3	67.8
Boron (ppmw)	0	200	13.8	34.3
Niobium	0	1770	39.3	136.8
Heat input (kJ mm^{-1})	0.6	6.6	1.19	0.7
Interpass temperature (°C)	20	350	200.19	31.23
PWHT temperature (°C)	20	760	185.36	257.24
PWHT time (h)	0	100	2.7	6.13
Test temperature (°C)	–196	136	–44.25	36.13

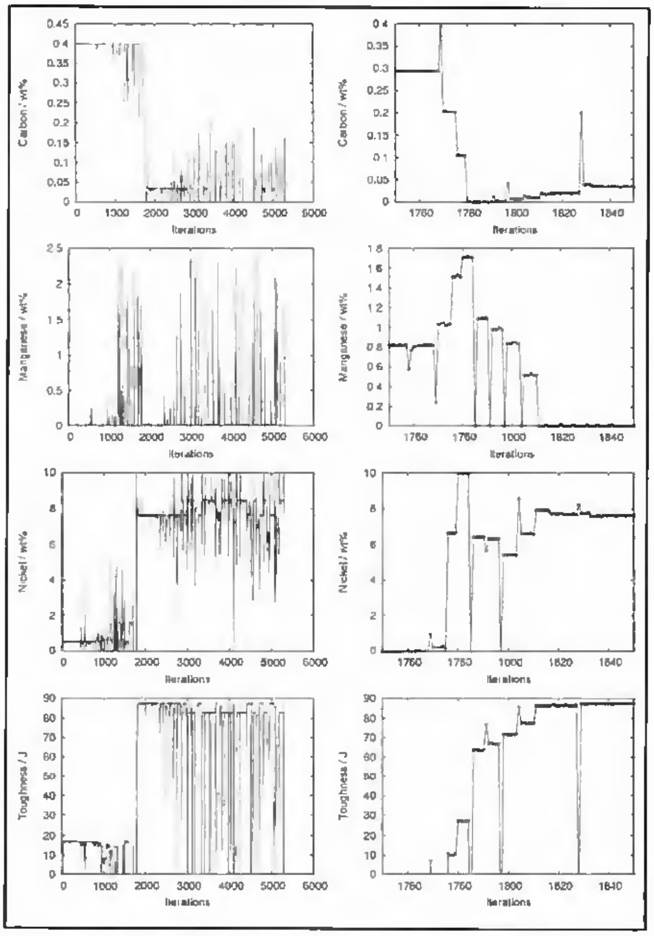

Fig. 3 — The sequential quadratic programming method succeeds in finding the optimum. Plots on right column are presented for clarity, focusing the region where the optimum was first found.

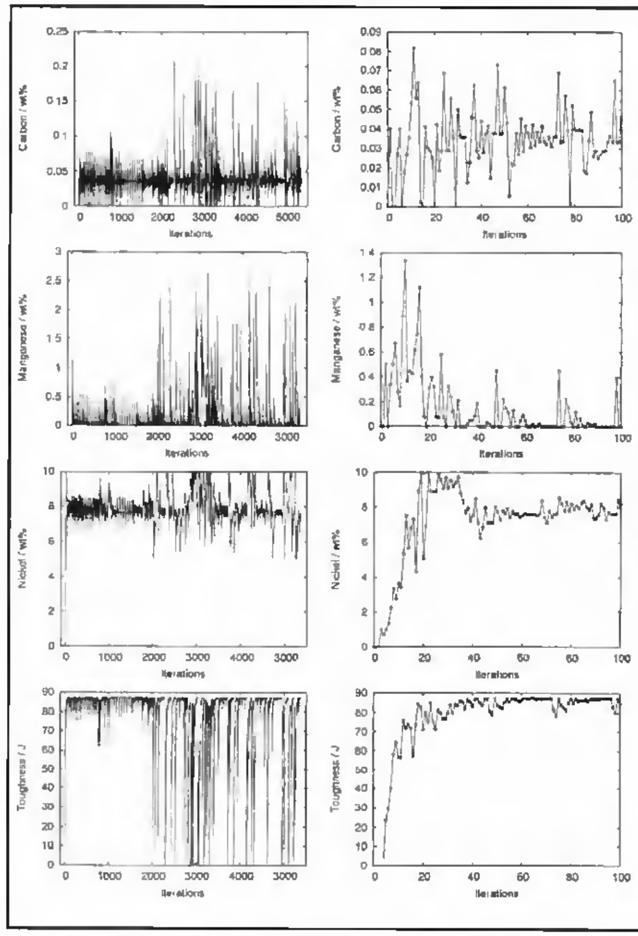

Fig. 4 — Downhill simplex finds the optimum in only 67 iterations, unlike any of the other methods. Plots on right column are presented for clarity, focusing the region where the optimum was first found.

bility of finding the global minimum when it is started with initial big steps (Ref. 8). Figure 1 shows reflections, contractions, and expansions in a clear manner (Refs. 7–9).

Genetic algorithms use mutation or recombination and selection to minimize the objective function. In this algorithm, a point is chosen in the design space, and a lot of points are generated around this point. This process is called mutation. Now, the best of all the points is selected. In recombination, a random number of points exchange values. Recombination and mutation are used in such a way so as to allow points to move toward a direction of objective function minimization. Genetic algorithms converge rapidly, but have trouble converging to the exact solution (Ref. 7).

A hybrid or local optimizer uses either of the above-described optimizers in an alternating manner, according to the need. For example, to converge fast toward the global minimum, the downhill simplex method may be used as a start, but when it comes to dealing with complex topographies, genetic optimizers do the

Table 2 — Parameters and Design Variables Used at the Start of Optimization

Element	Base value	Minimum	Maximum
Carbon (wt-%)	0.0	0	0.4
Silicon (wt-%)	0.65	—	—
Manganese (wt-%)	0.0	0	5
Sulphur (wt-%)	0.006	—	—
Phosphorus (wt-%)	0.013	—	—
Nickel (wt-%)	0.0	0	10
Chromium (wt-%)	0.21	—	—
Molybdenum (wt-%)	0.4	—	—
Vanadium (wt-%)	0.011	—	—
Copper (wt-%)	0.03	—	—
Cobalt (wt-%)	0.009	—	—
Tungsten (wt-%)	0.005	—	—
Oxygen (ppmw)	380	—	—
Titanium (ppmw)	80	—	—
Nitrogen (ppmw)	180	—	—
Boron (ppmw)	1	—	—
Niobium (ppmw)	10	—	—
Heat input ($kJ\ mm^{-1}$)	1	—	—
Interpass temperature (°C)	250	—	—
PWHT temperature (°C)	250	—	—
PWHT time (h)	16	—	—
Test temperature (°C)	–60	—	—

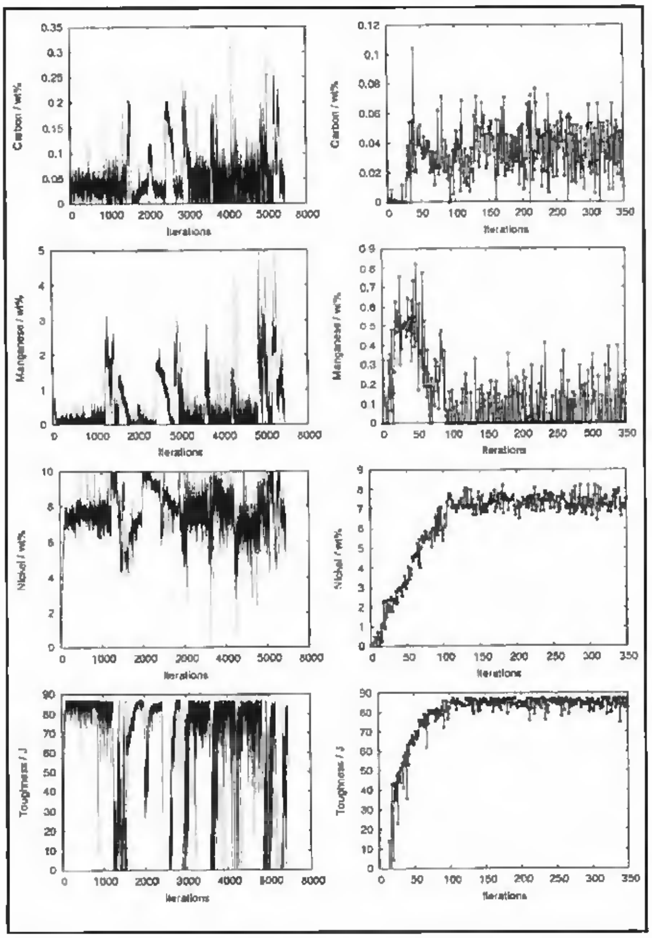

Fig. 5 — Genetic optimizers found the optimum after 323 iterations. Plots on right column are presented for clarity, focusing the region where the optimum was first found.

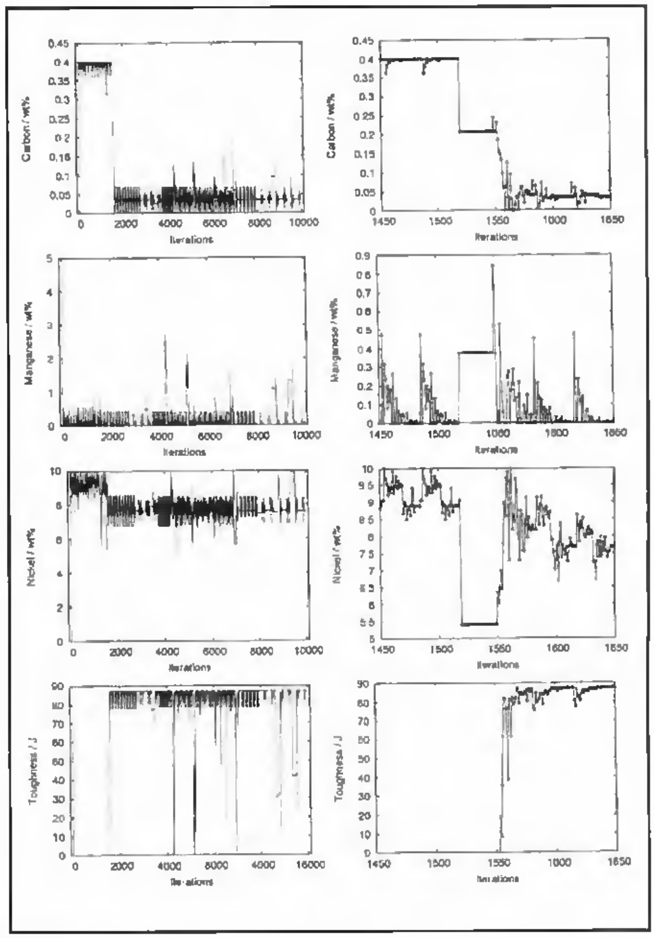

Fig. 6 — Hybrid optimizers succeeded in finding the optimum after 1600 iterations. Plots on right column are presented for clarity, focusing the region where the optimum was first found.

best. Hence, such an alternative implementation of optimizers is chosen by the pointer technology used in the hybrid/local optimizers. How this randomness is chosen by the local/hybrid optimizer is not presented here, due to proprietary reasons.

In this paper, we evaluated the above optimization methodologies to arrive at optimum weld composition by coupling an optimization software with a neural network model that relates the composition, welding process parameters, heat treatment, and Charpy toughness.

Optimization Calculations

The first step in the optimization for weld deposit composition is the selection of a computer model that relates the composition, welding process parameters, heat treatment, and Charpy toughness. In this research, we adopted a recently developed artificial neural network (ANN) model for Charpy toughness of steel welds (Refs. 2, 10). Artificial neural networking is an empirical modeling technique. It uses nonlinear regression in combination with a probabilistic approach to create a network between input variables and the output variable. Applicability of these models for prediction is mainly governed by the region covered by the input data on which they are trained, and the scatter in data. Within the regions covered by the input variables during training, the accuracy of the prediction becomes higher. A model was developed using this technique on a dataset consisting of 4000 data lines comprising composition, welding process parameters, Charpy test temperature, and preweld and postweld heat treatments. The range of the input variables gives an approximate representation of the model applicability (Table 1). It is important to note that welding process parameters are lumped into one parameter, i.e., heat input in this model. For information about the scatter in data, readers are referred to Ref. 2 (*http://www.msm.cam.ac.uk/phase-trans/2002/ananth.thesis.pdf*) and Ref. 10. The data used in the neural net simulation contain a wide range of elemental concentrations and are significant even with nickel concentrations in the range of 6 to 10 wt-%. The benefits of using the Bayesian neural network used in this paper are also discussed in Ref. 10. It is important to note that this ANN model is also capable of describing the uncertainty in the predictions.

