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WELDING *Journal*

October 2009



- **Brazing and Soldering Today**

- **Welding Aluminum**

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

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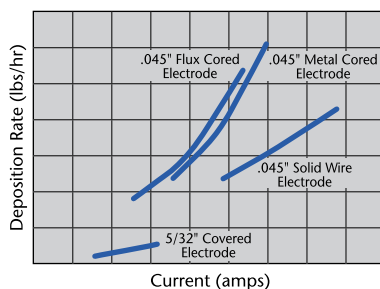
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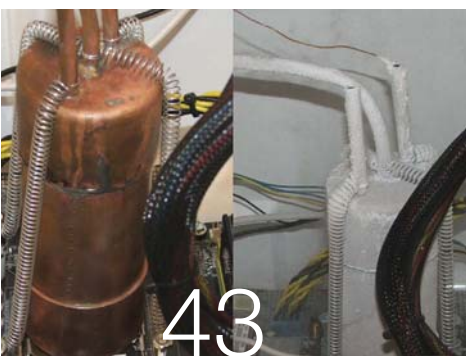
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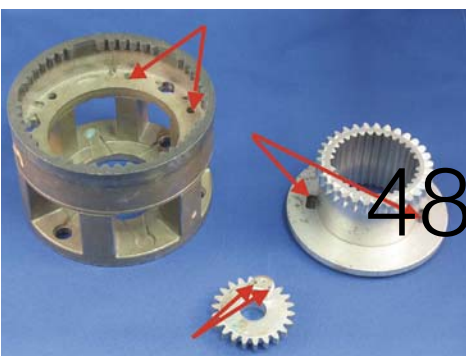
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On the cover: Three metal calibration cup assemblies designed and assembled at the NASA Goddard Space Flight Center, Greenbelt, Md., that will be used in the Sample Analysis at Mars (SAM) experiment on the Mars Science Laboratory (MSL) rover. Each cup is about 3 in. long and comprised of Ti-6Al-4V, Ni 200, Inconel 693, and Cu components joined together using vacuum brazing and electron beam welding. More than 300 vacuum brazed joints were required to build the SAM instrument. (Photo courtesy of Goddard Space Flight Center.)


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EDITORIAL

A Letter to Those Who Support the Welding Profession

As the new chair of the American Welding Society Foundation, I'll share some of the initiatives we have under way. Our major focus is addressing the shortage of skilled welders and our Welder Workforce Development fund-raising efforts.

Market research conducted with funds from the National Science Foundation and updated in 2009 with help from the U.S. Department of Labor shows that despite the current economic downturn the anticipated skilled welder shortage will exceed 200,000 persons in the near future.

The AWS Foundation has a two-pronged approach to help with the skilled welder shortage. First, we manage our traditional scholarship programs to assist students in gaining a welding education. Since its inception in 1991, we have awarded more than 3000 scholarships in an amount of more than \$3.8 million. The other effort, the AWS Welder Workforce Development Program, has generated a great deal of enthusiasm and excitement. Its focus is addressing the industry shortage of welders by helping with recruitment, training for specific industry needs, assisting with curriculum development where needed, and working with training institutions to accomplish the training. We have established the Solutions Opportunity Squad (SOS) to implement the coordination of these efforts and others that arise. These initial initiatives have created an enormous amount of interest and involvement by our many industry partners.

Our major funding support to date has been welding equipment and filler metals manufacturers, distributors, and individuals. Although we have received some donations from fabricators and construction companies who employ welders — and these are much appreciated — we feel there is an opportunity to speak with more of them as well as others who understand our business and know the efforts we have under way will strengthen the welding profession.

During these tough economic times we are reaching out to a broader base of supporters so we may continue our efforts. We have a significant need for qualified skilled welders to build the massive wind towers, nuclear power plants, and alternative fuel facilities like ethanol production, as well as to rebuild our bridges and other transportation products, etc.

We need everyone's help if we are to be successful in sustaining our welder workforce and the efforts to recruit and retain them. While we, the American Welding Society and the AWS Foundation, are extremely excited about the current evolution and position of our campaign, and more importantly, the impact our efforts have made on the welding workforce and profession, there is a great deal more to be done.

In your discussions about end of life planning, perhaps some of you "old-timers," like me, could consider putting the AWS Foundation in your estate plan. Request information; we can help make it an easy item on your to-do list.

Please review the card next to this editorial and

- Define what you can do to help directly,
- Request information you can present to fabricators who can provide support for their future welders,
- Supply names of others you know who understand and support our profession and who might wish to contribute to our efforts.

If you've been a supporter of the AWS Foundation in the past, let me express my appreciation of your efforts. If you are just now joining the ranks of those who support the welding profession through the Foundation's activities, thanks for your help.



Gerald D. Uttrachi
Chair, AWS Foundation



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WASHINGTON

WATCHWORD

BY HUGH K. WEBSTER

AWS WASHINGTON GOVERNMENT AFFAIRS OFFICE

White House May Create New Manufacturing Position

It has been widely reported that the White House plans to create a new position within the National Economic Council, which is part of the Executive Office of the President, that would be charged with developing policies relevant to U.S. manufacturing. It is not clear how the new position will interact with the Assistant Secretary for Manufacturing and Services within the U.S. Department of Commerce, an office that was created in 2003.

Federal Government to Review Export Control Regulations

In a development that most in the U.S. business community view as long overdue, both the White House and Congress have announced separate reviews of the U.S. export control system, including the dual-use and defense trade processes. The aim of both efforts is to consider and recommend reforms that maintain security but also promote economic growth. Much of the current system is rooted in the Cold War era of more than 50 years ago, and many believe that outdated rules are hindering U.S. competitiveness.

Hearing on National Manufacturing Policy

“The U.S. as Global Competitor: What Are the Elements of a National Manufacturing Strategy?” is the title of a hearing recently held by Congress before the Senate Banking Subcommittee on Economic Policy. It is the second Congressional hearing this year on the challenges and opportunities facing U.S. manufacturing.

The committee chairman offered the following five areas as possible components of such a national manufacturing strategy:

1. Innovation — creating a predictable climate for investment in research and development, including establishment of an Innovation Research Fund for work in clean energy, information technology, defense, and aerospace.
2. Supply Chains — giving supply manufacturers the tools to transition from contracting industries, like autos, to growing industries, like clean energy, including by investing in Manufacturing Extension Partnerships.
3. Skills — developing sector-based systems that link highly skilled workers with emerging industries to promote long-term competitiveness.
4. Coordination — creating a strategy and resources to rapidly assist workers, businesses, and communities when there is a massive disruption in the economy due to layoffs.
5. Fair Trade — strong enforcement of U.S. trade laws.

Federal Contracting Facing Reductions, Oversight

In 2008, the federal government awarded more than \$500 billion in contracts to more than 160,000 contractors. The Administration is seeking to reduce that by \$40 billion annually through better agency acquisition and acquisition-related program practices. The White House plans to meet this goal in large part by

mandating that all agencies 1) review their existing contracts and acquisition practices and develop a plan to save 7% of baseline contract spending by the end of FY 2011, and 2) reduce by at least 10% the combined share of dollars obligated through new contracts in FY 2010 that are awarded noncompetitively or on a cost-reimbursement or time-and-materials basis.

Legislation Seeks to Expand Worker Verification

The Secure America through Verification and Enforcement Act (S. 1505) would expand the E-Verify system, which presently is limited to federal contractors, to cover all employers, phased-in over four years. E-Verify is a Web-based system that allows employers to check the Social Security and visa numbers submitted by workers against government databases to confirm that their employees are eligible to work in the United States. Effective in September, all federal contractors (and most subcontractors) became subject to the E-Verify system.

OSHA Establishes Training Program ‘Watch List’

The U.S. Occupational Safety and Health Administration (OSHA) has announced the establishment of an “Outreach Trainer Watch List” that will identify those who have had their OSHA trainer authorizations either revoked or suspended. Trainers are authorized by OSHA by completing a one-week trainer course through an OSHA Training Institute Education Center. The trainers are then eligible to teach 10-h programs that provide basic information to workers and employers about workplace hazards and OSHA, and 30-h courses in construction, maritime, and general industry safety and health hazards. There are presently more than 16,000 independent, OSHA-approved trainers.

The Watch List can be viewed at www.osha.gov/dte/outreach/construction_generalindustry/watchlist.html.

New OSHA Administrator Named

David Michaels has been nominated by President Obama to serve as Assistant Secretary of Labor for Occupational Safety and Health. Michaels, an epidemiologist, is a professor at The George Washington University School of Public Health and Health Services. He previously worked in the Clinton administration as the Assistant Secretary of Energy for Environment, Safety and Health, overseeing worker health and safety issues in nuclear weapons facilities. ♦

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

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PRESS TIME

NEWS

Final Rule Issued on Continuous Welded Rail Inspection

The Department of Transportation and Federal Railroad Administration's (FRA) *Track Safety Standards; Continuous Welded Rail (CWR); Final Rule*, 49 CFR Part 213, became effective August 25.

Its summary reads, "FRA is amending the Federal Track Safety Standards to promote the safety of railroad operations over continuous welded rail (CWR). In particular, FRA is promulgating specific requirements for the qualification of persons designated to inspect CWR track, or supervise the installation, adjustment, or maintenance of CWR track. FRA is also clarifying the procedures associated with the submission of CWR plans to FRA by track owners. The final rule specifies that these plans should add focus on inspecting CWR for pull-apart prone conditions, and on CWR joint installation and maintenance procedures. This final rule will also make other changes to the requirements governing CWR."

The compliance dates are October 9 for Class I railroads, November 23 for Class II railroads, and February 22, 2010, for Class III railroads. The ruling also defined that currently CWR is rail that has been welded together into lengths exceeding 400 ft.

GE and Fanuc Dissolve Joint Venture

GE and FANUC have recently agreed to dissolve the GE Fanuc Automation Corp. joint venture. This transaction is expected to be completed by the end of 2009, subject to satisfactory customary closing conditions.

"Our joint venture has achieved great success toward its original mission, which was to cooperate on the global growth and technical development of the PLC and CNC business. Over this time period, markets and opportunities also have changed dramatically, and both companies further expanded into adjacent segments," said FANUC Honorary Chairman Dr. Seiueemon Inaba.

The terms are as follows: GE retains the software, services, embedded systems, and control systems businesses globally; the company will be known as GE Intelligent Platforms and led by Maryrose Sylvester; and FANUC retains the global CNC business.

SME and Purdue Unveil New Green Certificate Program

The Society of Manufacturing Engineers (SME), Dearborn, Mich., is collaborating with Purdue University's Technical Assistance Program (TAP) to develop the Green Manufacturing Specialist Certificate. This partnership includes SME developing an accompanying exam or outcome-based assessment that will be tested by participants in the Purdue TAP green workforce training program.

"The exam will be able to easily adapt to any green curriculum anywhere in the country. And once students pass it, they'll walk away with a certificate of completion of in-demand, green job skills," said Kris Nasiatka, manager, certification, books, and video at SME.

Beyond a broad study course, the certificate also offers varying levels of learning intensity. "The generalist level is intended to provide awareness, while the specialist level is intended to create project champions who have a more comprehensive body of knowledge. Upon completion of the six specialist modules, they are ready to sit for the SME exam and earn an SME certificate," said Ethan Rogers, manager, energy efficiency services, Purdue University TAP. He expects enrollment to grow to "a couple hundred people sitting for SME's certificate exam" by as early as 2010.

Superior Products Acquires West Coast Business

Superior Products, Inc., Cleveland, Ohio, has purchased Macro Technologies, Inc., Kirkland, Wash., a manufacturer of quick connects, relief valves, stainless hoses, and shutoff valves for compressed and cryogenic gases used in industrial, transportation, and home medical markets. It is also active in the emerging LNG and CNG markets.

"Our strategic acquisition of this fast-growing, innovative company broadens Superior's product lines and enhances our design capabilities for unique cryogenic and compressed gas products," said CEO Donald L. Mottinger.

Additionally, Superior Products has signed a Strategic Alliance with IBG-Cologne. "Working together in manufacturing and sales, we will be better able to service the welding and gas industries throughout the United States and the world," added Mottinger.

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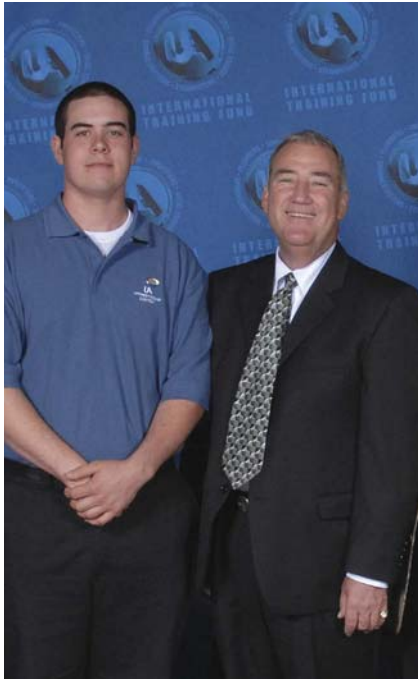
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NEWS OF THE INDUSTRY

International Construction Industry Competition Honors Winners in Welder, Pipefitter Disciplines



Peter LaRou (left), who won the welder division of the United Association's (UA) international apprentice competition held in Ann Arbor, Mich., is shown with William P. Hite, UA's general president.



Apprentice Peter LaRou works hard during the competition.



A contestant shows off his welding skills at the recent UA contest.

A group of apprentices from the United Association of Journeymen and Apprenticeships of the Plumbing and Pipefitting Industry of the United States and Canada (UA) recently took part in the organization's annual international apprentice competition in early August. They made their way through preliminary levels — local, state, regional — and competed in this final champion phase in Ann Arbor, Mich.

"Contractors should be standing right there recruiting these guys because they're the best of the best," said Andy Kireta Sr., president and CEO of Copper Development Association, Inc.

The 2009 winners in each division are as follows: Pipefitter, Nick Unfried, Local Union (LU) 136, Evansville, Ind.; Service Technician, David Fruehauf, LU 22, Buffalo, N.Y.; Welder, Peter LaRou, LU 597, Chicago, Ill.; Plumber, Jarrad Taylor, LU 5, Washington, D.C.; and Sprinklerfitter, Josh Coale, LU 669, Taylorsville, Ky.

"Reaching the final round was no easy task for any of these apprentices," said Mike Arndt, training director of the UA, "since all those competing have received the UA's high level of training in five required disciplines."

In addition, the winners and runners-up are recipients of awards such as gold rings, tool boxes outfitted for their specific craft, welding machines, jackets, and helmets. The best copper project in each craft receives \$1000.

"This is a tough competition," said Pete Marzec, a retired special representative from the UA's international training department and current chairman of the UA contest committee. "The contestants are challenged each year with the latest in industry technology, and they have to meet that challenge. The judges are all industry people, suppliers, and contractors, so they know what they're looking for — and once again, they got it."

Contestants can compete each year in the local and regional contests but can only take part once in the international competition. This year's event was made up of 30 participants from six geographic regions, five in the U.S. and one in Canada.

Nuclear Energy Institute Video Highlights Robotic Inspection Systems



Entergy Nuclear partnered with AREVA NP Inc. to develop this rail-and-trolley system that inspects the outer diameter of the boiling water reactor steam dryer at Vermont Yankee's nuclear energy station. The device's advantages include improved safety and reduced radiation exposure. (Photo courtesy of AREVA NP)

The Nuclear Energy Institute (NEI), Washington, D.C., has produced its fourth video, "Robotic Inspectors," highlighting new inspection devices developed at the Vermont Yankee nuclear energy station to closely analyze the facility's steam dryer. It is available at the following link: www.nei.org/resourcesandstats/documentlibrary/how_it_works/video/robotic-inspectors.

Also, Entergy Nuclear employees at this station are recipients of the Maintenance Process Award for developing tooling to inspect a boiling water reactor steam dryer, which is located in the top of the reactor.

Entergy Nuclear partnered with AREVA NP Inc. to develop two remotely operated inspection systems. The outer diameter innovation uses a rail-and-trolley system with a telescoping mast and camera to inspect all 213 welds and components. The inner diameter method uses an underwater crawler with a telescoping mast and camera to inspect all 253 welds and components.

An annual reduction of 3.6 person-rem of radiation exposure is expected along with a minimum \$500,000 cost reduction per outage. The tooling is transferable, too, as it was developed for use on all makes and sizes of dryers regardless of the rail configuration on the refuel floor, and can be used for dryer inspections at all boiling water reactors.

South Dakota's Labor Department Invests in Center's Welding, CNC Programs

The South Dakota Department of Labor (DOL) has partnered with the Regional Technical Education Center (RTEC) at Yankton, S.Dak., to expand programs for shielded metal arc welding (SMAW) as well as upgrade computer numerical control (CNC) machining. It provided RTEC \$11,000 to purchase five more SMAW machines and \$77,668 for the CNC machining program to purchase seven computers, more advanced software, two lathes, and a three-dimensional printer.

Introduction to Stick Welding is a 40-h course that will now have room for up to 13 students. New classes start monthly, and upon completion, students can take the American Welding Society qualification test. Plus, the CNC machining class began June 30 and is 210-h long. It has incorporated new technology and



**Do your part for the future
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A \$2,500 annual scholarship was established in 2005 by the Resistance Welder Manufacturers' Association for a college junior who wishes to become involved in the resistance welding industry. The hope is that the scholarship recipients will learn to appreciate the simple elegance and robustness of the process, so that they can carry the message forward to the next generation. The scholarship is awarded based on an essay, academics and recommendations.

***The deadline for the 2010 fall award is
January 15***

For details, visit
www.aws.org/foundation/scholarships/rwma.html



<http://www.aws.org/rwma/>



A student at the Regional Technical Education Center (RTEC) in Yankton, S.Dak., takes advantage of new welding equipment purchased with stimulus funds awarded by the South Dakota Department of Labor. (Photo courtesy of RTEC.)

green concepts used in advanced manufacturing. The next class begins in January and will take up to 23 students.

"Laid-off workers may each be eligible for up to \$5200 in tuition assistance from DOL," said State Labor Secretary Pam Roberts. "Our staff is available to help workers identify and enroll in workforce training opportunities leading to new careers."

Individuals interested in learning more about this training and tuition assistance should visit their local DOL office. Information on other training opportunities and a directory of DOL offices can be found at www.sdjobs.org.

Hobart Institute of Welding Technology Names Five Scholarship Winners



The Hobart Brothers Co. Scholarship supports area students interested in pursuing welding skills at the Hobart Institute of Welding Technology. Five \$2000 scholarships are awarded annually. Standing (from left) are Grant Harvey, vice president/general manager, Hobart Brothers; scholarship winners Brandon Livingston and Treg Hutchinson; Stephen Lucas, director of human resources, ITW Welding Products Group; Andre Odermatt, president/chairman of the board, HIWT; Sundaram Nagarajan, president, welding international, ITW; and Brenda Scott, director of compliance and student services, HIWT.

The Hobart Institute of Welding Technology (HIWT), Troy, Ohio, recently announced five area high school students as winners of the Hobart Brothers Co. Scholarship. Offered in conjunction with the Troy Foundation, this scholarship provides the stu-



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dents with \$2000 in funds that can be applied toward their tuition at HIWT during the upcoming academic year.

This year's winners are as follows: Brandon Livingston of New Weston; Treg Hutchinson of Versailles; Fred Noe Jr. of Dayton; Zachary Cox of Troy; and Jerry Strain of Union, Ohio.

To be eligible for the scholarship, applying students must hold a high school diploma, submit letters of recommendation, and provide a statement of how and why they are pursuing a welding career, along with what goals they wish to achieve at the HIWT. Priority for winners is given to children or grandchildren of employees at one of the ITW welding companies, then to a graduate of one of the local high schools, and finally to all other scholarship applicants.

Toyotetsu Manufacturing Plant Achieves Utility Savings with New Air-Filtration Units

At Toyotetsu America's plant in Somerset, Ky., a point-of-source, closed, air-filtration system has been installed for its 330 welding stations at the same time as a 2500-ton heating and air conditioning system. By filtering welding-generated smoke in a closed system that returns treated air back to the plant, management cut its usage of natural gas by up to 85% for a savings of close to \$60,000 in one month alone. The company is a division of Toyota whose business involves automotive stampings and the manufacture of motor vehicle parts, accessories, and hardware.

The project started in the spring of 2008 and involved extensive use of a helicopter to install both the A/C and filtration units on the roof. By May, 17 air-filtration units from Clean Air America, Inc., Rome, Ga., were placed into service, each possessing 48 cartridge filters within each collector, for a total filter-



Installing both the A/C and filtration units on the roof of Toyotetsu America's Somerset, Ky., plant involved extensive use of a helicopter. The filtration units feature 48 cartridge filters within each collector for a total filtering capacity of 340,000 ft³/min.

ing capacity of 340,000 ft³/min.

Installation of the air-filtration project was completed at the same time as installation of 40, 50-ton A/C units. Both systems were tied together through a single building automation system from Trane®, allowing facilities management to run everything from a centralized computer.

Taking into account electric utility savings when running the A/C system during the summer of 2009, annual utility-cost savings are projected to approach \$700,000.

— continued on page 91

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LETTERS TO THE EDITOR

Fifty-Year AWS Member Offers Advice on Welding Careers

I am 76 years old this year (see photo). I love welding and am always up for a challenge. I can't thank the American Welding Society enough for all the books and technical info I always relied on throughout my career in welding.

We sure need trained welders and real quality in all the training centers across the United States. Instructors in all these nice, new, real good shops sure need to offer students courses on what the outside jobs require, including lots of metallurgy and all aspects of power plant welding, tube welding, oilfield and refinery qualifications, military contracts, and even what's needed in fab plants, heavy mining equipment, and offshore platforms.

The AWS *Welding Journal* is a wonderful educational and technical journal. It expands our knowledge.

The editorial by AWS Vice President Bruskotter in the July issue (page 6, titled "Do You Have What It Takes to Weld Offshore?") really hits the nail on the head. A great article.



Wayne G. Potter (left) is shown with Bart Ney, a Caltrans bridge engineer, crossing the suspension cable walkway of the Alfred Zampa Memorial Bridge, which spans the Carquinez Strait between Vallejo and Crockett, Calif. Prior to his retirement, Potter was a welding instructor for 29 years at Contra Costa Community College, Diablo Valley College, and Los Medanos College in California, and a Boilermaker and instructor for Local 549.

The very paramount article on "Who Chooses a Welding Career?" (page 29, July 2009) is a great tool to reach the young welding students in all of the colleges or even high school vocational classes. This also alerts the adult welders and others out there to take an interest in AWS courses. Whoever picks up this July 2009 *Journal* makes the trades, construction welder, pipefitter welder, or many fab shop welders say, "I'm going to look into one of the AWS certification courses." Great job putting this together.

(My advice is) keep pursuing other areas of welding if one job is not fulfilling.

Wayne G. Potter
Pinole, Calif.

Dear Readers:

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

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About AWS Corporate Memberships:

The American Welding Society (AWS), understands that one size does not fit all. For that reason, we've created FOUR different levels of corporate membership, starting for as little as \$150 per year, allowing you to select a program that best fits with the way your company operates. With an 88-year history in the welding industry, and 50,000+ members worldwide, AWS Corporate Membership offers your company the ability to **INCREASE ITS EXPOSURE and IMPROVE ITS COMPETITIVE POSITION.**



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The AWS Foundation is pleased to announce additional scholarship for the 2009-2010 school year

National Scholarship Recipients



Congratulations to Dale David, the 2009-2010 recipient of the D. Fred and Marian L. Bovie Technical Scholarship

"I am very thankful for being selected as the recipient of the D. Fred and Marian L. Bovie Technical Scholarship. I appreciated and thank Mr. and Ms. Bovie as well as the AWS Foundation for awarding me this scholarship. I am also very thankful for their support and faith they have in me as I pursue my education as a welder."

North Dakota State College of Science – Welding Technology

Section Named Scholarship Program

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

Congratulations to Thomas E. Bartolomucci III, the 2009-2010 recipient of the Amos and Marilyn Winsand – Detroit Section Named Scholarship.



"I very much appreciate the financial assistance provided by Mr. and Mrs. Winsand and the AWS Detroit Section. The AWS has helped further my education in welding greatly throughout my college years. I look forward to being an active professional member of the AWS when I start my career in the welding industry after my senior year at Ferris State."

*Ferris State University
Welding Engineering Technology*

Congratulations to Paul Layman, the 2009-2010 recipient of the Ronald S. Theiss – Houston Section Named Scholarship.



"I am lucky to have such a supportive organization behind me. AWS has made me feel like there are other people that want me to succeed as much as I do. Without the support of AWS I may not have been able to continue, but, now I will not only continue but am looking forward to continuing my education in the BAS program for metallurgy. Thank you, AWS, for your support and knowledge. I look forward to being a lifetime member of AWS."

*Lone Star College
Cyfair – Welding Technology*

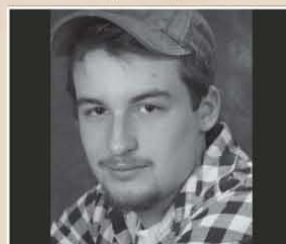
Congratulations to Tawnya Hermanson, the 2009-2010 recipient of the Paul O'Leary Memorial – Idaho/Montana Section Named Scholarship.



"I greatly appreciate being fortunate enough to receive the Paul O'Leary Memorial – Idaho/Montana Section Named Scholarship. I want to thank the Idaho/Montana Section and the O'Leary family for their contributions to the AWS scholarship program, as well as their support in helping me pursue my education in the engineering field."

*Montana Tech of the University of Montana
General Engineering –
Welding Engineering Option*

Congratulations to Rick Kocher, Jr., 2009-2010 recipient of the Lehigh Valley Professor Robert D. Stout Named Scholarship.



"I am truly honored to be awarded the Professor Robert D. Stout Scholarship. This scholarship will help me further my education and goals to become a more skilled welder and soon become a welding instructor to help further the education for the future generation of welders. I'd like to thank all involved in the selection process and all that contribute to the award."

*Northampton Area Community College
Career Technical Training –
Welding Technology*

Congratulations to Meredith Johnson, the 2009-2010 recipient of the Ronald S. Theiss – Houston Section Named Scholarship.



"I have been around welding for as long as I can remember, whether it was repairing miles of fences and cattle gates, building a house, or making a pit for our church's bar-b-q team. While I may not aspire to these feats of metal, I look forward to welding "artistic creations" that will surely last. I am honored to receive the 2009-2010 Ronald S. Theiss – Houston Section Scholarship. I know it will have positive effects on my education."

Lone Star College – Cyfair – Welding

Congratulations to Kelly Wilson, the 2009-2010 recipient of the Ronald C. and Joyce Pierce – Mobile Section Named Scholarship.



"I am honored to receive the Ronald C. and Joyce Pierce – Mobile Section Named Scholarship and would like to thank the members of the AWS Foundation and Mr. and Mrs. Pierce for their outstanding generosity. Inspiring, educating, and supporting the youth in preparation for their careers is one of the most honorable services an organization like AWS Foundation can perform. It actively insures a brighter, more successful future for society, and I feel privileged to be a part of it."

*University of Alabama
Materials and Metallurgical Engineering*

2009-2010 Tri-Tool, Inc. – Sacramento Section Named Scholarship
This award is sponsored by Tri-Tool and the Sacramento Section, and was awarded to students in District 22 as part of their District Scholarships

2009-2010 Louis DeFreitas – Santa Clara Valley Section Named Scholarship
This award is sponsored the Santa Clara Valley Section in recognition of Lou DeFreitas, and was awarded to students in District 22 as part of their District Scholarships

Congratulations to Alex Schryvers, the 2009-2010 recipient of the Donald and Jean Cleveland – Willamette Valley Section Named Scholarship.
Alex is attending Lane Community College in the Welding Technology program.

District Named Scholarship Program

Scholarships sponsored by AWS Districts and local companies to support students in their communities.

Congratulations to William J. Ebert, the 2009-2010 recipient of the Ed Cable-BUG-O District 7 Named Scholarship.



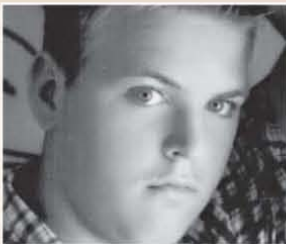
"I am honored to receive the Ed Cable – BUG-O District 3 Named Scholarship. I thank those who have funded this award and thank them for helping me further my education. I would also like to thank the AWS for this award, and promoting education in the welding field."
*Pennsylvania College of Technology
Welding and Fabrication
Engineering Technology*

Congratulations to Bryan L. DeCorte, the 2009-2010 recipient of the Detroit Resistance Welding – District 11 Named Scholarship.