In the second step, the above-mentioned ANN model was coupled with a commercial software package, *Epogy* (by Synaps Inc.), which is capable of performing both linear and nonlinear optimization (Ref. 7). This module was developed and evaluated on a Redhat Linux v9.0 computer. The steps involved in the calculations are schematically illustrated in Fig. 2. At the start of optimization, an initial set of input variables is chosen by the user. Moreover, the variables that need to be varied (defined as design variables) and the variables that have to be kept constant (defined as parameters) are identified. The optimizer then interrogates the ANN model to evaluate the toughness for the initial set of input data. Then, the difference between the target

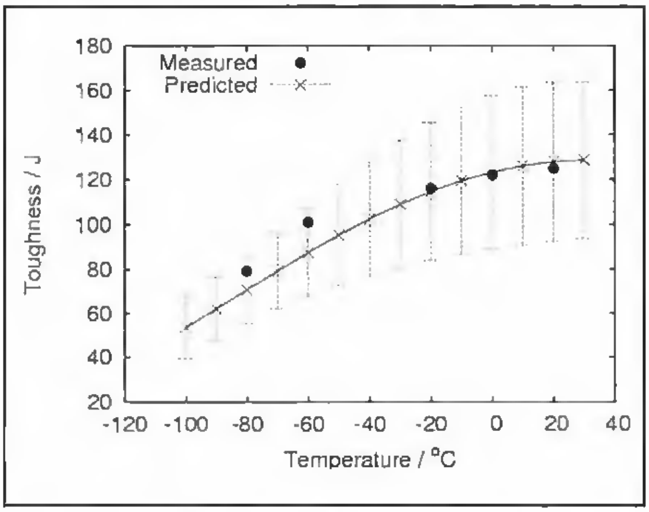

Fig. 7 — Comparison of Charpy toughness predicted using artificial neural network models and measured Charpy toughness values.

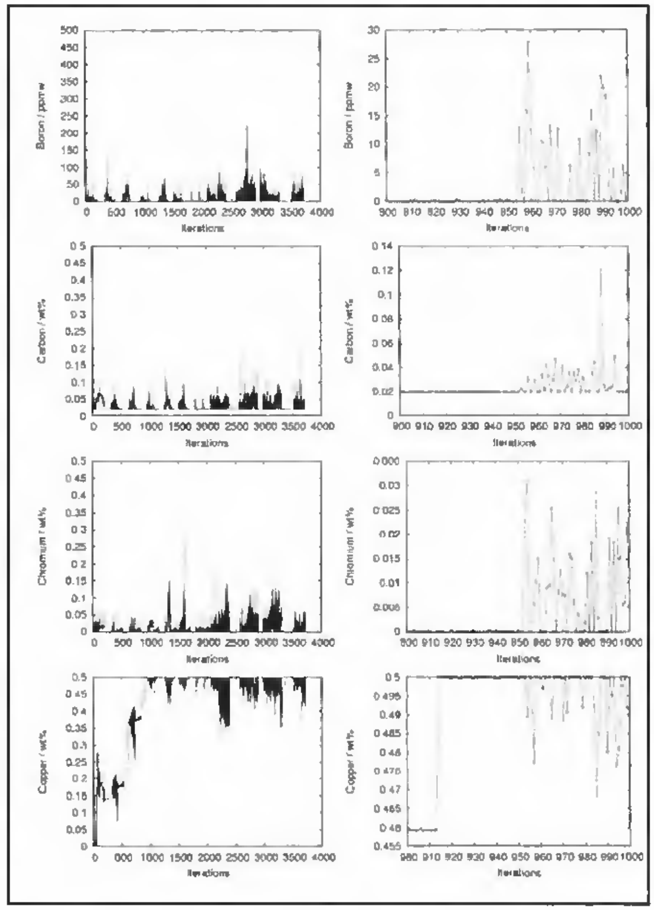

Fig. 8 — Plots showing the exploration done by local/hybrid optimizer for B, C, Cr, and Cu.

and the current calculation is evaluated for meeting the required criteria. On not meeting the criteria, the optimizer algorithm decides the direction in which the design variables need to be varied. Subsequently the whole process is repeated. On meeting the criteria, the module stops the optimization. If, after a large number of iterations, there is no improvement in the calculated value, then the module reports the highest possible toughness attainable for the given set of design variables and constraints.

In the first set of evaluations (Test A), the optimization techniques were tested for finding an optimum composition by considering nickel, manganese, and carbon concentrations as design variables. The constant parameter values are shown in Table 2. These parameters were selected based on earlier experimental research performed on similar welds (Refs. 2, 10). Therefore, Test A is aimed at evaluating the robustness of different optimization techniques. In the second set of evaluations (Test B), the design variables were increased from 3 to 13. The design variables included B, C, Cr, Cu, Mn, Mo, N, Nb, Ni, Si, Ti, V, and W. The criterion for optimization was set as attaining a Charpy toughness of 120 and 200 J at –60°C for Test A and Test B, respectively.

Results

Linear programming methods (described under the heading "Optimization Methodologies") failed to find an optimum in Charpy toughness. The linear methods increased the carbon and nickel concentrations but did not explore any other regions of input space. Hence, there was no possibility of finding the optimum using this method. This supports the earlier notion that Charpy toughness is not related to the input variables in a linear fashion.

The next four paragraphs present the results obtained from nonlinear optimization techniques. Figures 3–6 associated with these discussions are presented in a two-column format. Figures on the left column give an idea about the trend that each optimizer under consideration followed throughout the optimization run. Figures on the right column focus the iterations when the optimizer first reached the optimum value.

In the first part of the simulation, the SQP method increased the carbon concentration to ~0.4 wt-% (see Fig. 3) and explored the manganese and nickel concentration variations. In the next part, the carbon content was reduced to ~0.05 wt-% and the nickel concentrations were increased above 6 wt-%. The result shows that the SQP method clearly identified that the maximum rate of increase in toughness would be achieved by an increase in nickel content. Immediately after this step, around 1836 iterations, the SQP method reached the optimum composition for the first time. Interestingly, the SQP method explored only until 2.5 wt-% Mn, whereas the region of input space defined for manganese was from 0 to 5 wt-%. With further iterations, carbon, nickel, and manganese concentrations oscillated around this optimum composition before the termination of the optimization exercise.

Downhill simplex methods adapted a different strategy by varying carbon, manganese, and nickel concentrations simultaneously. Carbon was varied between 0 and 0.06 wt-%, manganese between 0 and 0.5 wt-%, and nickel between 6.2 and 8.3 wt-% — Fig. 4. The plots also show that the downhill simplex method identified the importance of increasing the nickel concentration within 20 iterations. Similarly, the importance of reducing the Mn levels to very low levels was also identified. The optimum composition was reached in 67 iterations for the first time. With further iterations until 5000, the downhill simplex method explored variations of carbon and manganese. Nevertheless, the downhill simplex method explored only until 0.2 wt-% for carbon and 2.7 wt-% for manganese, and did not explore near the maximum value specified in the design variable range.

Genetic optimizers adapted a step-by-step process in which, during the first 200 iterations, carbon concentration was kept at 0 wt-%, while nickel was increased gradually by varying manganese concentrations — Fig. 5. After a certain concentration of nickel, the carbon contents were also increased. The optimum composition was reached in 323 iterations for the first time. It is interesting to note that the shape of

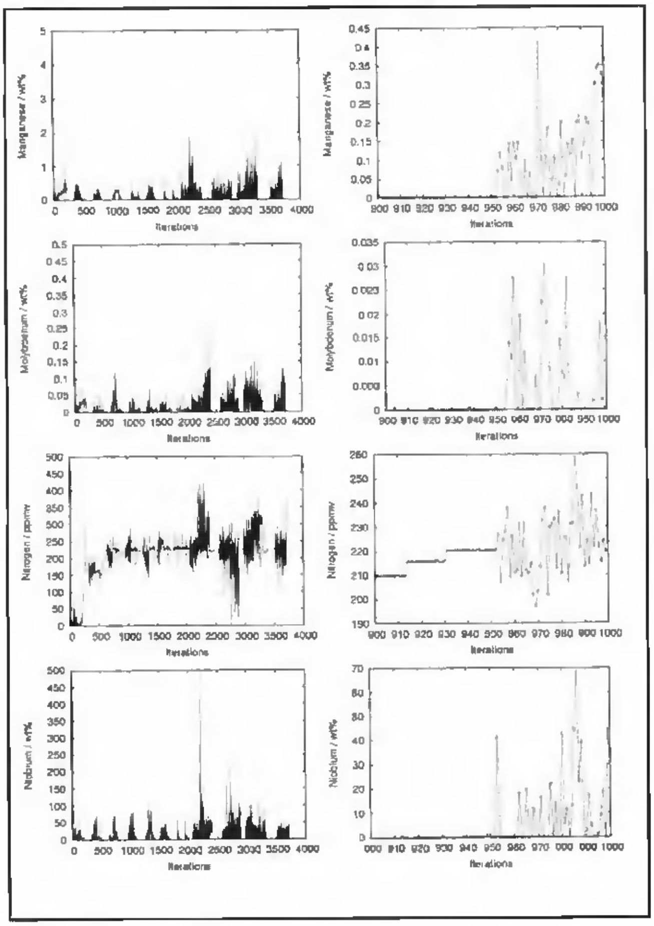

Fig. 9 — Plots showing the exploration done by local/hybrid optimizer for Mn, Mo, N, and Nb.

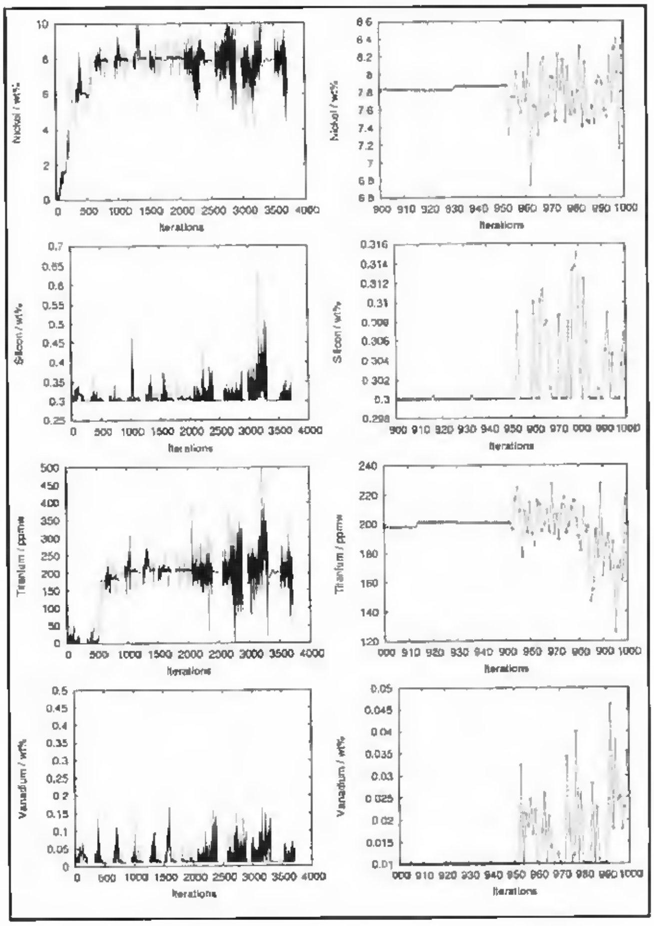

Fig. 10 — Plots showing the exploration done by local/hybrid optimizer for Ni, Si, Ti, and V.

variation of manganese and nickel concentration with the number of iterations before reaching the optimum value appears similar to that of the downhill simplex method. In other words, initially the manganese and nickel were increased, and then the manganese was reduced while increasing the nickel content. The only difference is that the genetic algorithm was slower in reaching the higher nickel and lower manganese concentrations that are closer to the optimum level. After reaching the optimum composition, the genetic optimizer explored the major part of the input space. This is in contrast to previous methods. Similar to other methods, the genetic optimizers did not explore very high carbon concentrations.

The next set of calculations considered an optimizer based on the local or hybrid methodology, and the results are shown in Fig. 6. It is interesting to note that in this methodology, the first part of optimization led to increased carbon concentration close to 0.4 wt-%, the maximum value defined in the input range, during the first 1500 iterations. Subsequently, the optimizer briefly reduced the carbon to 0.2 wt-% and explored at higher manganese and lower nickel contents. At this stage, the optimizer reached a plateau with no improved prediction of toughness. With further iterations, in the third part of the calculations, the optimizer correctly found the importance of reducing the carbon to the next level in the range of 0.05 wt-%. At this stage, the optimum composition was reached with increased nickel concentration after 1600 iterations. Although, the hybrid optimizer was slow, the methodology explored all of the input regions defined for all the three variables. This allows for testing the hypothesis that the final optimized composition (presented in the next paragraph) is the global optimum.

The performances of all optimization methods in Test A are compared in Table 3. It is reassuring to note that all the optimizers gave one optimized composition after the completion of Test A. However, the predicted toughness for this optimum composition was 87 ± 20 J. Therefore, the optimized value did not meet the required criteria of 120 J at –60°C. Nevertheless, the optimum composition was used to predict the variation of toughness with temperature using the ANN model. The optimization for the three variables C, Mn, and Ni compared well with that of the experimental results (Ref. 2). The experimental optimum weld composition was Fe -0.025 C -0.65 Mn -6.6 Ni -0.65 Si -0.038 O -0.018 N -0.013 P -0.006 S -0.03 Cu -0.008 Ti (wt-%) and the corresponding measured toughness of 101 J at –60°C is very similar to the predicted optimum weld composition. The predicted optimum weld composition was further compared with experimental measurements by predicting the variation of toughness with temperature — Fig. 7. The comparison shows fair agreement with the currently attained optimum composition and proves the power of this coupled ANN-optimization model.

In Test B, the effect of considering a wide range of design variables was explored with a hybrid optimizer. The optimum composition was arrived after 930 iterations (see Figs. 8–11). Figures 8–11 illustrate the trend with which the hybrid optimizer varied alloying elements. In Table 4, Test B gives the optimum composition obtained in this analysis. It can be seen that the optimizer has reduced Mn, Cr, Mo, W, B, and Nb to zero — on the other hand, increasing the contents of Ti and N to very high levels of 202.5 and 222.4 ppmw, respectively. However, there are no experimental data with such high levels of Ti, N, and Ni. Possible reasons for selection of this weld composition will be discussed in the next section.