"I am very thankful for the scholarship and recognition for my work in the Resistance Welding field. I have spent some time on RW experiments/projects both at school (Ferris State University) and further for the last two summers in Detroit at the RES Labs. I have also been blessed with input from my father who has 29 years in the RW industry. It is a special process that while not nearly as popular as others still has a prominent place in many industrial applications."
*Ferris State University
Welding Engineering Technology*

Congratulations to Bradley Feight, the 2009-2010 recipient of the Ed Cable-BUG-O District 7 Named Scholarship.



"I would just like to say that it is a privilege to be awarded the Ed Cable-BUG-O District 7 Named Scholarship. I would like to thank everyone who provided funding to make this scholarship possible, and to thank my family, friends, and professors for pushing me to do my best."
*Pennsylvania College of Technology
Welding and Fabrication
Engineering Technology*

Congratulations to Corey T. Simone, the 2009-2010 recipient of the Detroit Arc Welding – District 11 Named Scholarship.



"I would like to thank the AWS Foundation for supporting my future career in the welding industry. I have come to know the AWS Foundation is an important part of the Ferris State College of Technology. The District 11 Scholarship will be a great help as I finish my welding education and pursue a career as a welding engineer."
*Ferris State University
Welding Engineering Technology*

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



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ALUMINUM

Q&A

Q: After reading your Aluminum Q&A column in the June 2009 *Welding Journal* about design considerations of welded aluminum structures, I have a question related to the section on the reduction in strength of the base material after welding. It is apparent from the table in your article that the loss of strength in the heat-affected zone (HAZ) after arc welding, particularly in the heat-treatable alloys, can be significant. What I would like to know is what, if anything, can be done after welding to regain this lost strength and return the material to its original condition?

A: You are correct that the reduction in strength after arc welding can be significant in both the heat-treatable and nonheat-treatable alloys depending on the particular alloy and its original temper condition prior to welding.

In order to consider the possibility of returning a welded base alloy to its original condition, we need to evaluate both the effect of arc welding on the various tempers and the options available for postweld treatment.

The Effect of Arc Welding on Material Temper

The amount of heat developed in a base material during arc welding is generally sufficient to reduce the strength of the temper condition of the base alloy. The one exception to this is that no reduction in strength will be experienced in either a heat-treatable or nonheat-treatable aluminum alloy when welded in the "O"

temper. The "O" temper is the annealed condition and is sometimes referred to as dead soft. Unfortunately, this fact is of little practical consequence because owing to its low strength "O" temper material is seldom chosen for structural applications. The effect of welding on the various tempers is different when considering the heat-treatable and nonheat-treatable alloys, so we will evaluate them independently. Figure 1 shows the effects of arc welding on both the heat-treatable and nonheat-treatable alloys.

Nonheat-Treatable Alloys

The strength of nonheat-treatable alloys is initially produced by alloying the aluminum with additions of other elements. These alloys consist of the pure aluminum alloys (1xxx series), manganese alloys (3xxx series), silicon alloys (4xxx series), and magnesium alloys (5xxx series). A further increase in the strength of these alloys is obtained through various degrees of cold working or strain hardening. Strain hardening is a process used to increase the strength of aluminum alloys that cannot be strengthened by heat treatment. Strain hardening is accomplished through change of shape by the application of mechanical energy. As this physical deformation progresses (typically through rolling or drawing), it produces an elongation of the material's grain structure in the direction of working that provides a preferred grain orientation, high level of internal stress, and resultant increase in strength.

When these strain-hardened alloys are

heated during arc welding, recrystallization takes place in the HAZ, work hardened and deformed crystals are replaced by new strain-free crystals, and the base material within the HAZ is transformed into the annealed (dead soft) condition. This transformation is unavoidable in the nonheat-treatable alloys; regardless of the original prewelded temper, the postweld condition of the HAZ will always be annealed.

Heat-Treatable Alloys

The initial strength of heat-treatable alloys is also produced by the addition of alloying elements to pure aluminum. These elements include copper (2xxx series), magnesium and silicon, which are able to form the compound magnesium silicide (6xxx series), and zinc (7xxx series). When present in a given alloy, singly or in various combinations, these elements exhibit increasing solid solubility in aluminum as the temperature increases. Because of this reaction, it is possible to produce significant additional strengthening to the heat-treatable alloys by subjecting them to an elevated thermal treatment, quenching, and, when applicable, precipitation heat-treatment known also as artificial aging.

In solution heat treatment, the material is heated to temperatures around 900° to 1000°F, depending upon the alloy. This causes the alloying elements within the material to go into solid solution. Immediately following this heating process, the material is rapidly quenched, usually in water; this freezes or traps the alloying elements in so-

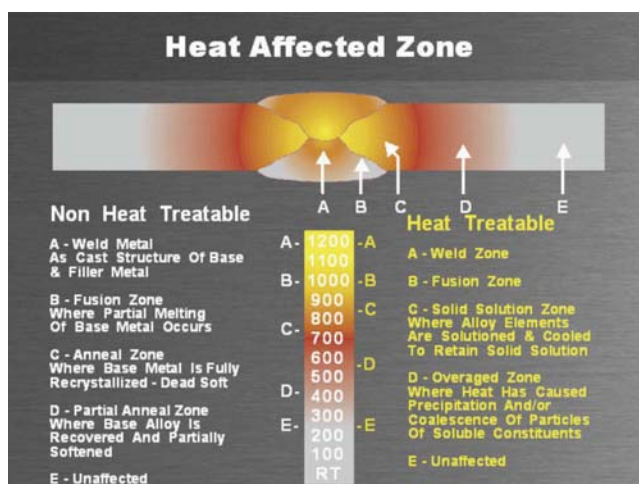


Fig. 1 — This diagram displays the effects of arc welding on both the heat-treatable and nonheat-treatable alloys.

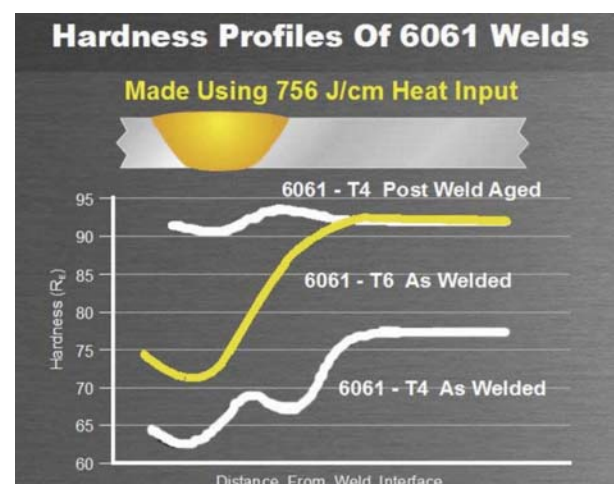


Fig. 2 — Three examples of strength levels in this graph include 6061-T4 and 6061-T6 in the as-welded conditions, and 6061-T4 in the postweld aged only condition. As shown, the 6061-T4 postweld aged condition exhibits excellent recovery of strength within the HAZ along with typical -T6 properties throughout the structure.

lution. A material in this finished condition is said to be "solution heat treated and naturally aged" and given the -T4 designation.

Precipitation heat treatment, also known as artificial aging, is often used after solution heat treatment. This involves heating the material for a controlled time (8 to 18 h) at a lower temperature (around 250° to 500°F) depending upon the alloy. This process, used after solution heat treatment, both increases strength and stabilizes the material. A material in this finished condition is said to be "solution heat treated and artificially aged" and given the -T6 designation.

When these heat-treatable alloys are heated during arc welding, they are typically not heated for a sufficient period of time to fully anneal their structure. However, they are usually subjected to sufficient heating to reduce their strength considerably.

While the duration of the heating from the arc welding process is normally insufficient to fully anneal the base material in the HAZ, it is sufficient to partially precipitate alloying elements out of solution. This will typically result in the base alloy HAZ becoming overaged and the appropriate loss of strength associated with this process. An example of this reduction in ultimate tensile strength can be appreciated when considering the 6061-T6 base alloy in the prewelded (45 ksi), postweld (24 ksi), and annealed (18 ksi) conditions.

Options Available for Postweld Treatment

Nonheat-Treatable Alloys

Unfortunately, in the case of the non-heat-treatable aluminum alloys, there is no practical way to rework the annealed HAZ to its original strain-hardened condition. It is customary, therefore, when using these alloys to design around the as-welded strength.

Heat-Treatable Alloys

In the case of the heat-treatable alloys, there are procedures that can be used to return the prewelded strength to the HAZ.

The -T6 Temper

In order to fully recover the original prewelded strength of a material that was in a -T6 temper prior to welding, a postweld heat treatment similar to that described above for solution heat treatment and artificial aging is required. It can be appreciated that in many situations, heating a welded structure to around 1000°F followed by quenching in water and reheating to around 350°F for extended periods may not be entirely practical. This type of postweld heat treatment is not

suited to localized application; the entire structure is typically required to be subjected to the procedure. When we consider the cost of conducting such postweld heat treatment, size limitations, and the possibility of producing residual stress and/or distortion into the structure, it is not surprising that we do not see this type of heat treatment conducted extensively in the aluminum welding fabrication industry.

However, this type of postweld heat treatment is conducted for some specialized applications. If full solution heat treatment and artificial aging is to be performed on a welded structure, it is advisable to consider the use of a heat-treatable filler metal. In the case of 6061-T6, a suitable heat-treatable filler metal would be Alloy 4643. A small addition of magnesium to this silicon-based alloy allows it to produce magnesium silicide and respond to this form of heat treatment. Using the correct filler metal and conducting the appropriate postweld heat treatment can return an arc welded component that was originally in the -T6 condition prior to welding to its original strength.

The -T4 Temper

One other option that is sometimes seen as a more practical method of postweld heat treatment for the heat-treatable aluminum alloys is to choose a base alloy in the -T4 temper. In the -T4 temper, the base material has been solution heat treated and naturally aged; no artificial aging has been performed on this material. The typical ultimate tensile strength of 6061-T4 is 35 ksi as compared with 45 ksi of 6061-T6. After arc welding on the 6061-T4 material, a considerable loss in strength is seen in the HAZ. However, the postweld heat treatment required in order for the 6061-T4 material to regain substantial strength in the HAZ (as well as the entire structure) can be far less complex than that required for 6061-T6.

Figure 2 shows the following three ex-

amples of strength levels: 6061-T4 and 6061-T6 in the as-welded conditions, and 6061-T4 in the postweld aged only condition. As can be seen, the 6061-T4 postweld aged condition exhibits excellent recovery of strength within the HAZ along with typical -T6 properties throughout the structure. The benefits associated with this processing are related to the fact that no high temperature solution heat treatment and quenching are required, only more moderate lower temperature artificial aging. This method of postweld processing is carried out by some manufacturers as a successful alternative to full solution heat treatment and artificial aging.

Conclusion

So in answer to the question: What, if anything, can be done after arc welding to regain lost strength and return aluminum alloys to their original unwelded condition?

For the nonheat-treatable alloys, no practical method of postweld processing is available. For the heat-treatable alloys, variations of postweld heat treatment are available for consideration. However, after explaining these methods, I feel it is reasonable to say that in reality the majority of the heat-treatable alloys used for structural welding applications are used in the same way as the nonheat-treatable alloys in the as-welded condition. ♦

TONY ANDERSON is corporate technical training manager for ESAB North America and coordinates specialized training in aluminum welding technology for AlcoTec Wire Corporation. He is a Registered Chartered Engineer and holds numerous positions on AWS technical committees. He is chairman of the Aluminum Association Technical Advisory Committee for Welding and author of the book Welding Aluminum Questions and Answers currently available from the AWS. Questions may be sent to Tony Anderson c/o Welding Journal, 550 NW LeJeune Rd., Miami, FL 33126, or via e-mail at tanderson@esab.com.

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TECHNOLOGY

Optimizing Welding and Brazing Processes with New Electrode Materials

Bercoweld® S2, a new alloy for welding electrodes, is based on the key qualities of a widely used copper-based alloy for joining zinc-coated steel sheets. This copper brazing wire provides optimized flowing properties, better ability to bridge root openings, and higher processing speed.

Initially, automotive manufacturers and their suppliers applied a copper-plated steel wire to join zinc-coated steel sheets, but it was soon replaced by a copper-based wire of the SG-CuSi3Mn type. The reasons for switching were that the copper-based alloy preserves the zinc coating of the sheets, minimizes reworking on the car body, and saves time as well as costs.

The Previous Copper-Based Alloy Electrode

The SG-CuSi3Mn electrode designated bercoweld® S3 from Berkenhoff GmbH, Germany, is a copper-based alloy for joining zinc-coated sheets. It is optimized to automotive engineering standards and has a controlled silicon content. This means that the electrode material and, subsequently, the joint is more ductile and has a lower tendency to embrittle. A Si content below 3% also improves the phosphate and paint adhesion.

The alloy is used for all joining processes from standard gas metal arc welding to laser and plasma brazing. Electrodes with 0.8- to 1.6-mm-diameter wire are available. Typical applications in car body construction are joining roof/side body parts, tailgates, sealing strips, crash boxes, and plug, slot, and lap welds — Fig. 1A–C.

New Trends in Car Body Construction

High-temperature brazing with the S3 electrodes has proved successful for many years. However, there is always the user's request for improvement. Because joining zinc-coated steel sheets is an essential step in car body construction, it seems reasonable to tailor developments coinciding with modern technical and economical trends.