Discussion

In the three-variable optimization case, downhill simplex and genetic optimizers follow a trend that can be interpreted using metallurgical principles, unlike SQP and hybrid optimizers.

Before reaching the optimum composition after 67 iterations with downhill simplex, there is a slow increase in carbon and manganese concentrations at lower nickel contents. Increase in carbon and manganese concentration improves the toughness by increasing the amount of acicular ferrite in the microstructure. However, as the concentration of nickel is raised above 7 wt-%, the hardenability is high enough to result in a martensitic microstructure (Ref. 2). Hence, above this critical concentration of nickel, any increase in manganese or carbon concentration leads to an even harder martensite, thus reducing toughness; whereas a nickel martensite at low carbon contents is expected to be tougher (Refs. 2, 10). Thus, the optimum composition has low carbon and zero manganese with high nickel concentration.

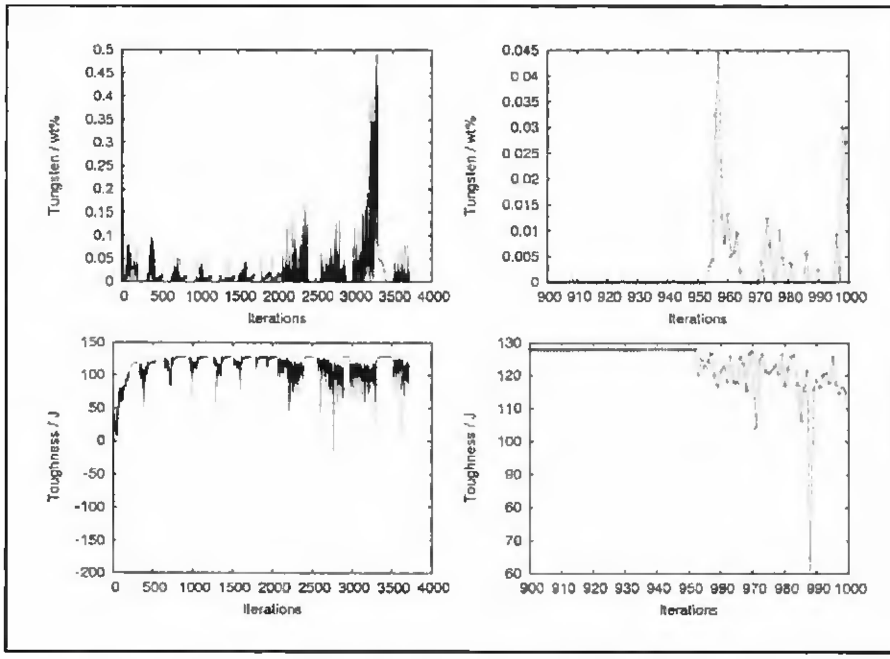

Fig. 11 — Plots showing the exploration done by local/hybrid optimizer for W. Also shown is the corresponding toughness at each iteration, where the alloying elements were varied.

Due to innate characteristics like reflection and contraction, the downhill simplex methods have explored regions even at higher nickel contents (near the defined maximum value minus 10 wt-%) than the optimum nickel concentration; whereas genetic optimizers have gradually increased the nickel concentration to the optimum level, after which they have not explored. This can be attributed to the restrictions imposed on the step sizes, which are relatively smaller and constant in genetic methods compared to the downhill simplex methods (Ref. 7).

All the optimizers arrived at the same optimum composition in the case studied in Test A. Thus, it is appropriate to consider this composition as the global optimum. Under this specific case, downhill

Table 3 — Comparison of Different Optimizers in Test A, for Successfully Finding Optimum Composition and the Number of Iterations Made before Finding the Optimum (The region of input space explored by the optimizer is also presented. Note that while comparing the performance of each optimizer based on the number of iterations, the starting point for all the optimization runs need to be the same)

Optimizer	Success or failure	Number of iterations before arriving at optimum	Region of input space explored by the optimizer looking for an optimum (This decides the chance for getting into a local optimum)	Optimized values (wt-%)
Linear	Failed	—	—	
SQP	Success	1836	C (0–0.4) Mn (0–2.46) Ni (0–10)	0.034 0 7.6
Downhill simplex	Success	67	C (0–0.2) Mn (0–2.72) Ni (0–10)	0.034 0 7.6
Genetic	Success	323	C (0–0.32) Mn (0–5) Ni (0–10)	0.034 0 7.6
Local/hybrid	Success	1600	C (0–0.4) Mn (0–5) Ni (0–10)	0.034 0 7.6

Table 4 — Parameters and Design Variables Used at the Start of Optimization

Element	Base value	Minimum	Maximum
Carbon (wt-%)	0.0	0.02	0.5
Silicon (wt-%)	0.0	0.3	0.7
Manganese (wt-%)	0.0	0.0	5
Sulphur (wt-%)	0.006	—	—
Phosphorus (wt-%)	0.013	—	—
Nickel (wt-%)	0.0	0.0	10
Chromium (wt-%)	0.0	0.0	0.5
Molybdenum (wt-%)	0.4	0.0	0.5
Vanadium (wt-%)	0.0	0.01	0.5
Copper (wt-%)	0.0	0.0	0.5
Cobalt (wt-%)	0.009	—	—
Tungsten (wt-%)	0.0	0.0	0.5
Oxygen (ppmw)	380	—	—
Titanium (ppmw)	0.0	0.0	500
Nitrogen (ppmw)	0.0	0.0	500
Boron (ppmw)	0.0	0.0	500
Niobium (ppmw)	0.0	0.0	500
Heat input (kJ mm^{-1})	1	—	—
Interpass temperature (°C)	250	—	—
PWHT temperature (°C)	250	—	—
PWHT time (h)	16	—	—
Test temperature (°C)	–60	—	—

simplex can be ranked the best as it arrived at the global optimum in only 67 iterations.

As already discussed in the previous section, since the use of individual optimizers did not cover all of the input space (Test B), the hybrid optimizer was used in optimizing 13 variables. The hybrid optimizers first reached the optimum after 1600 iterations for a three-variable case. With the increase in the number of design variables, it is expected that the number of iterations to arrive at the optimum would also increase. Whereas, in the present case where 13 variables were optimized, the hybrid optimizer reached the optimum in only 930 iterations as compared to 1600 iterations for the three-variable case. This is due to the randomness involved in the hybrid optimizer in selecting a particular optimization algorithm for a given kind of problem (Ref. 7).

The level of uncertainty predicted by ANN in Test A was 20 J and in Test B was 70 J. As mentioned earlier, the uncertainty is related to the training data used by the ANN model developed and is predicted using the methodology described in Refs. 2 and 10. Careful analyses showed that the input data do not contain any weld compositions with very low carbon (<0.02 wt-%) and very high titanium (>120 ppmw) and high nitrogen (>190 ppmw). It is important to note that the optimum composition in Test B contains 0.02 wt-% carbon, 202 ppmw titanium, and 222 ppmw nitrogen. Since this prediction is beyond the scope of the training data, one would expect a high uncertainty in the ANN model predictions. In agreement, the ANN model correctly predicted that the uncertainty in the calculated toughness was 70 J. In contrast, the optimum composition predicted by Test A was within the scope of the input space of the ANN model; as a result, the ANN model predicted a lower uncertainty of toughness prediction: 20 J.

Further, the optimization analysis resulted in a zero concentration of Mn, Cr, Mo, W, B, and Nb; whereas C, V, and Si assumed the minimum concentration in the allowed concentration range, unlike Cu, whose concentration was raised to the maximum with Ni, Ti, and N assuming an optimized value. From toughness point of view, it is very sensible that elements like C, Mn, Cr, and B that increase the hardenability should be kept at low concentrations. Raiter et al. have analyzed the effect of molybdenum on carbon manganese steels and have concluded that molybdenum decreases the ductile-brittle transition temperature (Ref. 12). However, this need not be true in the case of higher nickel welds. In the microstructure of carbon-manganese welds that consists of acicular ferrite, molybdenum is known to increase acicular ferrite microstructure in the reheated regions leading to an increase in the toughness (Ref. 12). Molybdenum also increases the hardenability of the alloy. But there is no account in literature about the molybdenum effect on welds containing martensite, as is the case with high-nickel welds.

Similarly, titanium increases the amount of acicular ferrite in carbon-manganese steels, thus improving the toughness (Refs. 1, 3–5). Higher titanium contents in combination with higher nickel levels cannot have the same effect in titanium on formation of acicular ferrite. Instead, it should have some complicated role in improving the toughness of a martensitic microstructure.

Increased silicon concentration may affect the inclusion content and microstructure evolution in a complex way. Evans (Ref. 13) has shown that silicon addition may decrease the oxygen pickup in the weld and also may increase the acicular ferrite at low levels of manganese concentrations, and may not have any significant effect at high manganese concentrations. Cr, W, Nb, and V are carbo-nitride formers that decrease the toughness because of precipitation of undesirable precipitates and solid-solution hardening. Also, these elements increase the hardenability of the steel weld drastically.

High nitrogen concentrations can cause porosity and are deleterious to toughness (Ref. 1). Evans has concluded that nitrogen has a varying effect on the toughness of C-Mn welds, depending on the concentration of Ti and B (Ref. 1). It was shown that high nitrogen contents decrease toughness in the presence of high titanium concentrations (>250 ppmw) (Ref. 1). But the same effect of nitrogen may not hold appropriate for the high-nickel welds.

As the optimized composition has a high concentration of nickel and nitrogen, the microstructure is speculated to be martensitic along with some amount of retained austenite at the cooling rates involved in welding.

From the research point of view, it would be really interesting to make an experimental weld of the optimized composition specified in Test B. The weld metal may, however, have poor strength, as most of the solid-solution hardening elements are set to zero.

The above discussion leads to an important question: Is it possible to optimize for both strength and toughness? Therefore, some preliminary research was done to optimize for both strength and toughness by coupling the ANN model for toughness, the ANN model for room-temperature yield strength (Ref. 2), and the optimization software (Ref. 14). In this hypothetical research, the objective was to maximize the yield strength to 1000 MPa $\left(YS^{RT}_{current}\right)$ at room temperature and the Charpy toughness of 90 J $\left(CVN^{NLC}_{current}\right)$ at –60°C. For this analysis, an objective function has to be defined as a target for the optimization software and it is set to minimize the difference between predicted and target values (LSE) for both Charpy toughness and yield strength, which follows.

$$LSE = \left(\frac{CVN_{current}^{-60^\circ C} - 90}{90}\right)^2 + \left(\frac{YS_{current}^{RT} - 1000}{1000}\right)^2 = 0 \qquad (1)$$

The hybrid optimizer was used for both optimizations. Six input parameters, i.e., carbon, manganese, nickel, copper, titanium, and interpass temperatures, were varied by the optimizer to look for the optimum composition that satisfied Equation 1, while all other parameters were kept constant (Table 2). The optimizer arrived at an optimum composition after 136 iterations. The optimum parameters were predicted to be 0.032 wt-% C, 0.0 wt-% Mn, 9.38 wt-% Ni, 0.086 wt-% Cu, 60 ppmw Ti, and an interpass temperature of 210°C, while the base composition of the weld metal was Fe–0.65Si–0.0Mn –0.006Cu–0.038O–0.018N–0.013P–0.00S (wt-%). For this condition, the predicted Charpy value was 80 ± 20 J at –60°C and the predicted room-temperature yield strength was 866 ± 89 MPa. It is noteworthy that this analysis showed that it is not possible to achieve 1000 MPa yield strength while maintaining a toughness of 90 J, and the predicted compromise was 866 MPa yield strength at room temperature and 80 J Charpy toughness value at –60°C. In addition, to achieve this result, the optimizer also increased the interpass temperature to 210°C. In the same analyses, relaxation of input ranges above the trained limits given in Table 1 led to reduction of carbon to 0.01 wt-%, increase of nickel to 10 wt-%, reduction of copper to 0.006 wt-%, reduction of titanium to 32 ppmw, and an increase in the interpass temperature to 300°C. However, the predicted toughness of 86 ± 18 J at –60 °C and predicted room-temperature yield strength of 840 ± 105 MPa are not significantly different from the earlier predictions. This analysis also showed that the selection of objective function and the number of input parameters, and the range of input parameters that can be varied during optimization, have a significant effect on the optimization results. The optimum composition predicted by this coupled strength and toughness optimization has not yet been validated by experiment and is the focus of the ongoing research.

Table 5 — Optimized Composition and the Maximum Obtainable Charpy Toughness for the Given Base Composition and Process Parameters as Suggested by All the Optimizers (Test A for three variable optimization involving C, Mn, and Ni. Test B pertains to the 13-variable optimization)

Element	Test A	Test B
Carbon (wt-%)	0.034	0.02
Silicon (wt-%)	0.65	0.3
Manganese (wt-%)	0.0	0.0
Sulphur (wt-%)	0.006	0.006
Phosphorus (wt-%)	0.013	0.013
Nickel (wt-%)	7.6	7.9
Chromium (wt-%)	0.21	0.0
Molybdenum (wt-%)	0.4	0.0
Vanadium (wt-%)	0.011	0.009
Copper (wt-%)	0.03	0.5
Cobalt (wt-%)	0.009	0.0089
Tungsten (wt-%)	0.005	0.0
Oxygen (ppmw)	380	380
Titanium (ppmw)	80	202.5
Nitrogen (ppmw)	180	222.4
Boron (ppmw)	1	0.0
Niobium (ppmw)	10	0.0
Heat input (kJ mm^{-1})	1	1
Interpass temperature (°C)	250	250
PWHT temperature (°C)	250	250
PWHT time (h)	16	16
Test temperature (°C)	–60	–60
Maximum toughness obtainable (J)	87	128
Uncertainty	20	70

Conclusions

An artificial neural network model was coupled with optimization software to predict weld metal composition that will maximize the toughness at –60°C. The coupled model used linear and nonlinear techniques to explore possible combinations of carbon, manganese, and nickel concentrations for a given set of welding process parameters. The analysis was performed with different optimization techniques, including simple linear and nonlinear sequential quadratic programming (SQP), downhill simplex, genetic algorithm, and local/hybrid methodology. The downhill simplex method arrived at optimum composition with the minimum number of iterations; however, it did not explore the full scope of input parameters space. In contrast, the local/hybrid method arrived at optimum composition after 1600 iterations; however, it did explore the full scope of input parameters space.