First, there is competitive pressure among the different material groups to be noted: It is no longer a given that a car body is made of steel. The steel producers are working to develop new materials such as higher-strength steels with improved crash properties. Current production processes such as hot forming are

BY UWE BERGER AND ROMAN MEINHARDT

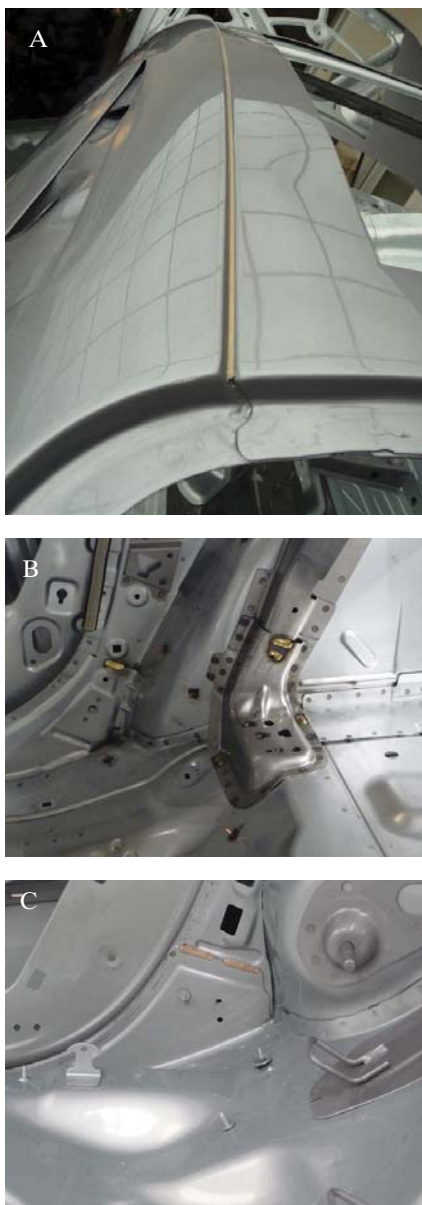


Fig. 1 — Car bodies can be joined with the S3 electrode. Some examples include the following: A — Roof joint; B — braze joint; and C — lap weld.

used to match properties of the respective components perfectly to requirements. At the same time, demands on quality and visual appearance are constantly increasing. The vehicle body must have a perfect finish, while at the same time, the pressure on manufacturers to reduce costs is steadily mounting.

Objective: Improved Joining

In relation to the joining processes, this means the filler metal must be able to bridge wide root openings when, for ex-

ample, components of differing dimensional accuracy have to be joined. Furthermore, it is important parts can be joined at a high process speed for cost and time savings.

Bearing this in mind, Berkenhoff's research and development team has worked to make improvements to the electrodes. This new alloy composition of the brazing wire electrode, bercoweld® S2, also known as COMAS, achieves better joining results.

The benefits include optimized flow properties, good bridging/adhesion of root openings, and a high processing speed along with corrosion resistance — Fig. 2A, B.

Thanks to its improved flowing properties, the alloy produces material closure joints even when bridging wide root openings, and offers improved corrosion resistance and adhesion to the zinc-coated steel.

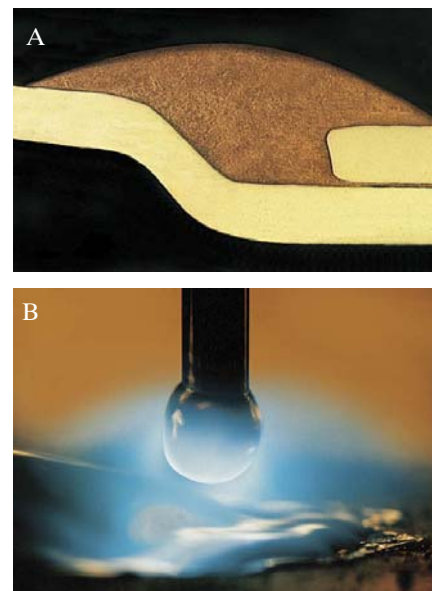


Fig. 2 — The new alloy offers optimized flow properties and high processing speeds. A — Micrograph with a magnification of about 25:1 showing an S2 gas metal arc brazed lap joint; B — photo displaying the high-speed gas metal arc brazing process.

There is a low tendency to porosity, and the formation of spatter is reduced. A cross-section comparison shows the improvement of these properties — Fig. 3A–D.

Suitable for All Joining Methods

The electrode material is suitable for all standard brazing processes, even for joining high-strength steels, which has become more frequently utilized in crash box

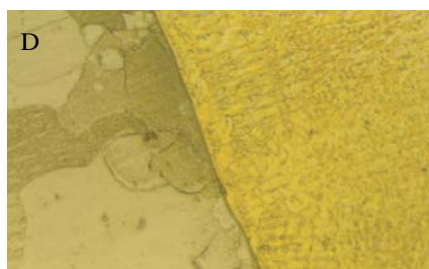
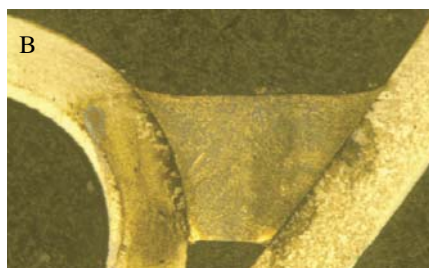
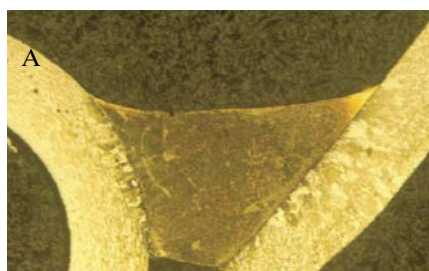


Fig. 3 — Cross-section comparison of gas metal arc brazed, T-joint microstructures with a 25- $\times$ magnification for bercoweld® S3 (A) vs. S2 (B), and a brazed tailgate surface combination featuring S3 (C) vs. S2 (D) using 500- $\times$ magnification.

and side member applications. In addition, the new alloy can be applied wherever Cu-based wire electrodes have been used. Users need only to insert the wire and make minimal changes to the welding inverter parameters.

Presently, bercoweld® S2 is being used by an automotive manufacturer and a car body contract manufacturer. Their experiences have shown the key qualities of the previous alloy are maintained. ♦

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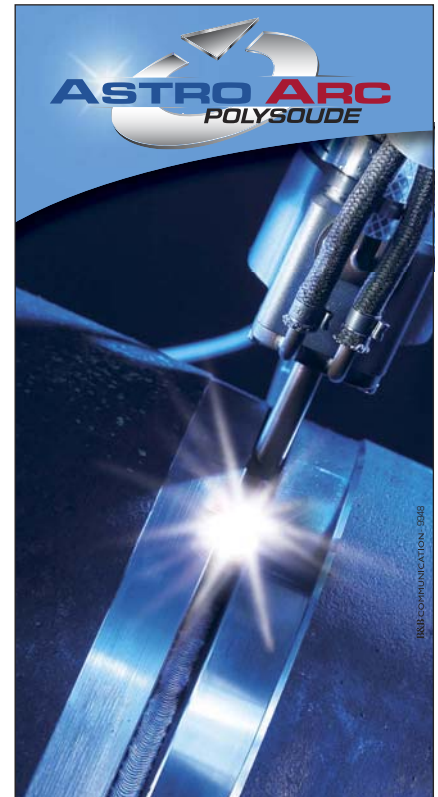
The Model KM14SC mitre saw uses a 14-in. carbide-tipped blade to produce clean cuts without burrs or heat genera-

tion. This enables precise dry cutting of thin-wall mild steel and aluminum, as well as 1/4-in. angle, pipe, and structural steel. Plus, it features heavy cast iron construction, a 1300 rev/min spindle speed, 1-in. arbor, sealed ball bearings, dual V-belt drive, dual camlock vises, and a safety guard that retracts when cutting. Capacities are 4 1/2 in. at 90 deg and 4 x 3.5 in. at 45 deg.

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Aluminum's Role in Welded Fabrications

This article discusses some of the many applications of aluminum within the welding fabrication industry and why its use has risen in these industries

BY TONY ANDERSON

Aluminum became an economically viable competitor to steel within the engineering environment as recently as the end of the 19th century. The electrolytic reduction of alumina (Al_2O_3) dissolved in molten cryolite was independently developed by Charles Hall in Ohio and Paul Heroult in France in 1886.

Perhaps the three most important events to drive the development of this new material were the introduction of the first internal combustion engine-powered vehicles, electrification that required immense quantities of lightweight conductive material for long distance transmission of electricity, and the emergence of the aircraft industry.

The first commercial applications for aluminum were items such as kitchen utensils — serving trays, pots, pans, ladles, and teapots. In time, aluminum grew in diversity of applications to the extent that virtually every aspect of modern life was directly or indirectly affected by its use.

Today, aluminum's unique characteristics of light weight, high strength, high toughness, extreme temperature capability, versatility of extruding, excellent corrosion resistance, and recycling capabilities make it a popular material choice by engineers and designers for a variety of welding fabrication applications.

Automotive Industry

Perhaps the most dynamic advancement of aluminum welding fabrication today is within the automotive industry. Promoted primarily through environmental issues such as increased fuel efficiency, corrosion resistance, and recycling, we are seeing more and more components manufactured from aluminum appearing



Fig. 1 — A Corvette 206 shown as a welded aluminum frame and also as a completed vehicle.

within the average automobile.

The development of the aluminum automobile frame (Fig. 1) and major structural components fabricated entirely from aluminum such as engine cradles, front and rear suspension frames, drive shafts, and wheels are complementing the more traditional nonstructural components such as heat exchangers, radiators, and air-conditioning units. Many of these welded structural components are manufactured using 6xxx series base alloys, making use of this material's ability to economically produce complex extruded shapes that are joined with the gas metal arc welding (GMAW) process.

Another issue — besides the fuel efficiency associated with the use of aluminum within this industry — is safety. Aluminum's basic physical characteristics lend themselves to creating automobiles

that not only perform better in a collision, but can actually help to prevent crashes. Aluminum's strength-to-weight ratio allows engineers to construct larger vehicle crash zones for better energy absorption — Fig. 2. Aluminum structures can be designed to absorb the same energy as steel at only 55% of the weight. This weight saving relates to less kinetic energy being absorbed in a collision. Aluminum-intensive vehicles provide better handling and braking capability, improving their ability to avoid crashes. A vehicle made of conventional materials weighing 3300 lb traveling at 60 mph requires 213 ft to stop. Given the same drivetrain, an equally sized aluminum-intensive vehicle would weigh 2000 lb and could stop in 135 ft. Similar improvements are seen in acceleration abilities, when a little extra speed could make the difference in avoiding a collision. Welding procedures used within the auto industry will vary, but typically makes use of robotics wherever possible. Fabrication of thin-wall heat exchangers make use of 4047 filler metal, which contains 11 to 13% silicon and provides exceptional fluidity. This helps to reduce leakage rates and improve productivity. The thicker material structural applications within this industry are often able to make use of filler Alloy 5356 for its improved strength and impact properties.

Shipbuilding

Fast ferry projects have advanced the use of aluminum in shipbuilding through development of a new concept in marine transportation. Shipping companies are looking at high-speed aluminum ferries as a means of fast, efficient, low-maintenance transport. The term "fast ferries"

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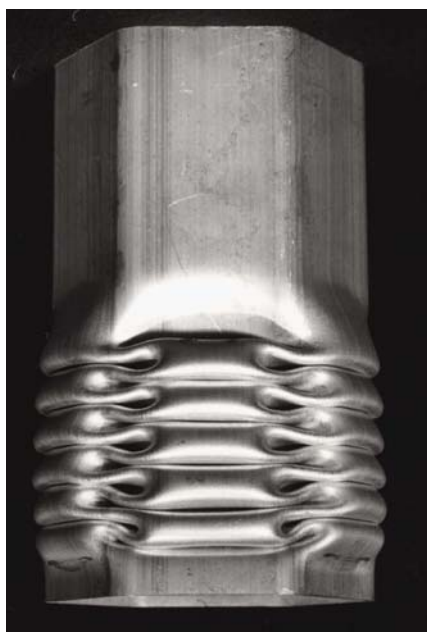


Fig. 2 — During a car crash, aluminum structures fold like an accordion to absorb energy and protect the vehicle passengers from destructive crash forces. Pound for pound, aluminum can be up to two-and-a-half times stronger than steel, and it can absorb twice as much energy. Structures can be designed to fold during a crash in a predictable manner. (Photo courtesy of Aluminum Association.)

applies to hydrofoils, wave-piercing catamarans, and both mono-hulled and multi-hulled vessels built to carry large payloads of passengers and cargo at high speeds. Typically, these vessels are around 100–130 ft in length and travel at 30–35 knots (35–40 mph). Aluminum-intensive mega-ferries are massive vessels measuring approximately 300 ft in length and carry up to 700 passengers and 150 cars.

Quadrimarans are among the newest marine transportation innovations. Measuring 180 ft in length, newer versions are designed to carry 600 passengers. These fast ferries can regularly travel at 60 knots (69 mph), but they could achieve speeds of up to 110 knots (126.5 mph). The concept of extremely light and fast marine transportation has been recognized by the military. A number of these types of vessels are being utilized by the U.S. Army — Fig. 3. For these applications, the ship-building industry has made use of the high-strength magnesium base metals such as 5083 and 5383 welded with 5183 and 5556 filler metals in order to obtain the minimum tensile strength requirements as specified in the appropriate welding codes. Often argon/helium shielding gas mixes are used when gas metal arc welding to reduce porosity and obtain broader and deeper penetration for these high-quality welds. Aluminum's unique combination of lightweight, high-strength



Fig. 3 — A U.S. Army Theater Support Vessel (TSV). The TSV may change the way the U.S. Army gets to the fight. They will allow the Army to quickly deliver combat-ready soldiers with their equipment and supplies. Future high-speed vessels promise to transport units within hours instead of days. (Photo courtesy of Incat.)



Fig. 4 — Aluminum bicycle frame manufactured from heat-treatable aluminum base metal. Welded with a heat-treatable aluminum filler alloy and subjected to postweld heat treatment in order to return the aluminum alloy to its original unwelded strength. (Photo courtesy of Cannondale.)

and corrosion-resistance characteristics make these high-speed developing marine applications possible.

Recreation and Sporting Equipment

The advancement of high-tech sporting equipment and the increased use of high-strength heat-treatable aluminum alloys such as the 7xxx series have revolutionized this industry. Many of the latest

designs have incorporated this lightweight, high-performance aluminum material. Bicycle frames, baseball bats, golf clubs, sleds, and snowmobiles are some of the many products within this industry dependent on aluminum alloys today — Fig. 4. This industry, with its thin wall joining and complex heat treatment, has promoted the development and use of specialized filler alloys designed to respond to thermal treatment and welding techniques and equipment designed to meet their strength and cosmetic requirements.