The predicted weld metal composition was Fe–0.034C–0Mn–7.6Ni–0.65Si –0.038O–0.018N–0.013P–0.006S (wt-%) and toughness at –60°C was 87 J ± 20 J. The published toughness for this weld was 101 J. This shows the applicability of coupled optimization and forward models to design weld metal composition.

Another interesting analysis done for optimizing 13 different variables proved that the optimum was not the same as in the case where C, Ni, and Mn were varied. Preliminary work with coupled optimization of strength and toughness led to a weld metal composition with high (>10 wt-%) nickel concentration. Both these predictions have not been experimentally verified, though.

Acknowledgments

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Friction Stir Welding of Aluminum Alloy to Steel

Aluminum alloy plate was successfully butt-joint welded to steel plate by friction stir welding

K. KIMAPONG AND T. WATANABE

ABSTRACT. The authors tried to butt-joint weld an aluminum alloy plate to a mild steel plate using friction stir welding.

This study investigated the effects of pin rotation speed, position of the pin axis, and pin diameter on the tensile strength and microstructure of the joint. The main results obtained are as follows:

Butt-joint welding of an aluminum alloy plate to a steel plate was easily and successfully achieved. The maximum tensile strength of the joint was about 86% of that of the aluminum alloy base metal. Many fragments of the steel were scattered in the aluminum alloy matrix, and fracture tended to occur along the interface between the fragment and the aluminum matrix. A small amount of intermetallic compounds was formed at the upper part of the steel/aluminum interface, while no intermetallic compounds were observed in the middle and bottom regions of the interface. A small amount of intermetallic compound was also often formed at the interface between the steel fragments and the aluminum matrix. The regions where the intermetallic compounds formed seem to be fracture paths in a joint.

Introduction

Energy savings and environmental preservation are important issues for us to resolve. Since reducing the weight of vehicles is one of the efficient measures, the use of the combination of steel and aluminum alloy has been increasing in fabricating vehicles. Under this situation, many trials to weld steel to aluminum alloy have been conducted. However, sound joints have not been produced so far, because hard and brittle intermetallic compounds were formed at the weld whenever steel was welded to aluminum by fusion welding.

At present, the following methods have been employed to produce a joint between steel and aluminum. One method utilizes a transition joint that consists of a steel plate welded in advance to an aluminum alloy plate by explosive bonding or rolling (Ref. 1). Others are solid-phase bonding methods, such as friction welding (Ref. 2), ultrasonic joining (Ref. 3), and rolling (Ref. 4).

The method using the transition joint, however, involves some difficulties in that the transition joint is not easy to produce and is expensive, and the joint is limited in shape. Rotary friction welding has the difficulty that at least one material to be joined should be circular in cross-sectional shape. Ultrasonic welding and rolling also have the shortcoming that they are applicable only to thin plate.

A new method has been tried in which the heat conduction from a steel plate heated by a laser beam melts the faying surface of an aluminum plate, resulting in welding the steel to the aluminum by the molten aluminum (Ref. 5). However, this method presents difficulties in that some brittle intermetallic compound is still formed and it is hard to control the heat input and the melting amount of the aluminum by laser irradiation. In addition, laser equipment is expensive.

Recently, a few preliminary studies have been reported on friction stir welding (FSW) — a process developed by TWI (Ref. 6) — of aluminum to steel butt joints (Ref. 7) and lap joints (Ref. 8).

In this paper, the authors applied FSW to produce a butt joint between aluminum alloy and steel, and are reporting the details of the joint performance.

KEYWORDS

Joining of Dissimilar Metals
Friction Stir Welding
Steel
Aluminum Alloy
Tensile Strength of a Joint

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Explanation of the Rotating Pin Position in the Friction Stir Welding Employed in this Study

Figure 1 is a schematic illustration to explain pin position in friction stir welding. Figure 1A is a bird's-eye view of the method, and B is a view of the cross section perpendicular to a weld interface.

A rotating pin is plunged into the aluminum as shown in the figure. Next, the rotating pin is pushed toward the faying surface of the steel and, consequently, the oxide film is mechanically removed from the faying surface by the rubbing motion of the rotating pin. Aluminum, which is in a fluid-like plastic state due to the heat generated by the friction of the rotating tool shoulder, adheres to the activated faying surface of the steel, so that joining between steel and aluminum is achieved. In this process, since the rotating pin is plunged into the softer aluminum and does not come in contact with the steel, the rotating pin shows minimal wear.

Welding by FSW is ordinarily completed through stirring by a rotating pin inserted around the center of the weld interface of butted base plates. A preliminary experiment proved that when the rotating pin was inserted around the center of the weld interface between the steel plate and the aluminum alloy plate, welding could not be achieved because of excessive wear of the rotating pin in a short duration. The wear caused insufficient stirring between the aluminum alloy and the steel. This point will be referred to later.

Experimental

Materials and Welding Conditions

Plates of 2-mm-thick SS400 mild steel (hereafter, Fe) and A5083 (Al-0.5 Mg-0.5 Mn wt-%) aluminum alloy (hereafter, Al) were welded. The ultimate tensile strength of the A5083 base metal was about 275 MPa and that of the SS400 was about 455 MPa. The shape and dimension of both plates was rectangular and 140 mm in length and 40

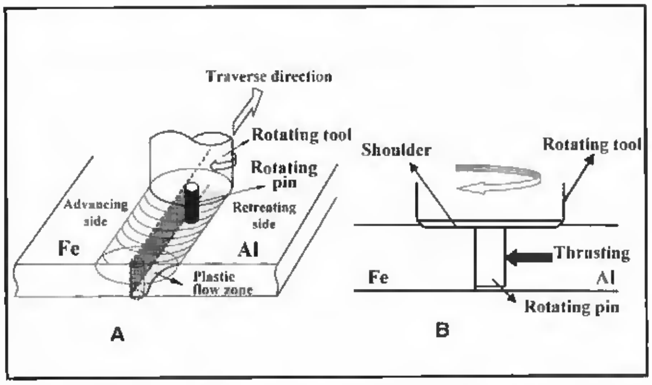

Fig. 1 — Schematic of the rotating pin position in this study: A — Bird's-eye view of the method; B — view of the cross section perpendicular to the weld interface.

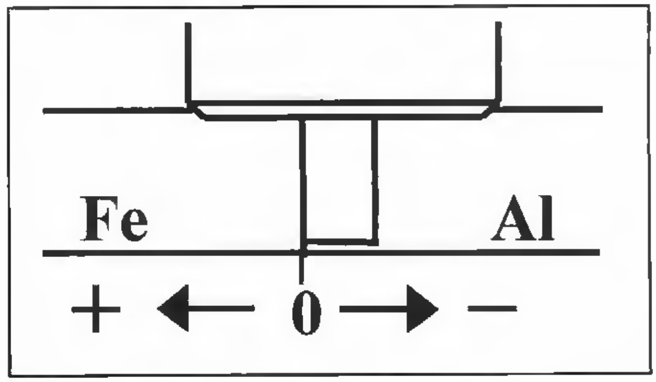

Fig. 2 — Schematic explaining the relationship between the pin position and the coordinate.

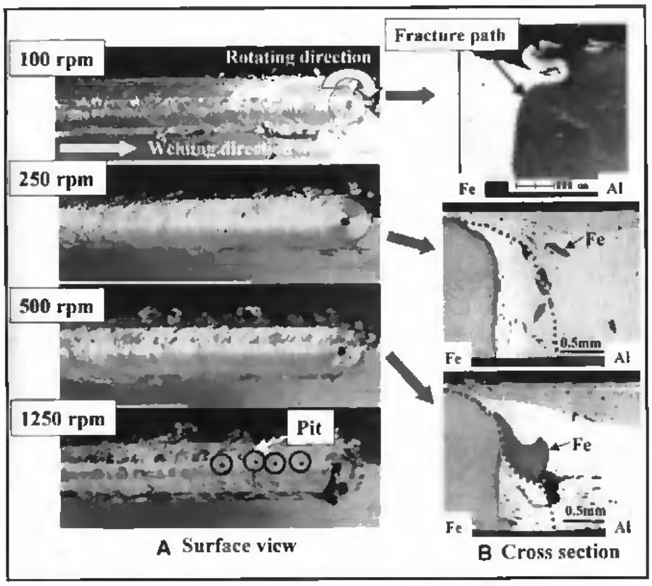

Fig. 3 — Effects of pin rotation speed: A —surface view; B — cross-sectional structure with the fracture path indicated by a dashed line in the welds.

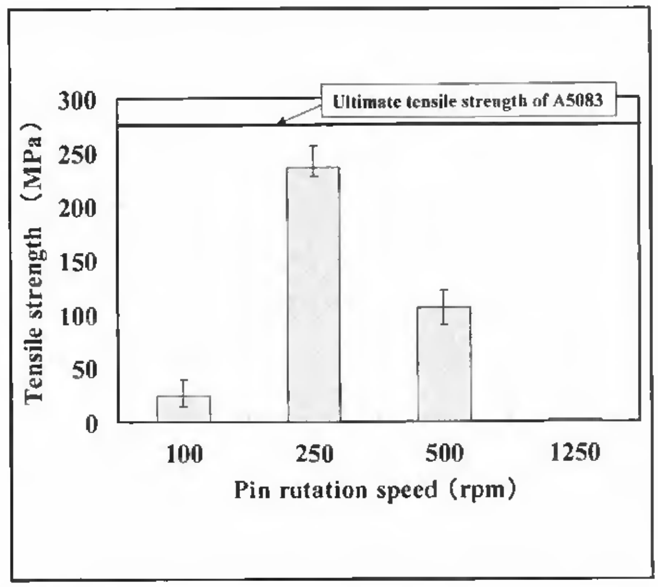

Fig. 4 — Relation between pin rotation speed and joint tensile strength.

mm in width. The 140-mm-long faying surface of each plate was polished with 400-grit emery paper, and then mounted in a jig to make a butt joint.

The rotating tool used in this study was made of high-speed tool steel (SKH57). It had a 15-mm-diameter shoulder and an unthreaded pin 2 mm in diameter and 1.9 mm long, as shown in Fig. 1. Welds were made with the pin rotating clockwise at speeds of 100 to 1250 rpm. The pin transverse speed, that is, welding speed, was 25 mm/min. The Al plate was located on the retreating side as shown in Fig. 1. After the rotating pin was inserted into the Al plate, the pin was thrust toward the Fe faying surface by the distances of –0.2 mm to 2 mm (zero is at the position where the pin side face is located just at the Fe faying surface, and the offset is defined as shown in Fig. 2).

A tensile test was employed to estimate the tensile strength of the joints and the fracture path. The tensile test specimens perpendicular to the weld interface were machined from the welds. The welded area was located in the center of the tensile specimen.

Metallographic samples were produced from the welds and etched with only an etchant of 3% Nital. Etched samples were examined using optical microscope and scanning electron microscope (SEM) with X-ray energy-dispersive spectroscopy (EDS).

Results and Discussion

Effect of Pin Rotation Speed on Joint Tensile Strength

First, the surface and cross-sectional structure of welds were examined when pin rotation speed was varied under the pin offset of 0.2 mm. Figure 3 shows the surface appearances and cross-sectional structures of the welds. The relation between joint tensile strength and pin rotation speed is shown in Fig. 4.

When pin rotation speed was too slow, i.e., 100 rpm, the pin wore out in a short time due to insufficient heat generation and insufficient plasticization of the Al. Consequently, about a quarter of the weld interface was welded; the balance of the joint was welded only on the surface. The fracture path (shown by a dotted line) of the tensile specimen produced under these conditions was along the interface where there was incomplete fusion between Fe and Al, so that the tensile strength of these specimens was low. Pin rotation speed of 250 rpm made a good joint, showing the maximum tensile strength of about 240 MPa, which was about 86% of the Al base metal tensile strength. The fracture path of these specimens was along the interface between the Al matrix and the Fe fragments (indicated by arrow in Fig. 3) scattering in the Al ma-

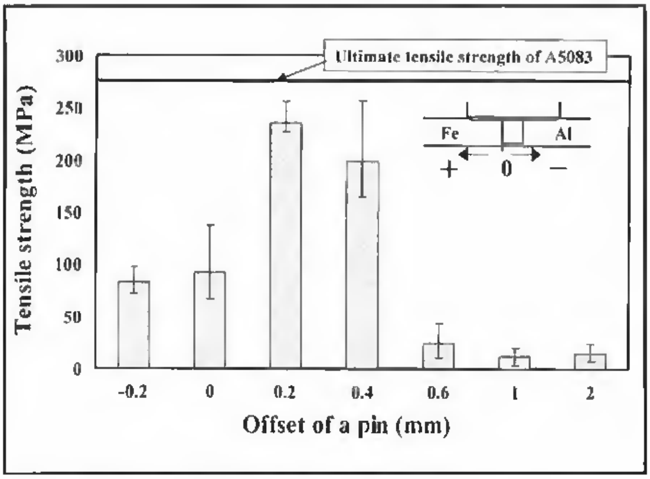

Fig. 5 — Relation between pin offset and joint tensile strength.