Fig. 5 — Liquefied natural gas (LNG) tanker with four large welded aluminum spheres (tanks). Many materials when subjected to these very low temperatures undergo changes in their physical structure that severely limit their usefulness in cryogenic applications. Some metals, for example many steels, become extremely brittle. Aluminum alloys, however, have been demonstrated to have an unusual ability to maintain their ductility and resistance to shock loading at extremely low temperatures approaching absolute zero -459°F (-273°C). As temperature decreases below room temperature, aluminum's tensile and yield strengths actually increase as the temperature decreases, and the ductility and toughness of most alloys increase as well. Even at the lowest test temperatures available, in liquid helium at -452°F (-273°C), strength remains high and ductility and toughness remain well above values for most alloys at room temperature.



Fig. 6 — The advanced amphibious assault vehicle (AAAV) uses welded aluminum to produce a lightweight, high-speed vehicle that is effective on land and water.

Transportation and Containers

For similar reasons as the automotive industry, transportation vehicles are adopting more aluminum. Heated rail cars with line heaters and steam lines make use of aluminum base Alloy 5454, welded with filler metal 5554 for their strength and high-temperature characteristics. Cryogenic tanks are manufactured from base metal 5083, welded with filler metal 5183 for their high strength at low temperature characteristics — Fig. 5. Truck bodies and panels are manufactured from 5052, 5086, 5083, and 6061 and often welded with filler metals 5356, 5183, and 5556 for their strength characteristics.

Defense and Aerospace

These industries use high-strength 5xxx series (Al-Mg) nonheat-treatable base alloys for some applications, but also make use of some of the more specialized heat-treatable aluminum alloys with superior mechanical properties. Aluminum base alloys are used for their impact strength and strength-to-weight ratio — Fig. 6. Alloy 5083 and 7039 base materials are welded with 5356 filler. Missiles are constructed of 2019 base metal welded with 4145 and 2219 base metal welded with 2319 filler.

Perhaps the most exotic aluminum alloys, with exceptional strength over a wide range of operating temperatures, are used in the aerospace industry. Some of these alloys are 2219, 2014, 2090, 2024, and 7075. These base materials are typically used in specialized high-performance applications and have their own welding characteristics and associated problems, which may require special considerations when joining.

The relatively recent introduction and development of friction stir welding (FSW) has helped to remove restrictions associated with the arc welding of some of the aluminum alloys used within this industry. Various 2xxx and 7xxx series alloys that are recognized as being unsuitable for arc welding are now welded with the FSW process.

The use of aluminum continues to grow within the welding fabrication industry in both size and complexity, and with it the need for aluminum filler metals that will meet these needs, the advancement of welding equipment specifically designed for welding aluminum, and the requirement for resources that can provide industry with technical support. ♦

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An approach used to analyze AlBeMet® 162 structure brazed with the AWS BAlSi-4 filler metal is provided

BY YURY FLOM, LEN WANG, MOLLIE M. POWELL, MATTHEW A. SOFFA, AND MONICA L. ROMMEL

Evaluation of strength margins in structural components is a normal practice used in the design of metallic and composite structures. Mechanical, welded, or adhesively bonded joints in such structures are routinely assessed for their load-carrying capabilities in accordance with widely accepted engineering analysis techniques and failure criteria (Refs. 1–5). Brazed joints, however, seem to be an exception. Literature searches for analytical methods of the evaluation with the strength or margin of safety (MS) of complex brazed joints produced no satisfactory results. This is particularly true when the brazed joints are subjected to multiaxial loads.

Although this article does not explore the reasons for a lack of books or guides on structural analysis of brazed joints, it would be beneficial to mention several factors commonly identified by designers as stumbling blocks precluding them from a comprehensive analysis of the brazed joints. These factors are as follows:

- Lack of knowledge of the mechanical properties of the brazed joint filler metal interlayer;
- Uncertainty of how to use these properties even if they, somehow, are made available;
- Inadequate attention to the analysis of the brazed joints from the structural professional community and academia as compared with other methods of assembly such as welding, adhesive bonding, or fastening;
- Lack of techniques to account for defects commonly found in brazed joints like incomplete fill or trapped salts; and
- Nonstandard joint configurations

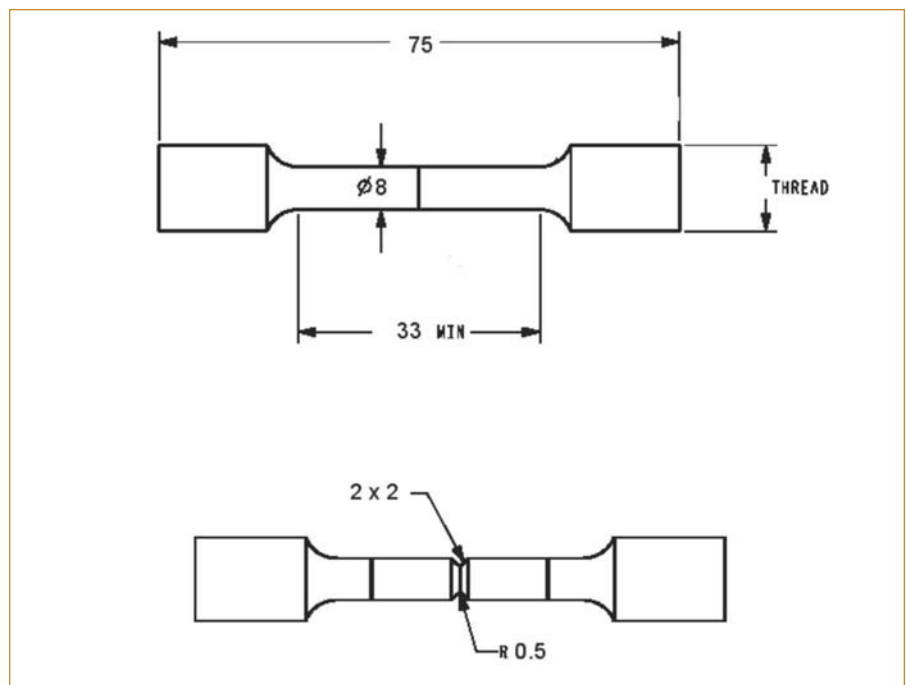


Fig. 1 — Smooth (top) and notched (bottom) brazed butt joint tensile specimens. All dimensions are in mm. More detailed information on specimen geometry is provided in Ref. 7.

that have not been tested to validate analytical models.

It is quite clear that these factors offer challenging problems to metallurgical, materials, and mechanical engineers in terms of understanding the interaction between the filler and the base metals, experimental techniques of measuring mechanical properties of the joints, as well as the appropriate interpretation of the results. This article deals with the issues that fall within the second factor

mentioned previously.

Many challenges exist in the analytical modeling of the braze joint. The foremost difficulty is that braze joints are normally very thin (less than a hundred microns thick) compared to their lateral dimension. This disproportionally large aspect ratio not only makes the analytical calculation of the stress and strain incredibly difficult but also, most importantly, changes the fundamentals of the failure mechanism of a ductile material. The

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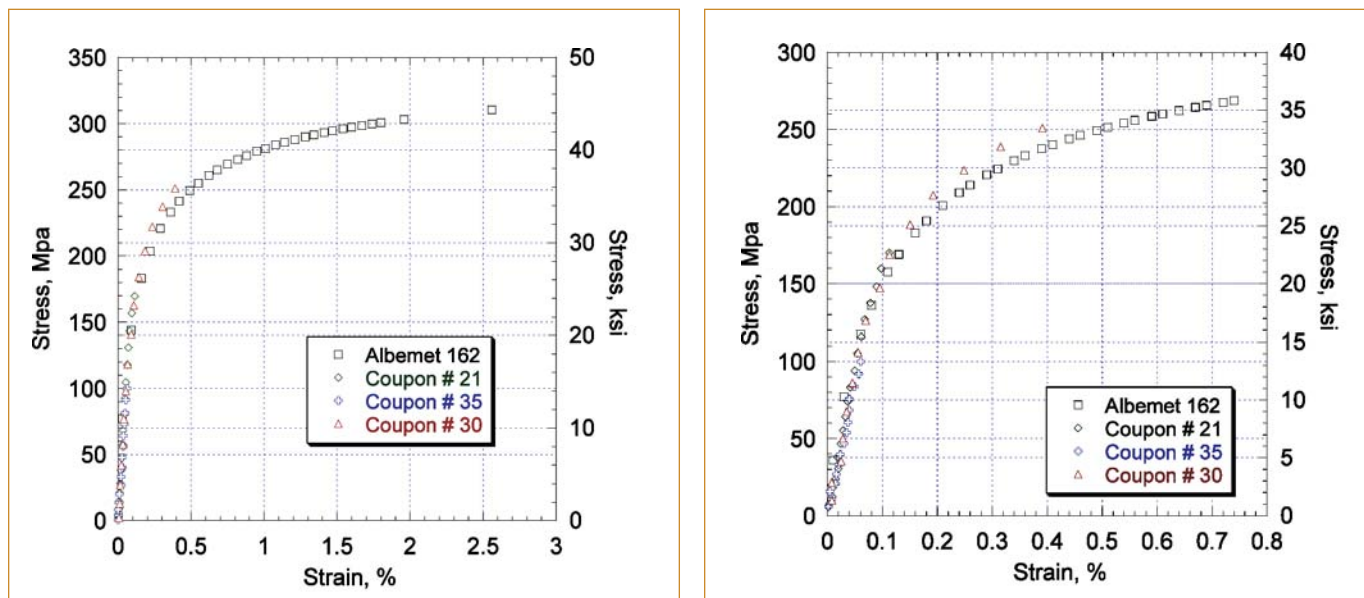


Fig. 2 — Examples of typical stress-strain curves from tensile tests of brazed butt joint specimens (only three coupons are shown for clarity) compared with the base metal AlBeMet® 162. The left plot shows the strain range, and the right plot shows the initial portion of the test.

Table 1 — Tensile Test Results, MPA (ksi)

Specimen	Min σ_{TUS}	Max σ_{TUS}	Avg σ_{TUS}	A-basis σ_{TUS}
Smooth	104 (15.1)	255 (37)	185 (26.9)	86
Notched	105 (15.2)	221 (32)	180 (26.1)	(12.5)

extraordinarily large aspect ratio constrains the braze joint in such a way that only a nearly pure shear loading condition, such as lap shear, can be handled using a standard yielding and failure approach, such as the Tresca (maximum shear) and von Mises criteria. Under nearly pure shear loading, the filler metal will yield, undergo plastic deformation, and reach failure in the normal failure process of most ductile metals and alloys.

However, when loading braze joints in tension or compression, a totally different failure mechanism is involved. Taking the standard butt joint brazed specimens described in AWS C3.2, *Standard Method for Evaluating the Strength of Brazed Joints*, as an example, when the specimen is loaded in tension, the filler metal, which is the focus of the test, is no longer in the simple tensile loading condition. Large lateral tensile stress develops due

to the lateral constraint. The lateral tensile stress can be as high as ~90% of the axial tensile stress, depending on the property differences between the filler and base metals. Often, thermal stress exists due to the mismatch of coefficient of thermal expansion (CTE) between the base and filler metals; the lateral tensile stress can exceed the applied axial tensile stress. Under such a loading condition, the filler metal is actually under triaxial tensile loading. The filler metal will not yield except at the very edges. Often, the failure strength of the notched and smooth samples of such configuration are not much different, as will be shown by test results of the current study. When loading such a specimen in compression, the filler metal will basically be in hydrostatic compression. The filler metal will not undergo macroscopic plastic deformation prior to failure. Apparently,

under such conditions, the filler metal fails very differently compared to the homogenous tensile or lap shear specimens. Even for a very ductile filler metal, it fails in a quasibrittle manner. Finite element analysis (FEA) showed when the brazed butt joint is under tensile loading, overall shear and von Mises stresses are small in the filler metal (Ref. 6). The stress peaks at the edges of the joint cannot be reliably used as a failure indicator. Conventional yield and failure criterion, such as von Mises and Tresca criterions, can hardly be applied.

When braze joints are under complicated loading conditions, such as combined axial and lateral shear loads, this problem magnifies itself making the analytical prediction nearly impossible. Consequently, the logical approach in solving this problem is to find a failure criterion that combines the two major driving failure mechanisms and, at the same time, is suitable for practical use.

The purpose of this work is an attempt to develop a simple methodology enabling designers to estimate the safe operational range for the brazed joints under static multiaxial loads. In order to accomplish this task, the following approach was implemented:

- Establish brazed joint allowables by testing the standard test specimens described in the AWS C3.2 specification

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(Ref. 7) under near-pure shear and tensile loads. As explained above, the tensile test of braze joint measures the dilatational (volume change, see Ref. 8) tensile strength of the filler metal, not the simple tensile properties of the filler metal.

- Develop an interactive equation to account for the combined action of distortional shear and dilatational tensile loads.

- Verify the interactive equation by testing customized specimens subjected to multiaxial loads.

The brazed joints in this study were comprised of Brush Wellman AlBeMet® 162 (62% Be, 38% Al) metal matrix composite dip brazed with AWS BAISi-4 (Al, 12% Si) filler metal. This system was selected because of its importance in aerospace applications.

Procedure

Tensile Allowables

Tensile allowables were determined from the tensile tests of the standard brazed butt joint specimens described in AWS C3.2. In addition to the standard geometry, notched tensile specimens were also tested to determine the notch sensitivity of the AlBeMet® 162/BAISi-4 system. The results of the tests are summarized in Table 1. No significant difference in the failure loads was observed between the smooth and notched specimens. As mentioned above, this is not a surprise. Consequently, all values of failure load were pooled together to improve the statistical interpretation of the results. Forty specimens were tested. Figure 1 depicts the geometrical features of both types of specimens.

The failure loads were divided by the initial cross-sectional areas to obtain the ultimate tensile strength σ_{TUS} . A-basis is a statistical value of σ_{TUS} indicating that at least 99% of the population is expected to be equal or exceed this value with 95% confidence (Ref. 9). It was computed using the procedure described in Ref. 10. Typical stress-strain curves from the tensile tests are shown — Fig. 2.