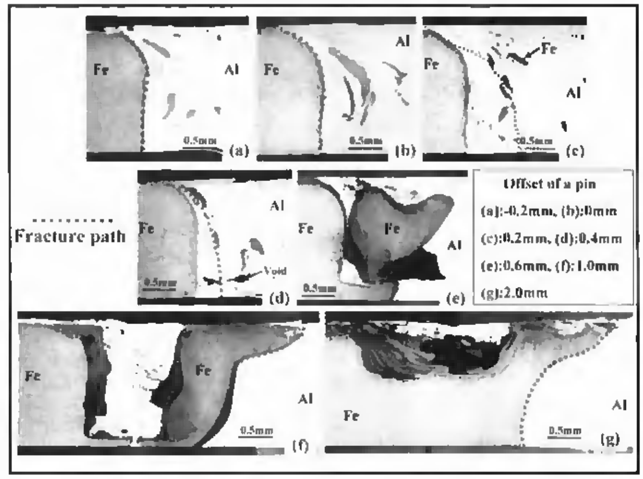

Fig. 6 — Effects of pin offset on the microstructures and fracture paths of welds.

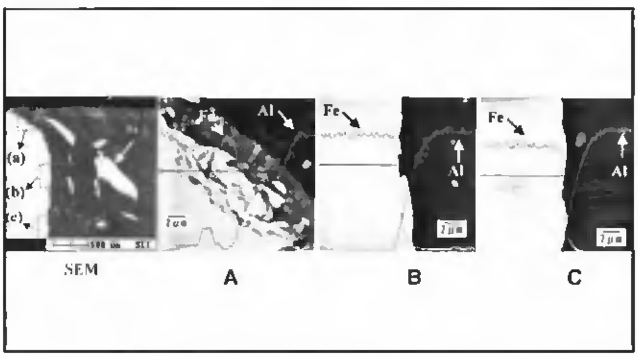

Fig. 7 — SEM images and line analyses of Fe and Al around the interface between the steel and the aluminum alloy: A — upper position; B — middle position; C — bottom position.

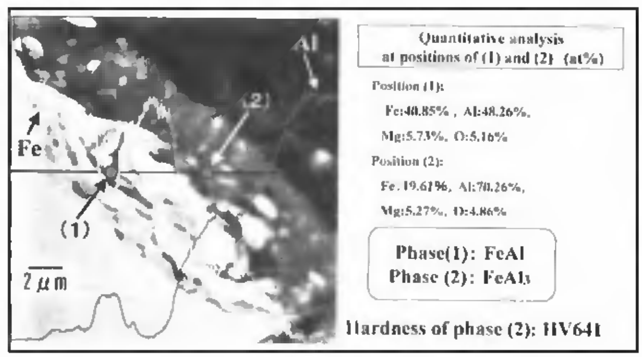

Fig. 8 — Quantitative analyses of the phases at the positions indicated by (1) and (2).

trix. Energy-dispersive spectroscopy analysis revealed that the chemical composition of the fragments was identical with that of SS400 Fe base metal and the fragments in the Al came from the Fe.

At a pin rotation of 500 rpm, the surface morphology of the weld was similar to that in the case of 250 rpm rotation speed; however, the joint strength was much lower than that at 250 rpm rotation speed.

At the faster pin rotation speed of 1250 rpm, oxidation occurred during the welding process due to Mg in the Al base metal; however, there is no direct evidence of oxidation of Mg in the Al. The weld could not be completed and the joint fractured during machining to make a tensile test specimen. The fracture surface appeared to be heavily oxidized and appeared to be burned.

According to the above results, a pin rotation speed of 250 rpm was adopted thereafter as the optimal rotation speed for the welding experiments.

The Effect of Pin Offset on Joint Tensile Strength

Figure 5 shows the effect of pin offset on the tensile strength of a joint made under the conditions of a 25 mm/min welding speed and a 250 rpm pin rotation speed.

When the offset was zero or negative, that is to say, the side face of the pin just contacted the Fe faying surface or was located in the Al matrix, the joint tensile strength was low, but higher than when the offset was larger than 0.6 mm. Maximum joint strength was obtained at 0.2-mm offset. As offset was increased, joint tensile strength decreased.

Pin Offset, Cross-sectional Structure, and Fracture Path

Figure 6 shows the cross-sectional structures and fracture paths of the joints made at various pin offsets. When the offset was zero or negative, removal of the oxide film from the Fe faying surface was probably insufficient, so that fracture of the joint occurred along the interface between Fe and Al.

As the pin offset became positive, the joint strength increased and reached a maximum strength at an offset of 0.2 mm. The fracture path of the joint shifted from the Fe/Al interface to the Al matrix. When the offsets were 0.6 and 1 mm, Fe fragments scattering in the Al matrix became larger and some voids were formed, resulting in a decrease in joint strength. Fracture in the joint made with a 1-mm offset occurred along multiple paths as shown in Fig. 6, and the pin wore out in a short duration. The weld with the 1-mm offset using a 2-mm-diameter pin is typical of conventional FSW; however, a sound joint was not produced under this condition. At an offset of 2 mm into the Fe the pin wore out in a much shorter time and, consequently, only the upper region of the joint was welded and joint tensile strength was low.

Analysis and Observation of Joint Cross-sectional Microstructure

Cross-sectional Microstructure Perpendicular to a Weld Interface

Maximum tensile strength was obtained in the joint made under the following welding conditions: 25 mm/min welding speed, 250 rpm pin rotation speed, and 0.2-mm pin offset. Scanning

Fig. 9 — Cross-sectional view of the broken part of the joint after tension test. Fracture occurred along the interface between the steel fragment and the aluminum matrix.

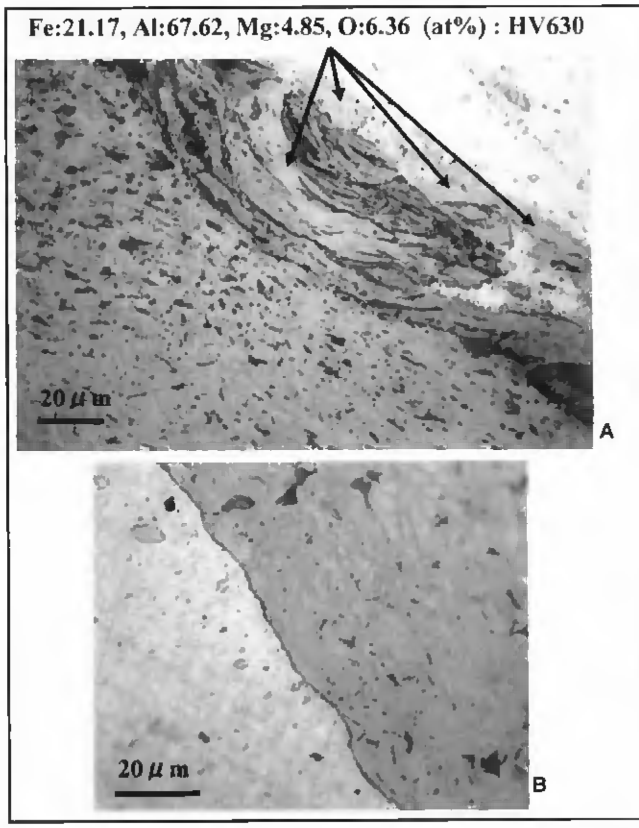

Fig. 10 — Enlarged optical micrographs of parts (a) and (b) in Fig. 9. Intermetallic compounds appeared at part (a) of the interface between the steel fragment and the aluminum matrix. No intermetallic compounds appeared at part (b).

electron microscope observations of the microstructure and the EDS analysis with the weld produced under these conditions were performed on the cross section perpendicular to the weld interface to examine whether intermetallic compounds were formed at the interface between the Fe and the Al.

Figure 7 shows enlarged SEM photographs and EDS line analyses of Fe and Al elements corresponding to the upper (A), central (B), and bottom (C) regions as shown in the photograph at the far left. Judging from the SEM photograph and EDS analysis, no intermetallic compounds were observed at the central and bottom regions of the interface between Fe and Al. However, the EDS line analysis of Fe and Al suggests that intermetallic compounds were formed at the upper region of the interface. Figure 8 shows the EDS quantitative analysis results at points 1 and 2 in the upper region of the interface. The chemical compositions of points 1 and 2 are 40.85%Fe-48.26%Al-5.73%Mg-5.16%O, and 19.61%Fe-70.26%Al-5.27%Mg-4.86%O (at-%), respectively. It appears that the intermetallic compounds of points 1 and 2 are FeAl and $FeAl_3$, respectively, based on this analysis and the Fe/Al phase diagram (Ref. 9). The hardness of the intermetallic compound of 2 was HV641.

A small amount of intermetallic compounds was observed at the upper region of the Fe/Al interface where the temperature was the highest during welding. As for the temperature, Ulysse (Ref. 10) has shown that the temperature at the upper region rubbed by the shoulder of a rotating tool is higher than the other regions in the weld.

Tensile testing of these joints showed that cracking tended to occur initially at the upper region of the joint and propagated toward the bottom region. The intermetallic compounds formed at the upper region of the Fe/Al interface appear to reduce the joints' strength.

Figure 9 shows an optical micrograph of a cross-sectional view of a fractured tensile specimen near the Fe/Al interface. This photograph shows that the fracture occurred along the interface between the Fe fragments and the Al matrix, and that the incipient cracking (indicated by an arrow in the photograph) occurred at the interface between the Fe fragment and the Al matrix. This suggests that cracking and fracture tend to occur at the interface between the Fe fragment and Al matrix.

Enlarged views of parts (a) and (b) in Fig. 9 are shown in Fig. 10A and B, respectively. A gray phase (indicated by an arrow) is observed at part A, and the phase composition analyzed quantitatively by EDS was 21.17%Fe-67.62%Al-4.85%Mg-6.36%O (at-%). It seemed from the composition and the hardness (HV630) that the phase was $FeAl_3$ intermetallic compound. However, there were also interfaces in which no intermetallic compounds appeared as shown in Fig. 10B.

Cross-sectional Microstructure Parallel to a Weld Interface

Figure 11 shows the SEM photographs of the cross-sectional microstructure parallel to the weld interface of the joint discussed in the previous section. A cross section was made about 700 μm from the Fe/Al interface for metallurgical analysis. The SEM photograph shows that Fe fragments are lined in rows in the Al matrix.

Scanning electron microscopy photographs of the fracture surface of this joint are shown in Fig. 12. Figures 12A and B are a macrophotograph and an enlarged SEM photograph, respectively. The uneven Al fracture surface suggests that fracture occurred along the interface between the Fe fragment and the Al matrix, as discussed in the previous section. Figure 12C is an enlarged SEM photograph showing a dimple pattern that indicates ductile fracture occurred.

The Effect of Rotating Pin Diameter on Joint Strength

In the previous sections, the 2-mm-diameter rotating pin was used to make a joint. In this section, the effects of various pin diameters on joint strength are examined. Joints were made using pins of 1, 3, and 4 mm diameter under the welding conditions of 0.2-mm pin offset, 250-rpm pin rotation speed, and 25-mm/min welding speed. The relation of pin diameter to joint strength is shown in Fig. 13. A pin of 1 mm diameter wore out in such a short duration that a sound joint could not be produced. The tensile strength and the microstructures of joints made using a pin of

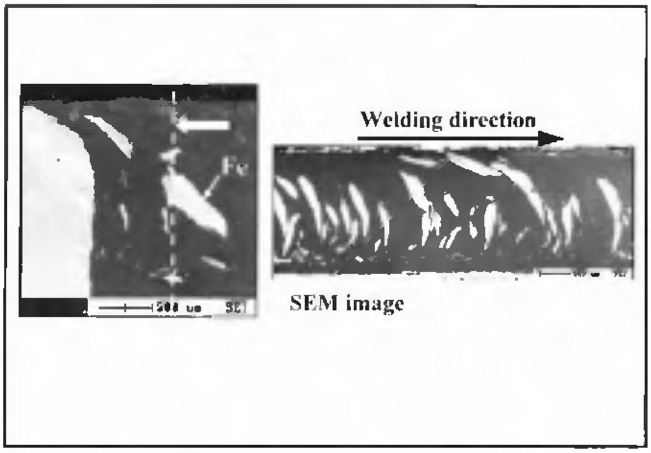

Fig. 11 — Cross-sectional SEM image longitudinal to welding direction. Many steel fragments are observed in the aluminum matrix.

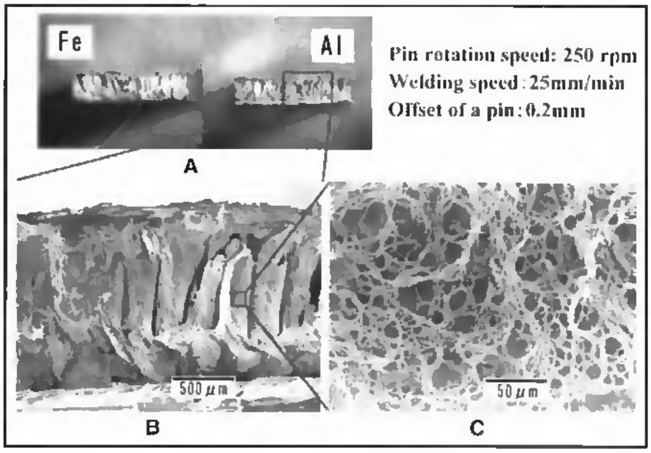

Fig. 12 — Fracture surface of the weld made under the optimal welding conditions: A — macrophoto of fracture surface; B — SEM image of fracture surface; C — enlarged SEM image of B. Fracture seems to occur along the interface between the steel fragments and the aluminum matrix, and a dimple pattern is observed in the fracture surface.

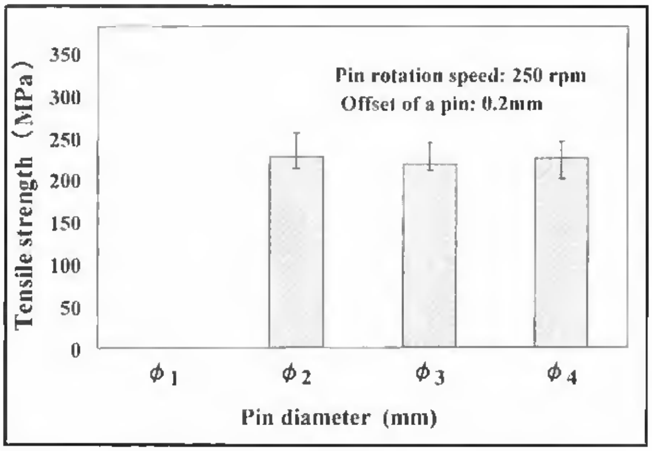

Fig. 13 — Relation between joint tensile strength and pin diameter.

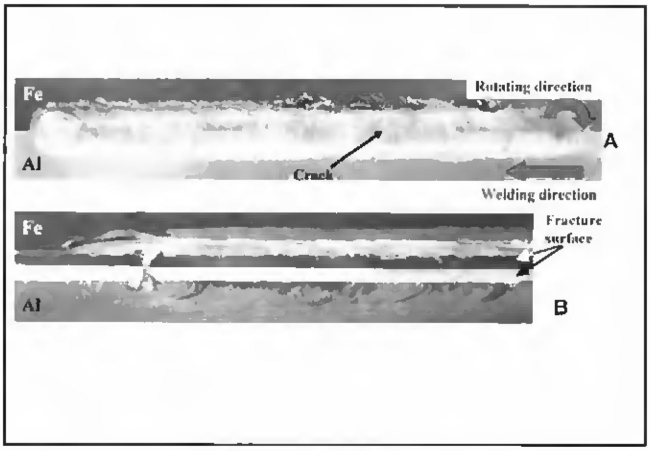

Fig. 14 — Surface view and fracture surface of the weld when welding direction was reversed, that is, the pin rotation direction was counterclockwise.

3 or 4 mm diameter were similar to those made using a 2-mm-diameter pin. It appears that rotating pin diameter has little effect on joint strength or microstructure.

The Effect of the Counterclockwise Rotation of a Pin

The effect of pin rotation direction on joint performance was also examined. The pin direction was reversed compared to the previously mentioned welds. With a counterclockwise pin rotation direction, the Al was located in the advancing side of the joint. The welding conditions consisted of a pin diameter of 2 mm, a pin rotation speed of 250 rpm, and a welding speed of 25 mm/min.

The top surface view of the weld made with a counterclockwise rotating pin is shown in Fig. 14A. It appears from this view that welding was successfully achieved. However, welding was restricted to the top surface and showed little bonding within the plate. Figure 14B shows a macrophotograph of the fracture surfaces of both Fe and Al sides. Both fracture surfaces appear flat and there seems to be no evidence of fusion on the butting surfaces.

The Fe faying surface polished with 400-grit emery paper was observed before and after welding to examine the surface morphology after rubbing by a rotating pin. Figure 15A and B shows the SEM photograph of the Fe polished faying surface before and after welding, respectively, with an offset of 0.2 mm. The photograph shows that the Fe polished surface was obviously rubbed with a pin, but fusion was not achieved. Figure 15C shows the Fe surface after welding with a pin offset of 0.4 mm. A more highly rubbed Fe surface was observed, but fusion welding was not achieved in this case, also.

It appears that fusion was not achieved with a counterclockwise pin rotation. The incomplete fusion can be explained using the schematic shown in Fig. 16. Figure 16A shows the case where the pin was rotated clockwise with the Fe plate mounted on the advancing side and the Al plate mounted on the retreating side. Figure 16B shows the case where the pin was rotated counterclockwise. When the pin rotates clockwise, the whirling Al, which is in a fluid-like plastic state, as shown by an arrow, is pressed to the Fe faying surface (indicated by a bold line) that has been already activated by the rubbing motion of the rotating pin and adheres to the Fe, resulting in welding of both plates. On the other hand, when the welding direction is opposite, as shown in B, the whirling Al in the plastic flow state, as shown by an arrow, is pressed to the Fe faying surface (indicated by a bold dotted line) that is not activated by a rotating pin, resulting in no welding.

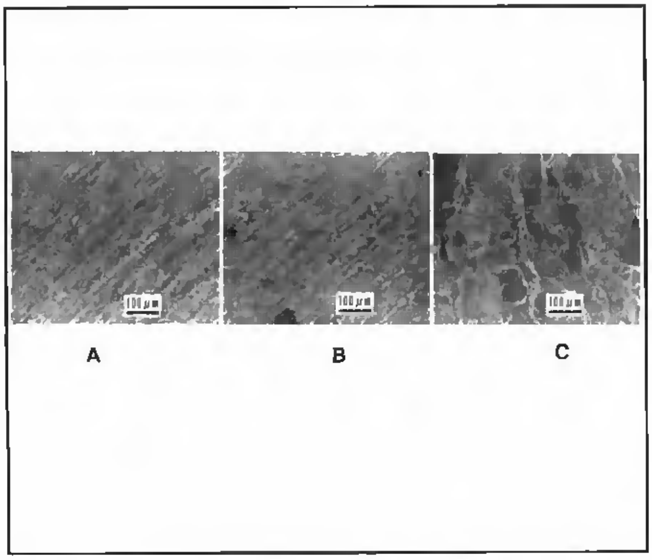

Fig. 15 — SEM photographs showing steel faying surfaces before and after welding when the welding direction was reversed: A — before welding; B — after welding with an offset of 0.2 mm; and C — after welding with an offset of 0.4 mm.

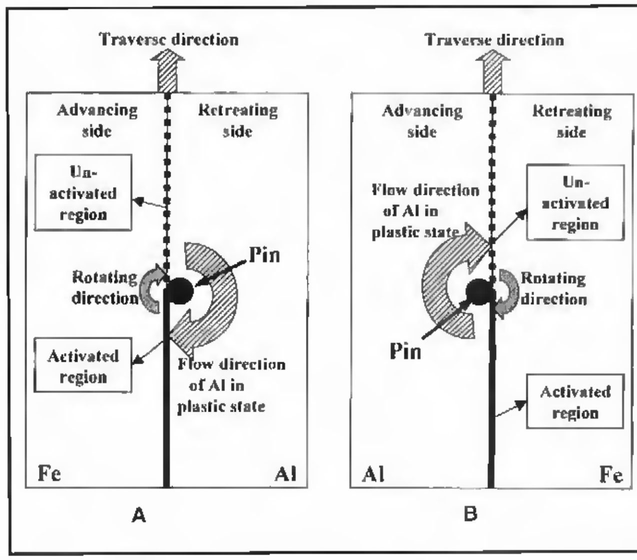

Fig. 16 — Schematic illustration showing plastic flow direction of aluminum for aluminum-to-steel FSW: A — clockwise pin rotation of a pin; B — counterclockwise pin rotation.

Conclusions

The authors applied friction stir welding in order to join an aluminum alloy containing magnesium to steel. In this study, the effects of pin rotation speed and pin offset toward the steel faying surface on the tensile strength and the structure of a joint were investigated. The following results were obtained.

1) Adjusting a rotating pin position to activate the faying surface of the steel enabled a joint to be produced between steel and an aluminum alloy. Welds were produced by placing the aluminum alloy on the retreating side of the joint.

2) There was an optimum rotation speed for the pin to make a sound joint. A lower rotation speed gave rise to an insufficient increase in temperature at the weld, so that the pin wore out in a short time. At a higher rotation speed, the temperature increase was so excessive that the magnesium in the Al alloy oxidized and resulted in an unsound joint.

3) The maximum tensile strength of the joint was obtained at the pin offset of 0.2 mm toward steel. At a larger offset, steel pieces scattering in the aluminum alloy matrix became larger in size and some voids were formed, resulting in a decrease in joint tensile strength.

4) Intermetallic compounds were not observed at the interface between the steel and the aluminum alloy. However, some intermetallic compounds were observed at the upper region of the weld where the temperature was higher due to the additional heat generated by the rotating tool shoulder. The intermetallic compounds formed at the upper region of the Fe/Al interface deteriorated the joint strength.

5) A minimum pin size was required to produce a weld. Pins that were too small in diameter, i.e., 1 mm diameter, could not produce a weld. Pin diameters from 2 to 4 mm showed similar joint tensile strength.

6) Welds could not be produced when the pin was rotated counterclockwise, i.e., the aluminum plate was mounted on the advancing side.

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Flame-Focusing Modification of a Wire-Core Thermal Lance

Improvement shown to double cutting speed

BY H. WANG, P. PRANDA, AND V. HLAVACEK

ABSTRACT. In order to optimize lance performance, a nonreactive, nonmelting layer to cover the wire-core thermal cutting lance has been tried. The layer stabilized the lance combustion (aluminum-hybrid iron wire-core lances). Lances covered by this layer produced a highly convergent stream of cutting oxygen and did not suffer from major radial leakage of cutting oxygen typical of commercial thermal lances. The layer also improved the cutting continuity by avoiding the soldering effect and lance extinction. A novel lance, Sharp-Fire (O)™ has been developed. Experimental data indicate that the new lance cuts steel or iron two times faster than conventional commercial thermal lances. The cost of cutting with the new lance is also economical. The cutting data reveal that the savings can be in the range of \$1–\$10/ft of material cut.

Introduction

The thermal lance process represents the oldest commercial use of oxygen cutting or piercing of massive objects (metallic materials and concrete) (Ref. 1). The invention of the oxygen lance was based on an exothermic reaction of iron provided by the lance and a gaseous oxygen supply (Ref. 2). There are plenty of oxygen lance designs; however, the wire-core lance is the most common lance design in the industry, because it provides more iron for combustion and is easy to fabricate.

In the thermal lance cutting process, the lance rod, which is made of low-carbon steel tube with several iron wires (Fig. 1), reacts with a supplied flow of oxygen. The oxidation reaction generates a large amount of heat, melting the target. Excess oxygen is used to oxidize and blow out the molten target (the slag). The process has always been regarded as a crude method of cutting and severing, since it relied on the evolution of a large amount of heat at the point of cutting/piercing (Ref. 1).

The oxygen cutting jet plays an important role in the design of a thermal lance because most of the heat is provided by the burning of the cutting plate. This oxygen also helps to blow out the unreacted materials to make a cut. In the process of heavy cutting, the pressure of the cutting oxygen entering the cutting tip is of paramount importance, because of the distance the cutting jet must traverse through the kerf (Ref. 1). As opposed to oxyfuel cutting technology, the cutting tip of the thermal lance can always touch the cutting spot to avoid this problem. The efficiency of oxygen is therefore increased in the thermal lance cutting process.

In the past, research and inventions were focused on questions like A) how to change the lance design in order to get a better lance performance; B) is it possible to replace the iron fuel by other metals to achieve a higher lance burning temperature (Refs. 1, 3, 4); or C) how to apply chemical flux processes for increased performance (Refs. 5, 6).

In this paper, we focused our attention on a nonmelting, nonreactive layer modification of the wire-core thermal lance. This layer is applied around the thermal lance and serves as a flame-focusing element and consequently improves the lance cutting efficiency. Although it is well known that plastic and ceramic layers are applied for the insulation purpose of electric-aided cutting rods (Refs. 4, 7), we did not find any previous report on the flame-focusing effect of an inert layer.

Experiment Setup

The setup of a commercial thermal lance system is depicted in Fig. 1.

The principle of the experimental thermal lance system is described as follows: oxygen comes from the cylinder, through the oxygen hose and the torch, and finally reaches the lance rod. Oxygen flow rate is controlled by both the cylinder regulator and the torch trigger. The iron wire-core lance rod, commercially produced, has been made of low-carbon steel tube with several low-carbon steel wires along the inside surface of the tube (some steel is replaced by aluminum, in aluminum-hybrid iron wire-core lances). There are hollow areas inside to allow the oxygen to pass through — Fig. 1, upper-right corner. In the modified lance design, this assembly was surrounded by a nonmelting, nonreactive inert jacket.

By scrubbing the lance tip on the striker plate, sparks are generated on the lance tip. The sparks initiate the lance burning. By adjusting the oxygen flow, the lance burning propagates by itself. The burning lance targets the cutting plate to start the cutting. In our experimental testing, we have measured the flow rate of oxygen, time of cutting, consumption of the lance, and length of the cut. This information made it possible to calculate the cutting speed. The experiments have been repeated several times and the values reported here represent a reliable average value. Four types of lances were tested: commercially available iron wire-core lances (CAL), aluminum-hybrid lances, and inert-layer modified lances of both CAL and aluminum-hybrid types.