Shear Allowables

Single lap shear test specimens per the AWS C3.2 standard were pull tested to determine the average shear strength of the brazed joints. The overlap length tested ranged from 1T to 3T, where T was the thickness of the base metal — Fig. 3. Only the 1T specimens failed in the braze. All

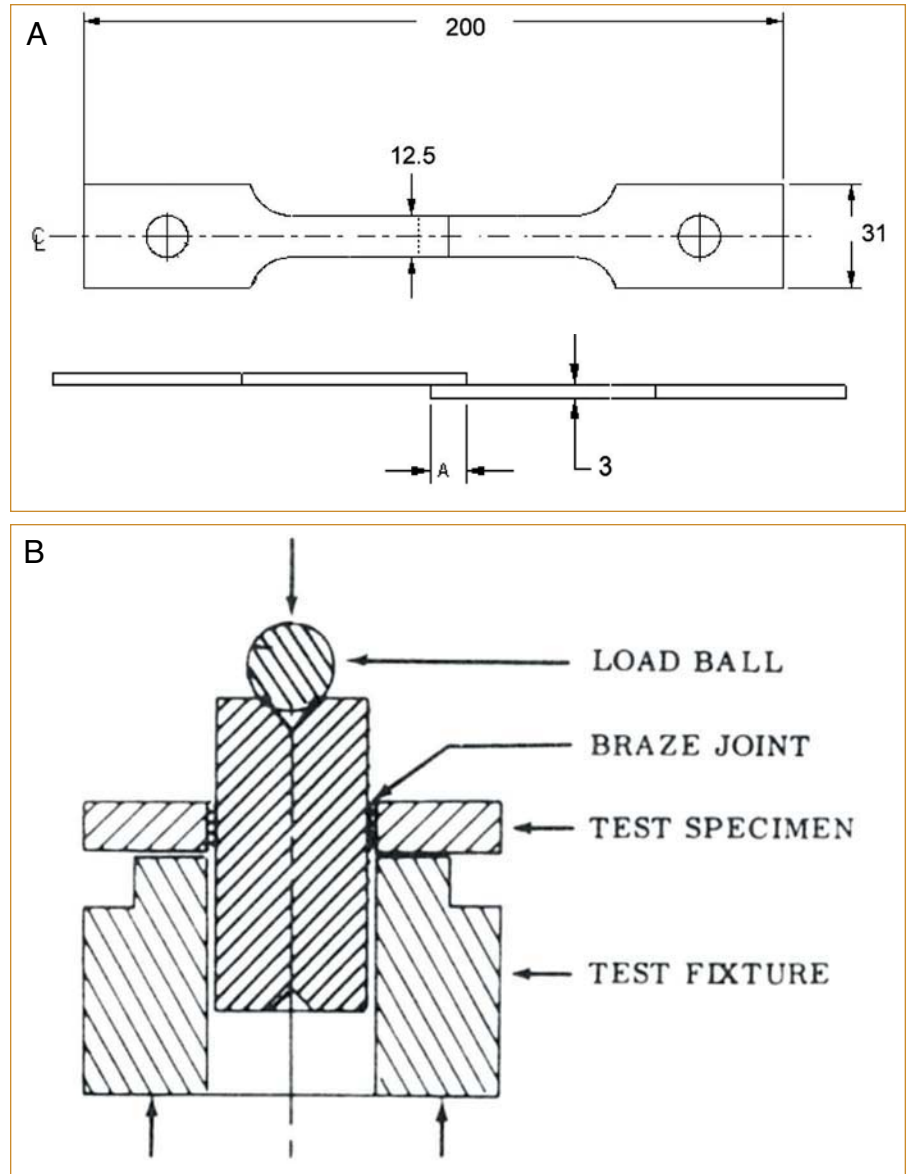


Fig. 3 — Single lap shear (A) and pin shear (B) specimen configurations. The pin shear specimen geometry has been used for a long time as process control and witness samples for dip brazing (Ref. 11). Dimensions are in mm.

Table 2 — Shear Test Results, MPA (ksi)

Specimen	Min τ_{sus}	Max τ_{sus}	Avg τ_{sus}	A-basis τ_{sus}
Lap shear, 1T	100 (14.5)	122 (17.7)	115 (16.7)	49
Pin shear	67 (9.7)	112 (16.2)	86 (12.4)	(7.1)

other specimens failed in the base metal away from the brazed joint.

Consequently, only 1T test results

were used for analysis. The ultimate shear strength τ_{sus} of each tested lap joint was determined by dividing the failure load by

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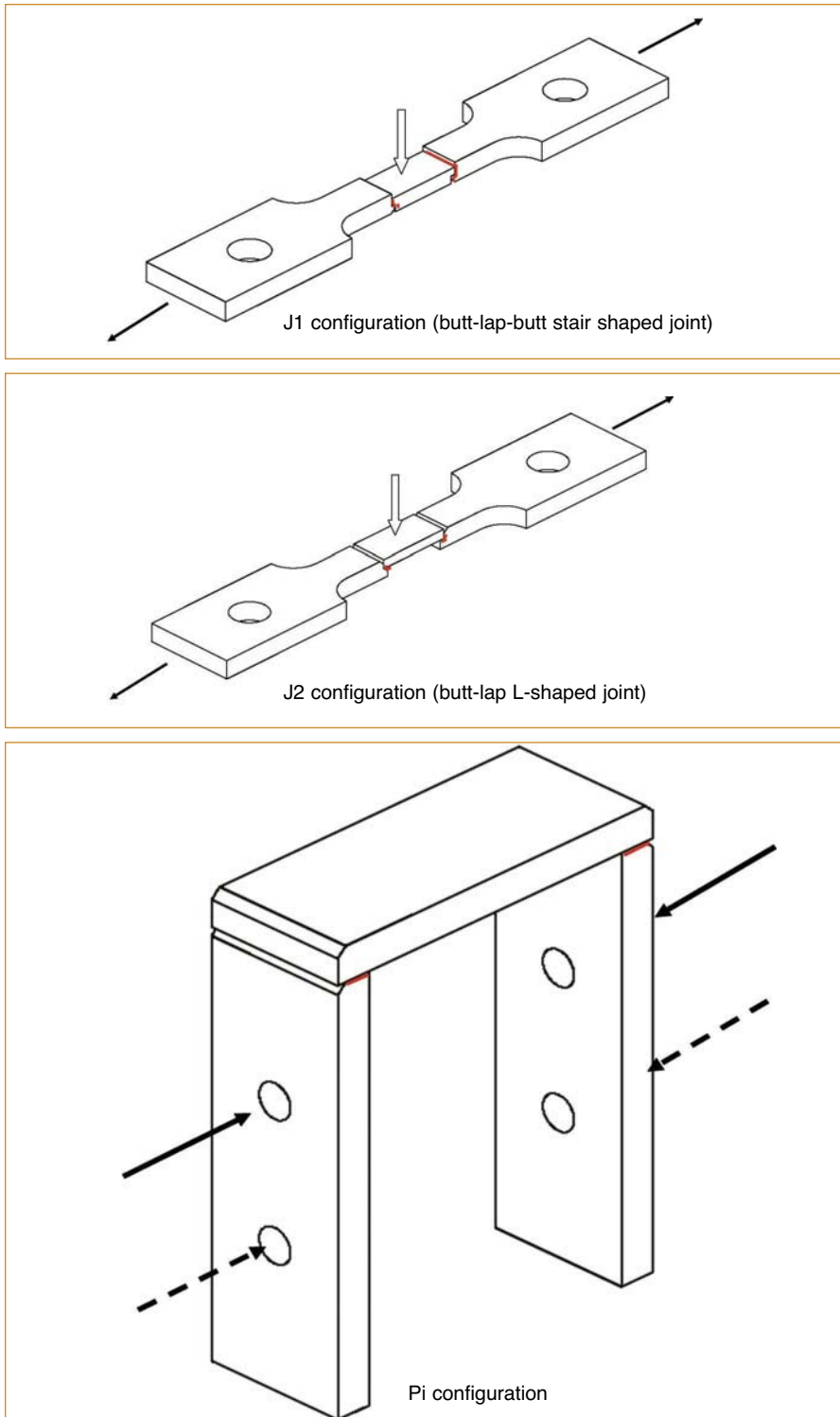


Fig. 4 — J1, J2, and Pi configurations of the validation brazed test specimens. Base metal thickness was 6 mm (0.025 in.). The arrows represent various loading conditions. Specimens J1 and J2 were tested in uniaxial loading (solid arrows) and combined, tension + bending (solid + block arrows), conditions. The Pi specimens were tested in compression either along the black arrows or dotted arrows. The distance between the first set of holes and top plate is 25 mm (1 in.), span or offset = 25 mm, and the distance from the top plate to the second set of holes is 50 mm (2 in.), span = 50 mm.

the total area of the overlap. Table 2 contains a summary of the lap shear test results. A total of 16 lap shear 1T specimens were tested. The historical data of testing pin shear specimens (a total of 46 specimens) brazed by the same vendor are also included in this table.

Failure Criteria and Interactive Equation

A number of interactive equations or curves have been developed in the past to predict failure in structures subjected to combined loads (Refs. 1–3). These equations had been used to estimate the conditions of structural failure in homogeneous and ductile materials. Although most interaction equations were obtained empirically, they are based on the ductile behavior of metals and can be traced to the Tresca and von Mises failure theories. Since the brazed joints do not behave as ductile homogeneous materials, with the exception of a “pure” shear condition, the conventional interaction equations do not apply to the highly restrained brazed joints subjected to multiaxial loading conditions. Consequently, highly constrained brazed joints should behave closer to the brittle materials.

It is instructive, therefore, to look at other failure criteria capable of predicting failures in brittle materials. There are at least two well known such criteria. One of them is the Coulomb-Mohr fracture criterion (Refs. 12, 13). According to this criterion, fracture takes place in a given plane in a material when a critical combination of normal σ and shear τ stresses has occurred. In its simplest form, this stress combination assumes a linear relationship, as shown below.

$$\tau + \mu\sigma = c \quad (1)$$

In this expression, μ and C are material-specific parameters. The other criterion is by Christensen (Ref. 13) who modified the Coulomb-Mohr criterion and offered a more general form of failure condition by considering a combined effect of dilatation/hydrostatic and distortional/von Mises components of stress. His failure theory provides a clearer physical meaning of the failure mechanism and better correlation with the experimental results for homogeneous materials (Ref. 13).

The authors have demonstrated (through unpublished work) that both

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failure criteria can be applied to the analysis of the braze joints to produce satisfactory results. While the Christenson failure criterion requires detailed FEA modeling of the braze joints, the Coulomb-Mohr failure criterion can be approximated by using mechanics of materials under the assumption that the normal stress applied to the brazed joint will result in triaxial tensile/compression stress of the same magnitude. This approach greatly simplified the analysis and made it possible to be readily applied to any braze joint without FEA modeling. The authors also found that while the Christensen failure criterion is likely more accurate, the Coulomb-Mohr failure criterion is more conservative. The following analysis is entirely based on Coulomb-Mohr failure criterion.

If a normal stress is zero, as in the case of pure shear, Equation 1 takes the form of the Tresca (maximum shear) criterion, such as $\tau = C = \tau_{SUS}$. It is easy to see that the parameter C is the ultimate shear strength of the material. With respect to the brazed joint, this is the maximum shear stress determined from the lap shear pull tests. Taking Equation 1 and dividing it by τ_{SUS} and rearranging the terms, the following is obtained:

$$\frac{\tau}{\tau_{SUS}} + \mu \frac{\sigma}{\tau_{SUS}} = 1 \quad (2)$$

Recall that during tensile testing of the brazed butt joint specimen, the conditions within the thin braze layer approach those of a triaxial tensile stress state (or hydrostatic tension). Under such conditions, shear stress within the brazed joint approaches 0. If $\tau = 0$, Equation 2 becomes

$$\mu \frac{\sigma}{\tau_{SUS}} = 1 \text{ or } \sigma = \frac{\tau_{SUS}}{\mu}$$

The fracture condition of the brazed butt joint tensile specimens is achieved

when the tensile stress pulling the joint apart equals the maximum dilatation stress that a brazed joint can withstand. To be consistent, it is called ultimate tensile stress σ_{TUS} of the brazed joint (not to be confused with σ_{TUS} of the filler metal tested in free form).

$$\sigma = \frac{\tau_{SUS}}{\mu} = \sigma_{TUS} \text{ or } \mu = \frac{\tau_{SUS}}{\sigma_{TUS}}$$

From this it is seen that the material property μ , with respect to the brazed

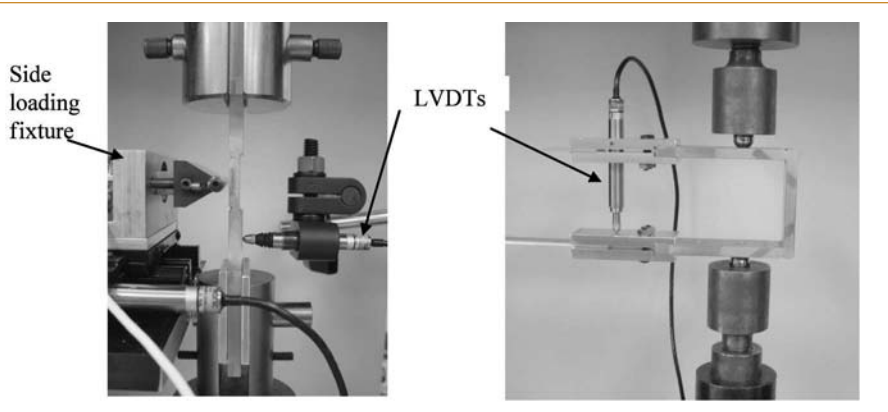


Fig. 5 — Photographs of the validation specimen test setups for J1 and J2 and Pi specimen configurations. Five specimens of each type were tested. Linear variable displacement transducers (LVDTs) recorded deflections of the specimens during the test.

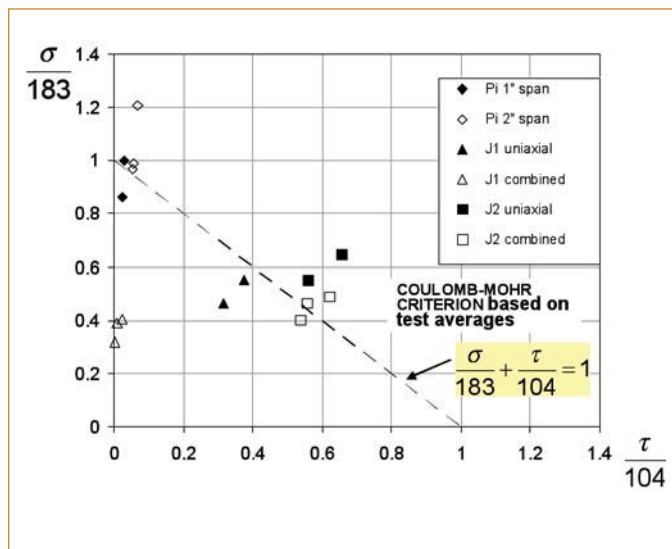


Fig. 6 — Test results of validation specimens Types J1, J2, and Pi tested to failure under uniaxial and combined loads. The three specimens (Δ) from the J1 category tested under combined loads failed at much lower stresses than predicted by the Coulomb-Mohr failure criterion based on the test averages (see Tables 1 and 2). Examination of the fracture surfaces of these specimens revealed almost an 80% lack of braze.