Flame Focusing, Flame Stability Theory, and Lance Modification

Combustion of metals in oxygen is a strongly exothermic process. It is well known that strongly exothermic processes feature all types of instabilities occurring both in space and in time. Typical time instability is represented by a longitudinal oscillation of the flame, and the temperature in the flame can oscillate by several hundred °C. We have observed this type of behavior for the flame produced by aluminum or titanium lances. The angular oscillation of the flame results in the rim burning at different speeds. We observed that after lance extinction the lance rim looked jagged.

In addition to flame instability, there is another problem brought by the wire-core

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KEY WORDS

Thermal Cutting Lance
Exothermic Processes
Soldering Effect
Flame Stability

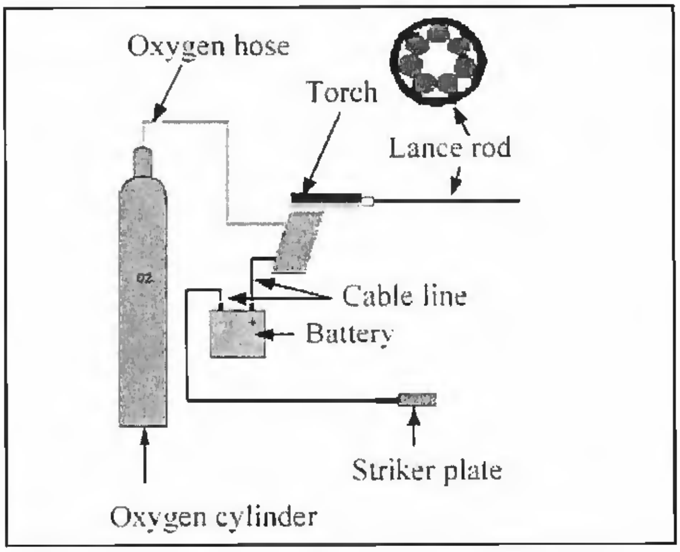

Fig. 1 — Commercial thermal cutting setup.

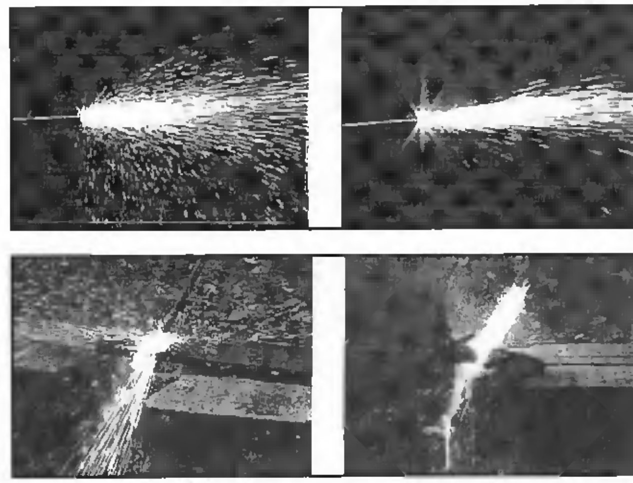

Fig. 2 — Flames produced by a CAL, left, and a modified iron-wire core lance, right.

lance design. The lance is made of thin metal tubing and several metal wires. The dimension of the tube wall is usually much less than the diameter of the wires (e.g., for industrial standard iron wire-core lances, the wire diameter is three times larger than the tube wall thickness). Hirano (Ref. 8) and Sato (Ref. 9) indicated that the metal flame-spreading speed increases as the metal piece dimension decreases. Therefore, it is no surprise that the lance rim burns faster than the inside wires. We observed this phenomenon in the burning CAL lances.

Because of a jagged rim, together with different flame-spreading velocities of the lance rim and body, a certain portion of the oxygen is ejected in the radial direction and the flame loses the focus. The burning lance looks like a spear — Fig. 2, left. Parts of the flame and oxygen are not focused on the cutting target and they are wasted.

In order to keep the flame focused, it is possible to wrap up the lance body with a thin layer of an inert jacket. The jacket burns slower than the lance. A modified lance with the trademark Sharp-Fire (O)™ was developed by Ceramic and Materials Processing, Inc., by this method. This provision allows the iron to burn, but the jacket prohibits radial oxygen leaking. The effects of oxygen leaking and its elimination can be clearly observed in Fig. 2. The material for the focusing sleeve, shown in the figure, is of great importance for the success of this method. The sleeve is made of a thin, flexible sheet of graphite with the thickness of about 0.01 in. (0.25 mm). The graphite sleeve is an inert material. By adjusting the sleeve thickness, the consumption speed of the sleeve is just slower than that of the lance, offering a focusing effect without disturbing the cutting. The reaction rate of the sleeve with oxygen is very slow, and for practical reasons we can assume nonreactivity. Since the sleeve is not consumed by oxygen in a significant way, the metallic part of the lance burns inward. The sleeve is weak and, if not supported by a rigid metallic body of the lance, it easily breaks off during the combustion process. Consequently, a self-regulation occurs without any interaction with the operator, and the combustion process produces a combustion zone configuration that sits on the rim of the burning lance, which is surrounded by a "wall" of the sleeve that extends 1–3 mm above the combustion front. Once the wall of the sleeve grows more, it is mechanically broken off by the interaction of the flowing gas and slag. Small scales of the unreacted sleeve are part of the slag. Details are described elsewhere (Ref. 10).

Experimental Results

Cutting with CAL and Sharp-Fire (O)™ Lances

In this section, the cutting performance of the nonmelting, nonreactive jacket-modified iron wire-core lance is compared with original commercially available iron wire-core lances. A commercially available iron wire-core lance (BROCO lance, produced by BROCO Inc.) has been tested against the modified lance (CAL with a thin, inert jacket).

Figure 3 displays the cutting speed as a function of the plate thickness for ⅜-in. outside diameter (OD) CAL and modified lances (0.375 in./0.952 cm OD, 0.028 in./0.071 cm wall thickness, with seven low-carbon steel wires [0.09 in./0.229 cm OD]) under different oxygen flow rates: 282 L/min at oxygen pressure of 50 lb/in.^{2}/345 kPa) and 411 L/min (at oxygen pressure of 80 lb/in.^{2}/345 kPa), respectively. Cutting plates used were mild steel slabs with thicknesses from 2.5 cm (0.984 in.) to 12 cm (4.72 in.). The figure shows that the modified lance cuts faster than the CAL lance at both oxygen flow rates.

In order to compare the performance difference between CAL and modified lances, we introduced a parameter: relative cutting speed index.

The definition of the relative cutting speed index (RCSI) is as follows:

$$RCSI = \frac{\text{Cutting Speed}_{\text{Modified}} - \text{Cutting Speed}_{\text{CAL}}}{\text{Cutting Speed}_{\text{CAL}}}$$

The higher the RCSI number, the more efficient is the use of modified lances rather than CAL lances under the same cutting conditions.

Figure 4 shows that both curves have a maximum cutting plate thickness around 7 cm (2.76 in.). As the cutting plate thickness increases from 0 to 7 cm (2.76 in.), the cutting performance difference increases. As the cutting plate thickness increases further, the performance difference decreases. No experiments were done at a thickness above 12 cm (4.72 in.).

The lance burning speeds under all cutting conditions were measured. As we found out, there is no obvious trend between lance burning speed and types of lances (CAL and modified), cutting plate thickness, or oxygen flow rate. The lance burning speed oscillates in the range of 0.65–0.95 cm/s (0.256–0.374 in./s).

Experiments with ¼-in. OD lances (¼-in./6.35-mm OD, 0.028-in./0.071-cm wall thickness, with six low-carbon steel wires

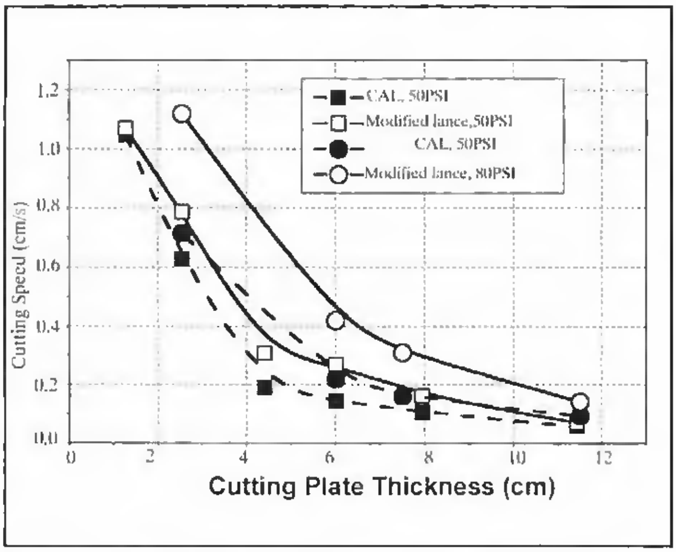

Fig. 3 — Cutting speeds for different cutting plate thicknesses and oxygen pressures using ⅛-in. OD lances (1.2 cm/s = 0.472 in./s).

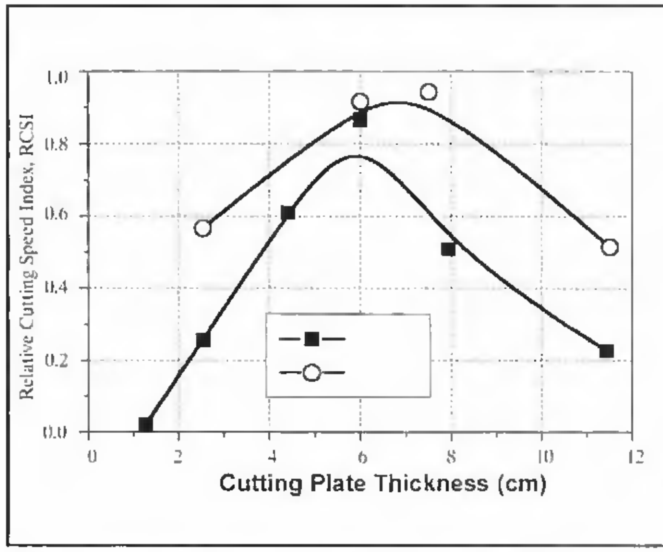

Fig. 4 — Relative cutting speed index at 50 lb/in.² (345 kPa) and 80 lb/in.² (552 kPa).

Table 1 — Comparison of Aluminum-based Lance and CAL

Cutting #	Type of Lance	Time s	Length of cut in. (cm)	Cutting Speed in./s (cm/s)	Observation
	Steel plate (thickness = 1.02 in. [2.6 cm]) at oxygen flow rate 80 L/min				
1	CAL	89.59	8.86 (22.5)	0.099 (0.251)	
2	Fe tubing +7 Al wires	—	—	—	No ignition,
3	Al (3003) tubing +7 Fe wires	—	—	—	Extinguished
4	Al (6061) tubing +7 Fe wires	—	—	—	Al burns faster than Fe wires
5	Al (6061) tubing + 7 Fe wires and inert jacket	38.29	6.1 (15.5)	0.159 (0.405)	Combustion
6	Al (3003) tubing + 7 Fe wires and inert jacket	61.45	8.86 (22.5)	0.144 (0.366)	Combustion
	Steel plate (thickness = 1.38 in. [3.5 cm]) at oxygen flow rate 80 L/min				
7	Al (3003) tubing + 7 Fe wires and inert jacket	73.94	5.71 (14.5)	0.077 (0.196)	Combustion
8	Al (6061) tubing + 7 Fe wires and inert jacket	53.68	5.71 (14.5)	0.106 (0.270)	Combustion
9	CAL	79.99	5.71 (14.5)	0.071 (0.181)	—

[0.065 in./0.163 cm OD]), cutting on ½-in.-(12.7-mm-) thick plate at different oxygen flow rates, were performed to investigate the influence of oxygen flow rate. The results are shown in Fig. 5. Figure 5 shows that the RCSI decreases abruptly as the oxygen flow rate increases.

The lance burning/cutting observations (Fig. 2) show the inert jacket placed on the surface of a CAL modifies the oxygen flow, and a well-focused stream of the cutting oxygen is achieved. The fluid flow properties are illustrated in Fig. 2. The tiny droplets of iron oxides that are released from the body of the burning lance follow the streamlines. Figure 2 clearly indicates that for the modified lance, the streamlines are not dispersed and, consequently, the cutting oxygen is transported to the cut without any radial leakage. It is well known that oxygen quality is important for steel cutting (Ref. 11); therefore, the oxygen focusing effect provided by the jacket improved the cutting speed substantially (as shown in Fig. 4). Other advantages of the modification from our cutting experiences are as follows:

1) The cover decreases the heat dissipation between the lance and the cutting plate. As a result, the flame does not extinguish during random perturbations, and high stability of the cutting regime results. Thus the annoying reignition operation is safely removed; this is important especially for underwater operations.

2) The cover also eliminates the "soldering effect," by avoiding direct touching of the lance and the plate. The soldering effect, which happens with iron thermal lances, is induced by the fast cooling of the cutting area during cutting. The fast cooling process solidifies the melted metals and the lance sticks to the plate. The soldering effect (lance sticking to the cutting plate) often happens in the case of a low oxygen supply flow. The modification decreases real cutting time and improves the convenience.

Aluminum-Iron Lance and Flame Stability Control

Aluminum metal behaves differently from iron; it reacts with both oxygen and nitrogen. Unlike iron, the melting point of aluminum is low and the adiabatic temperature is high. The adiabatic temperature of aluminum combustion in oxygen is approximately 3700°C (6700°F); the experimentally observed value is around 2500°C

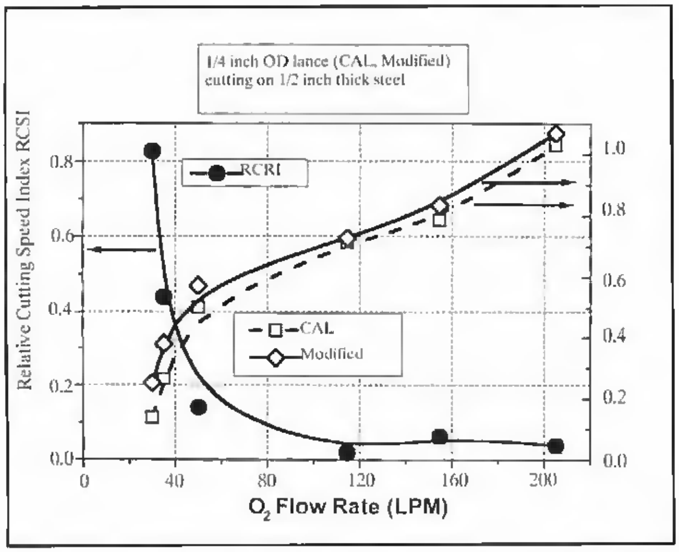

Fig. 5 — Relative cutting speed index as a function of oxygen flow rate (1.2 cm/s = 0.472 in./s).

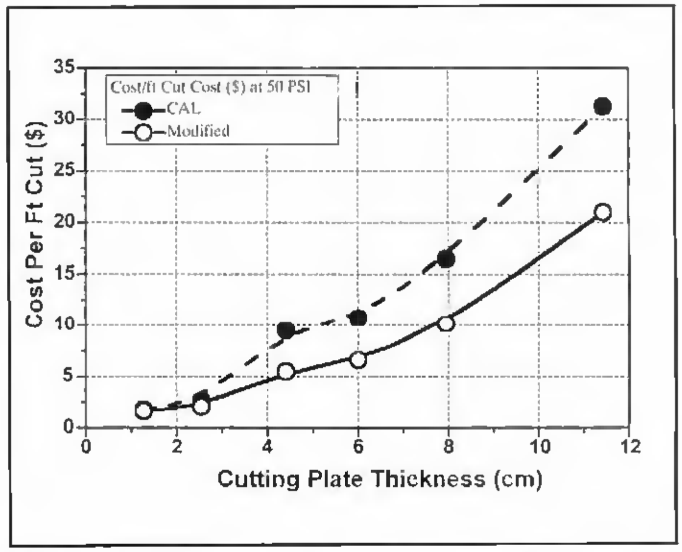

Fig. 6 — Overall cutting-cost comparison of CAL and modified lances at 50 lb/in.² (345 kPa).

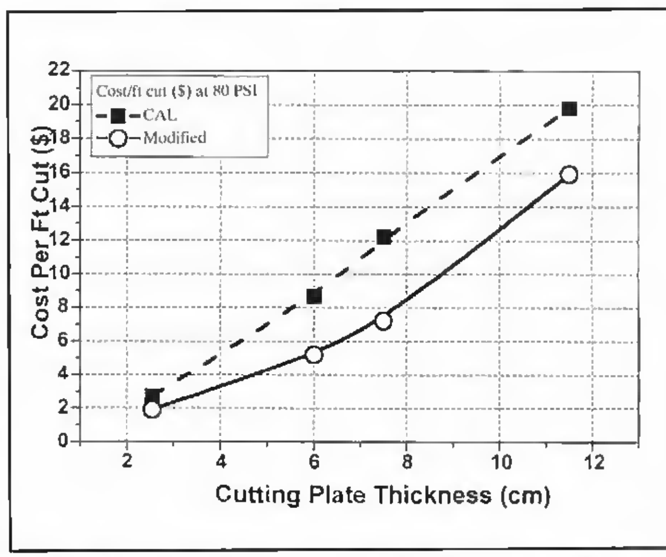

Fig. 7 — Overall cutting-cost comparison of CAL and modified lances at 80 lb/in.² (552 kPa).

(4500°F) (Ref. 12). There are studies that report that aluminum burns as vapor or both as liquid and vapor (Refs. 13–15). Because aluminum has a higher adiabatic temperature, it is widely used to replace iron to increase the flame temperature. Due to instability of aluminum combustion, a stable self-propagating lance flame is possible only if a small part of iron is substituted by aluminum (Refs. 4, 16).

We have tested the performance of aluminum metal in the design of a wire-core lance, and the results have been compared with the performance of the commercially available lance (⅜-in. OD CAL) with the same dimension and design. In the experiments reported below, we used Fe wires of 0.09 in. (2.29 mm) and aluminum wires of 0.08 in.(2.03 mm). The results of the test are reported in Table 1.

Aluminum wires or aluminum tubing, if used in proper relation to the iron material of the lance, can substantially increase the cutting speed compared to CAL performance. However, this increase of the cutting speed is at the expense of the combustion stability of the lance. Aluminum metal melts in the flame, the small droplets of liquid aluminum are carried away by the oxygen stream, and afterburning of aluminum takes place. The self-propagating combustion regime is extinguished as the oxygen flow rate increases above 80 L/min. An application of an inert jacket on the aluminum lance is very important for a stable combustion. Experimental observations indicated that the absence of the nonreactive, nonmelting jacket would result in highly unstable combustion, resulting in the flame extinguishing. The implementation of the inert jacket improved the flame stability of the hybrid Fe-Al lance.

Discussion

Application of other metals to a regular iron lance can have positive results if the relation between iron and the additional metals is kept in a certain range. Experiments described above revealed that a hybrid Fe-Al lance does not burn in a stable mode, and a stable combustion can be achieved only if the iron material is in excess and the lance is protected by an inert jacket at the low oxygen flow conditions. In particular, a combination of iron wires and aluminum 6061 tubing turned out to be a very effective lance with a high cutting speed if an inert jacket was applied. The inert jacket has the effect of flame stability improvement. The following qualitative explanation of the improved flame stability can be presented. It is known in the theory of strongly exothermic, strongly nonadiabatic flames that the behavior of the flame shows major longitudinal oscillation that eventually results in flame extinction. The theory also indicates that the decrease of heat loss from the flame improves stability behavior. Obviously, the unreacted piece of the sleeve, before being broken off, represents a radiation mirror, and the radiation flux in the radial direction is smaller. Consequently the flame is hotter and more aluminum evaporates. A homogeneous flame usually exhibits higher stability compared to a flame-consuming fine spray of drops. The thermal conductivity of graphite is also much less than that of aluminum. These facts reduced the energy loss and heat dissipation to the environment. The flame was therefore stabilized.

As the experimental results of ⅜-in. OD wire-core iron lances show, the inert jacket modified lance cuts faster than the commercially available lances under the same oxygen flow rates. With increasing cutting plate thickness, the difference between CAL and modified lances increases. In cutting procedure, the lance flame heats up the plate surface first. After the plate is heated up to the ignition temperature, the iron material from the plate reacts with the excess oxygen provided by the lance. When the plate is very thin, the preheating time and focusing of the oxygen/flame stream play a minor role, and the plate is cut immediately by the lance flame. That is the reason RCSI is small for thin plates. When the cutting plate is thick, the cutting kerf actually played a role of focusing element; therefore, RCRI decreases — Fig. 4. The performance difference between modified and CAL lances in cutting iron or steel plates is most obvious in the range of 6–8 cm (2–3 in.) of plate thickness.

At a given cutting plate thickness, the performance difference between CAL and modified lances decreases with the increasing oxygen flow rate — Fig. 5, ¼-in. OD lances. At very low oxygen flow, the focusing effect substantially increases the efficiency of the oxygen. The modified lance cuts almost two times faster than the CAL lance. However, after the oxygen flow is increased, that difference disappears. It is also a proof that the inert wrap not only focuses the flame, but oxygen as well.

It is instructive to calculate the cost of cutting both for the modified lance and for the commercially available lance. Data on cutting speed, lance burning speed, and oxygen consumption must be considered. The following cost data have been used in our calculation: ⅜-in. OD lances, CAL price \$4.06/3 ft, modified lance price \$4.57/3 ft, oxygen price/L \$0.00419.

The cost comparison is shown in Figs. 6 and 7.

Figures 6 and 7 show the calculated cutting cost based on the data of cutting speed, lance burning speed, oxygen flow rate, and the unit price of a lance and oxygen gas. The figures reveal that the overall cutting costs are lower for the modified lance compared to commercial lances. Oxygen consumption cost is about 35% of the overall cost for both the CAL and the modified lances at 50 lb/in.^{2} (345 kPa). Oxygen consumption cost is about 45% of the overall cost for the CAL lance and 40% for the modified lance at 80 lb/in.^{2} (552 kPa). The reduced cost of using the modified lance is due to the facts that cut speed is increased and the material and fabrication cost of adding an inert jacket is also low. Adding an inert jacket increases the lance cost less than 50 cents.

Conclusions

The nonmelting, nonreactive jacket improves the wire-core lance performance through the following ways:

The jacket stabilizes the lance flame. The hybrid iron-aluminum lance does not produce a stable self-propagating combustion regime without the nonmelting, nonreactive jacket at the oxygen flow rate of about 80 L/min. In the cutting process, the jacket reduces the flame extinction and soldering effect by reducing the heat loss and by direct contact between the lance and the cutting plate.

Through the focusing effects of both oxygen and the lance flame provided by the jacket, the cutting time of the inert jacket modified lance is substantially reduced. The cutting speed is increased by a factor of two for 6–8-cm-thick iron plates.

The cutting cost of the modified lance is also much lower than that of the CAL lance because the modified lance has a higher cutting speed. The cost of the nonmelting, nonreactive jacket is only marginal.

Acknowledgment

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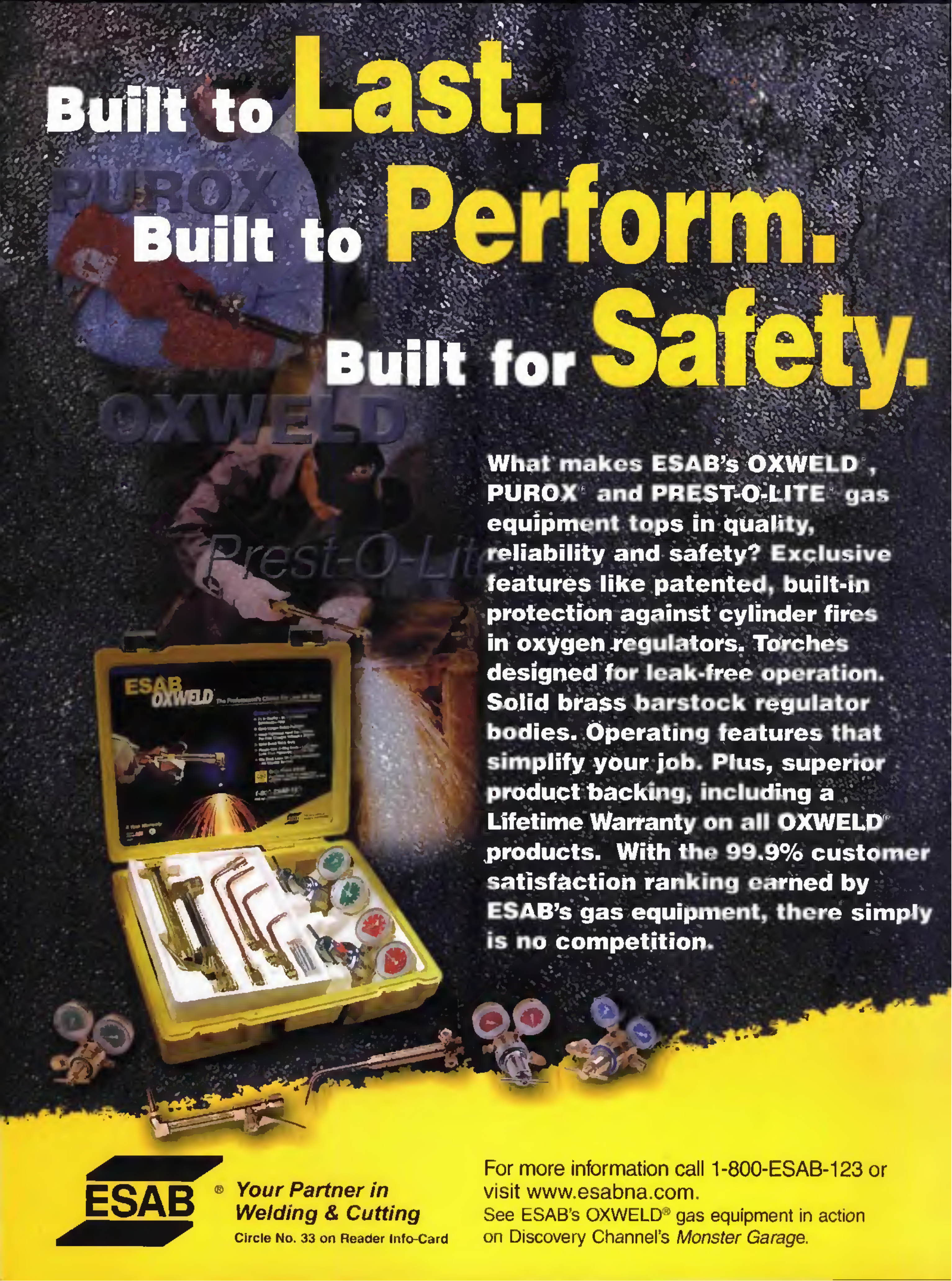

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