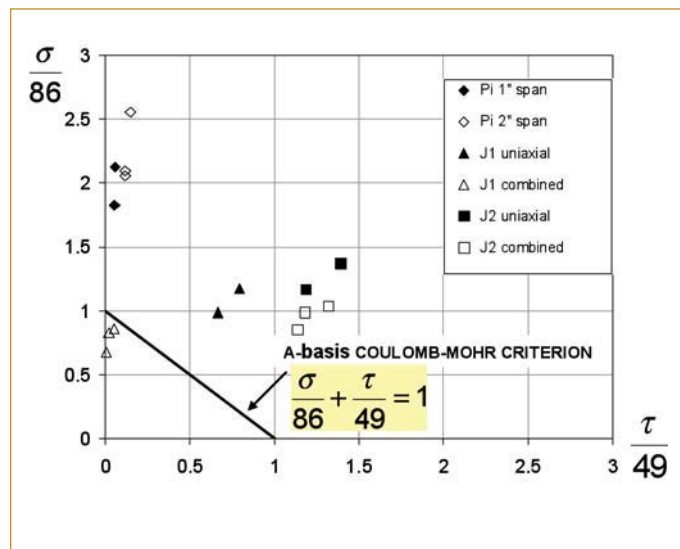


Fig. 7 — Same test results as in Fig. 6. Here, A-basis Coulomb-Mohr failure locus conservatively defines a “safe” zone where failures are not expected to occur. Again, the exception are the three specimens (Δ) from the J1 category showing the presence of a severe lack of braze.

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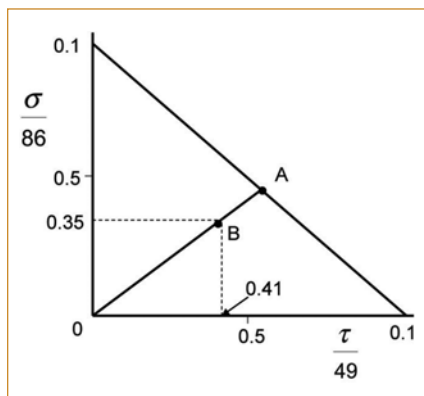


Fig. 8 — Point B represents an example of the brazed joint under a safe loading condition when $\sigma = 15$ MPa and $\tau = 10$ MPa; factor of safety (FS) = 2; and the margin of safety (MS) can be calculated graphically as $MS = OA / OB - 1$.

joints, is the ratio of ultimate shear stress to ultimate tensile stress of the brazed joint. Substituting μ with the ratio of the stresses into Equation 2 leads to the following modified Coulomb-Mohr expression:

$$\frac{\sigma}{\sigma_{TUS}} + \frac{\tau}{\tau_{sus}} = 1 \text{ or } R_{\sigma} + R_{\tau} = 1 \quad (3)$$

Where R_{σ} and R_{τ} are the tensile and shear stress ratios, respectively.

Validation

In order to test the validity of Equation 3 in predicting fracture in brazed joints, several types of specimens were fabricated using the same brazing process and vendor that produced the standard test specimens. Figure 4 shows the configurations of the validation test specimens and the directions of the applied test loads.

These specimens were tested under uniaxial and multiaxial loading conditions using specially designed and built loading fixtures. Figure 5 shows some of the test setups used to test the validation specimens. During each test, load vs. displacement records were obtained using load cells and linear variable displacement transducer (LVDT) outputs. Using the maximum failure loads obtained experimentally, each specimen type was analyzed using hand calculations based on beam theory and the principles of stress superposition. From these analyses, the stress ratios R_{σ} and R_{τ} were calculated for each tested validation specimen at

fracture loads using average and A-basis values for σ_{TUS} and τ_{sus} (Tables 1, 2). Figures 6 and 7 show the calculated stress ratios compared with the modified Coulomb-Mohr failure criteria. As one can see, all combinations of stress ratios that resulted in failure of all but three specimens lie outside the “safe” region below the A-basis Coulomb-Mohr failure locus.

Discussion

One of the main emphases of the current effort was to be conservative in analysis, testing, and data interpretation. Therefore, A-basis statistical requirements were applied to the test data that resulted in significant knock down of the ultimate tensile and shear stresses used to define the lower bound of the failure region.

This was done to better align the analysis of the brazed joints with the standard practice of using A- or B-basis values in the design of aerospace structures. On the other hand, the Coulomb-Mohr failure locus based on the test average values for σ_{TUS} and τ_{sus} (see Tables 1 and 2) is a better choice for predicting the actual stress ratios at failure obtained experimentally from testing the validation specimens — Fig. 6.

In addition to the expected test data scatter, there is another factor that needs to be taken into account when attempting to define the load-carrying capability of the brazed joints. This factor is related to our ability to detect the internal discontinuities in the brazed joints. Notice the three data points (“J1 combined”) located relatively far from the predicted failure locus as well as lying inside the “safe” zone defined — Fig. 7.

Examination of fracture surfaces of these validation specimens showed that in some cases up to 80% of the brazed joint areas were not brazed. Typically, most of the quality specifications allow lack of braze only up to 20% of the total area of the brazed joints. The quality of the rest of the validation specimens was not as bad, although the lack of braze was still considerably higher than the permissible 20%. However, based on the fact that all but three specimens failed outside the “safe” zone indicates that the conservatism exercised in this work was adequate to account for the presence of internal discontinuities well in excess of the 20% acceptable by most specifications.

Nondestructive examination of complex brazed assemblies is not trivial. Some

discontinuities may remain undetected. In order to account for undetected flaws, it is reasonable to further reduce the expected load-carrying capability of the brazed joints in critical brazed structures.

The MS of the brazed joint following the approach described in Ref. 4 can be determined. Ideally, if the sum of stress ratios in Equation 3 is less than 1, the brazed joint is safe. However, various uncertainties must be accounted for such as dimensional errors, heat treatment parameters, assembly stresses, and braze joint discontinuities (as discussed above) during the manufacturing and brazing processes. These uncertainties have a negative impact on the strength of the brazed structure. Consequently, it is a common practice to introduce a certain factor of safety (FS) to downgrade the load-carrying capability of the critical structure. With the inclusion of FS, Equation 3 can be expressed as $(R_{\sigma} + R_{\tau}) \times FS = 1$. Thus, MS can be estimated as follows:

$$MS = \frac{1}{(R_{\sigma} + R_{\tau}) \times FS} - 1 \quad (4)$$

For example, if the brazed joint is under the combined action of 15 MPa tensile and 10 MPa shear stresses and using the A-basis ultimate tensile and shear stresses determined in this study (86 and 49 MPa, respectively), and using FS = 2, the MS would be

$$MS = \frac{1}{\left(\frac{15}{86} + \frac{10}{49}\right) \cdot 2} - 1 = 32\%$$

Graphically, this is represented in Fig. 8.

Conclusions

The following conclusions can be drawn from this study:

1) The modified Coulomb-Mohr failure criterion can be used to predict failures in the brazed joints, especially when they are subjected to multiaxial loading conditions. The procedures developed in this study could be used to verify failure criterion in design and structural analysis of the critical brazed joints in other base/filler metal combinations.

2) The methodology of determining the allowables is based on testing standard brazed specimens, which is relatively simple and inexpensive.

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3) It is important to be conservative in determining the ultimate properties of the brazed joints when testing standard specimens. A quantity of test specimens selected for testing should be sufficient to allow for a good statistical interpretation.

4) The quality of brazed joints in the standard and validation specimens should be representative of the quality of production assemblies. An appropriate FS should be used to account for the uncertainties of the brazing process.

5) One of the main advantages of the proposed methodology is that it does not require a specific knowledge of the properties of the filler metal inside the brazed joint. The allowables are determined by testing standard tensile and lap shear specimens and used to construct the modified Coulomb-Mohr fracture line and evaluate MS — Equation 4 and Fig. 8. ♦

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Solving the Problems Inherent to Torch Brazing Aluminum

Substituting aluminum for copper in thermal-transfer products challenges manufacturers to rethink their brazing techniques, filler metals, and fluxes

BY KENNETH ALLEN

The volatility in the price of copper has removed cost certainty for manufacturers of copper heat-transfer devices. This market instability and the escalating warranty claims associated with formicary corrosion have caused some manufacturers to consider making their thermal-transfer devices out of aluminum. While a change to aluminum offers significant material cost savings, brazing aluminum presents several serious concerns.

Unlike brazing copper-to-copper assemblies using phosphorus-containing filler metals, the brazing of aluminum components requires the use of a flux. This raises several questions: What are the basic requirements of the flux? What fluxes are available? And, how should the flux be applied?

Another major problem is the close thermal proximity between the melting temperatures of the brazing filler metal and base metals. Frequently there is less than a 100°F difference between the liquidus temperature of the braze alloy and the solidus temperature of the aluminum. The opportunity for successful brazing is further complicated when a thermal-transfer device has a dense population of components. This type of design tends to shield some of the braze joints from proper heat exposure — Fig. 1.

The manufacturer considering a change from copper to aluminum must resolve three important factors affecting the brazing operation:

1. Choose the right flux to use for the application.
2. Determine how to apply the flux to the part.
3. Decide how to manage the small



Fig. 1 — Air-conditioning coils are one example of a high-volume assembly currently manufactured out of aluminum.

thermal window between the melting temperature of the brazing filler metal and thermal damage to the base metals.

Selecting the Correct Flux

The first requirement of an aluminum brazing flux is to be chemically effective. Fluxes are categorized as active (corrosive) and inert (noncorrosive). Active fluxes — generally consisting of potassium chloride with numerous proprietary additives — create sound brazements. The appearance of the part after brazing is bright

and shiny. However, the postbrazing residues must be properly removed to prevent the occurrence of electrolytic corrosion. Simply rinsing the part in water is not sufficient. These fluxes require a significant exposure to hot water to remove the corrosive flux residue. Attention must be given to chemicals on the outside of the assembly and to any residues that have migrated to the inside of the part. Obviously, a simple water rinse cannot adequately remove flux chemicals that, due to migration, are shielded from contact with the rinse water. If not removed, these chemi-

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Fig. 2 — ChannelFlux products contain the noncorrosive flux in a groove formed in the wire.



Fig. 3 — The pictured return bend was delivered preloaded with a flux ring. This enabled the brazing facility to eliminate all labor in the application of flux and braze metal.

calcs can cause postbrazing corrosion.

Noncorrosive fluxes alleviate any concern regarding postbrazing activity. These fluxes include the higher-temperature potassium aluminum fluoride options and the lower activated cesium fluorides. Noncorrosive fluoride fluxes do not require any postbrazing cleaning or treatment; however, these fluxes do leave a white, gritty residue on the part. The residue is primarily a cosmetic issue, but it can make subsequent brazing in the region more difficult. If this residue can be tolerated, the use of a noncorrosive flux is highly recommended.

Fluxes must be thermally matched to the melting phase of the braze filler metal. One key to the success of NOCOLOK® flux is its thermal activation proximity to the 4xxx aluminum-silicon filler metals. Cesium fluoride options have been developed that provide the same noncorrosive performance at a substantially lower temperature.

Applying the Flux to the Part

A major component of a successful aluminum brazing project is the convenient application of flux and braze filler metal. While this is accomplished in controlled-atmosphere brazing (CAB) processes with a recirculating flux spray system and clad

base metals, this option is not practical for many flame brazing projects.

Listed below are the most common methods of presenting controlled amounts of flux to optimize torch brazing results.

1. Dispensable fluxes utilize standard flux chemicals with an added binder or suspending agent. The mixture remains homogenous and can be automatically applied to the part. Dispensable fluxes can be used in conjunction with wire feed or preforms as a two-step system of material deposition.

2. Paste is a blend of alloy filler metal in powder form, flux, and a neutral suspending agent. Paste enables the flux and the alloy to be dispensed in a single step using pneumatic or positive-displacement devices.

3. Flux/powder metal (PM) fabrication uses PM principles to form solid rings made from powdered metal and flux. Control of powder mesh size dispersion is critical to ensure lot-to-lot consistency.

4. Flux cored wire starts with a flat strip to which noncorrosive flux is applied. The strip is then rolled to create a wire with a flux core. Typically, these wires have flux voids that can reduce their effectiveness.

5. ChannelFlux® is a rectangular wire featuring a groove filled with a noncorrosive flux. This product offers precise placement of both brazing alloy and flux — Figs. 2, 3.

Enlarging the Thermal Processing Window with 78Zn 22Al

Addressing the narrow thermal processing window is perhaps the biggest concern when contemplating an aluminum brazing project. The problem, simply stated, is that the aluminum base metals melt at about the same temperature as the brazing filler metal. Table 1 provides the melting ranges of several of the more common materials used in brazing applications.

Note that the solidus temperature, the

Table 1 — Melting Range of Al Base Metals (°F)

Grade	Solidus	Liquidus
1100	1190	1215
3003	1190	1210
6061	1100	1205
6063	1140	1205

Table 2 — Melting Range of Al Filler Metals

Grade	Solidus	Liquidus
4047	1070	1080
78 Zn-Al	826	905

BRAZING & SOLDERING TODAY

last temperature at which the alloy is completely solid, marks the point where damage begins to occur in the base metals. The lowest melting option of the standard BAlSi brazing alloys (4047) is 1070°–1080°F.

Table 2 shows a comparison between the melting temperature of the brazing alloy and the point at which the base metal is damaged illustrates the challenge. There is no margin for error.

The availability of cesium fluoride fluxes and their very-low melting range of 788°–842°F have ignited renewed interest in Zn-Al brazing alloys. The 78Zn 22Al is specifically designed for use on thermal-transfer devices. The low melting phase of this alloy (826°–905°F) is perfectly matched to the thermal activity of the Cs fluxes. The lower melting temperature (as compared to 4047) provides a substantial thermal window for most brazing applications. This is especially true for 6xxx series aluminum.

Postbrazing residues must be properly removed to prevent the occurrence of electrolytic corrosion

Tensile strength and burst tests with the 78Zn 22Al consistently show the braze joints demonstrate greater durability than the base metals. Saltwater spray testing to ASTM B117 for 2000 h showed no signs of visible corrosion and no deterioration of mass. While we might expect certain applications where the high-zinc filler metal might be sacrificially offered, independent tests indicate that this process is quickly

arrested by the almost immediate formation of aluminum oxide.

Conclusion

This article presents a number of options to enable a manufacturer to conveniently apply aluminum brazing materials. The method selected should utilize a flux that meets the cleanliness and corrosion-resistance requirements of the part and be thermally matched to the filler metals.

The acceptance of cesium-based fluxes has created a developing opportunity to investigate Zn/Al alloys as a low-temperature alternative to the popular aluminum-silicon products.

The use of a flux-containing single-step material application with a low-melting filler metal enables the manufacturer to properly address the most significant challenges found in the torch brazing of aluminum thermal-transfer devices. ♦

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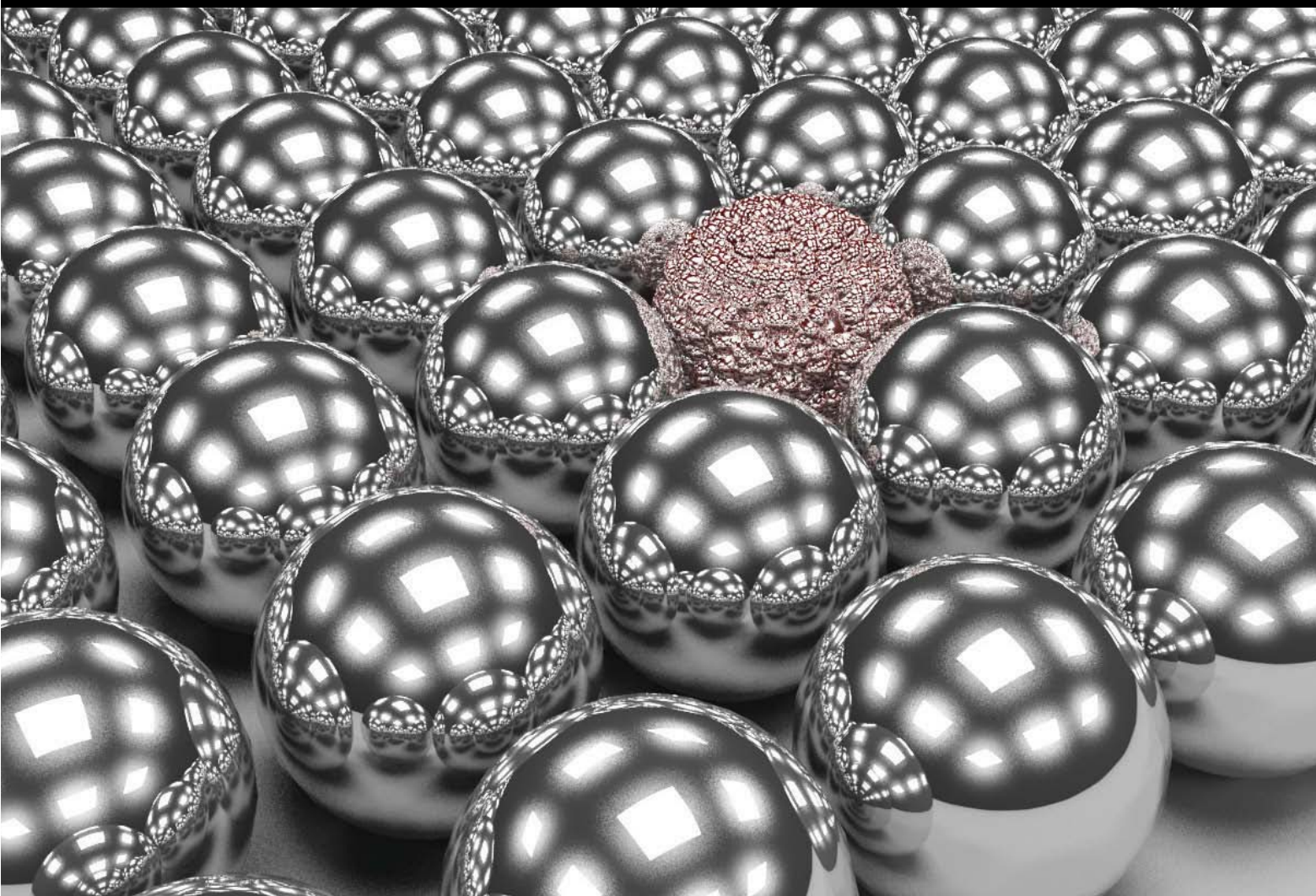
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The overall activity is immense. Cladding and strip overlay processes have become more popular means of protecting parts exposed to heavy corrosion. Duplex stainless is now being welded for over-the-road tankage. New processes, like friction stir welding and the more

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BRAZING & SOLDERING TODAY

Soldering Silver to Aluminum and Copper for Cryogenic Applications

Cryogenic evaporators were manufactured by soldering with silver heat-conductive plate to explore the internal design range of a possible electronics cooling solution

BY LEONID A. SHAPIRO

Microprocessor design has recently turned in another direction relative to the past 30 years. The emphasis is now placed on spreading computational workloads to multiple smaller, separated devices. This change was brought about in part as a solution in electronics cooling (Ref. 1). Consistent miniaturization of transistor parts decreases thermal resistance and power consumption per part, but growing device complexity and part density increase the heat flux at the device's surface, necessitating more formidable and massive cooling items to prevent heat-induced materials-expansion-related stresses and current leakage (Refs. 2, 3).

Moreover, the future is invariably that of mobile devices. The market is driven by demand from consumers for mobility, and power inefficiency is now a primary concern. Although microprocessor manufacturers presently increase the overall number of processors, while lowering operating clock frequency per processor, and produce dies wherein multiple otherwise self-contained processor cores exist on a single processor die, that methodology is but a successful temporary compromise between increased device performance and its heat output, since increases in the number of processor cores can only provide marginal benefits. It's the law of decreasing marginal utility. Efficient distribution of software tasks is not possible in many circumstances, and miniaturization of transistor parts cannot continue forever (Ref. 4).

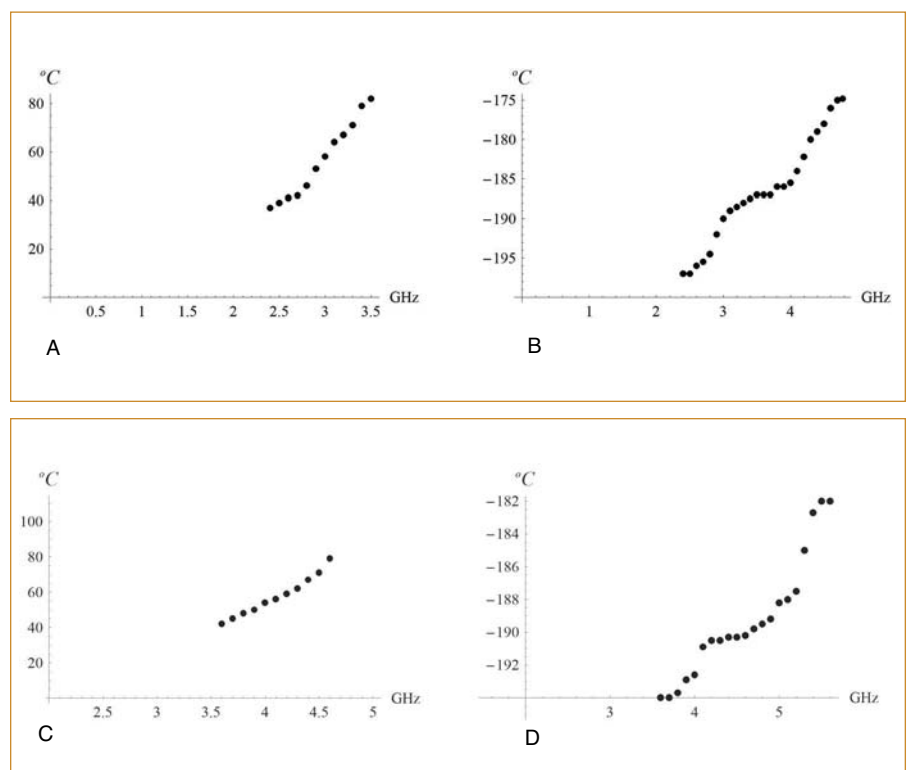


Fig. 1 — Mean temperature and operating clock frequency of last single-core processors (Ref. 12). A — Fan and heat-sink: Celeron D 2.40 GHz; B — pulses of liquid N₂: Celeron D, 2.40 GHz; C — fan and heat sink: Pentium 4 3.60 GHz; D — pulses of liquid N₂: Pentium 4, 3.60 GHz. Operation clock frequency of device and its voltage increased in BIOS. Heat output of each device increased at a rate greater than operating clock, and the device experienced increased Joule heating and exhibited greater thermal resistance. Control: aluminum heat sink cooler containing six copper heat pipes, primary forced convection part being 120 × 120 × 20 mm fan, Windows® XP run.

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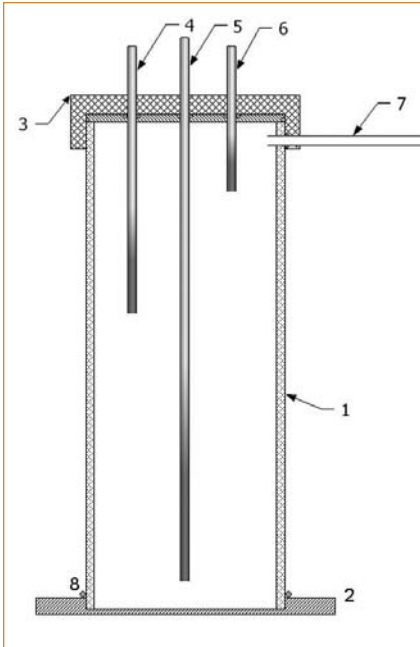


Fig. 2 — Evaporator design. The cold plate at the bottom contacts the cooled surface. This design assumes automated supplying of refrigerant by a temperature-monitoring controller (Ref. 12). 1 — Aluminum cylinder, 2 — Sterling silver cold plate, 3 — Soldered lid, 4 — Thermocouple input, 5 — Liquid N_2 supply tube, 6 — Vapor output, 7 — Vapor distribution tube, 8 — Solder joint.

Dissipating Heat

Heat spreaders subject to free air convection can conduct heat away from a contacted surface. To dissipate greater heat loads, their surface area must either be increased linearly or exposed to greater air flow (Ref. 5). Larger heat-sinks predominantly utilize forced air convection parts, and contain technologies facilitating greater rates of internal heat transfer such as heat-pipes, which are elements wherein heat is transferred between two ends of a sealed chamber by a liquid that is evaporated at one end to condense passively at the other (Ref. 6). Software throttling in response to heating or net computational workload exists (Ref. 7). However, the next big step has been debated.

Advances in Technology

Contemplated leaps to technologies, which manage the concentrated dynamic heat-loads expected in the near future, all assume wider use of mediums other than

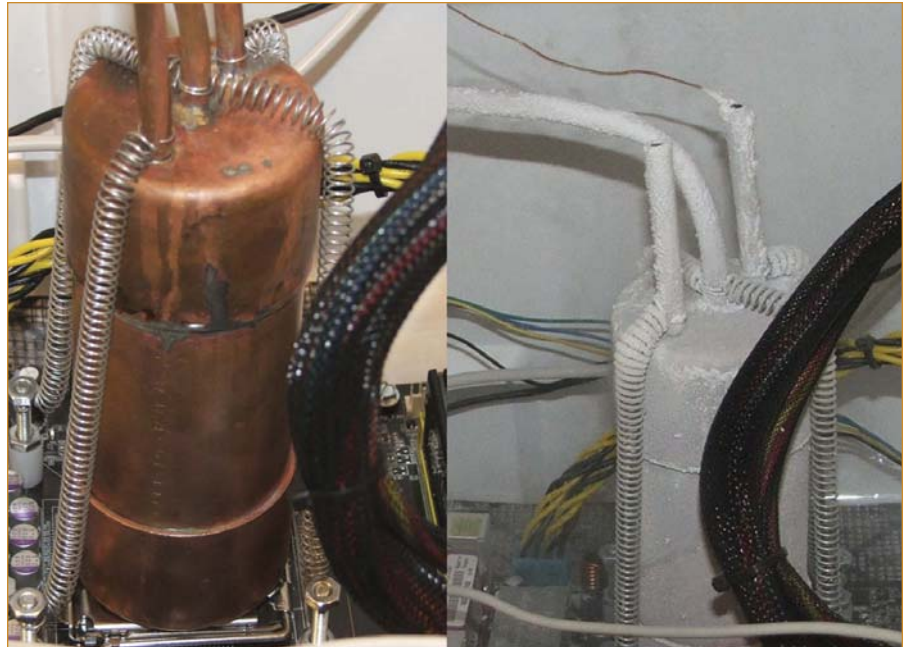


Fig. 3 — Computer installed within automated refrigeration system, wherein liquid N_2 is the working fluid. The Cu evaporator is pictured (Ref. 12).

air, such as working fluids like water, low-boiling-point refrigerants, low-melting-point alloys, and cryogenics. Water has a higher thermal effusivity and volumetric thermal capacity than air ($0.16 \text{ W/cm}^2/\text{K/s}^{0.5}$ and $4.185 \text{ J/m}^3 \cdot \text{K} \cdot 10^6$, respectively, at 60°C). Systems utilizing liquid alloys of sodium or gallium pumped by electromagnets are even more favorable in this regard (Refs. 8, 9). Water may be released upon a surface by small jet arrays in quantities such that its boiling removes as much as 1000 W/cm^2 from the surface. Refrigerants such as chlorodifluoromethane and tetrafluoromethane boil at lower temperatures (Refs. 10, 11). Technologies exist that allow for as much as 100% increases in the operating clock frequency of modern computing devices, or comparatively yielding changes in device complexity — Figs. 1 and 2.

However, producing marketable solutions requiring a relatively high level of capital investment on the part of consumers involves satisfying the related objectives of 1) eliminating hassle and service costs related to minimum maintenance by increasing the life cycle of relevant parts, and 2) increasing the marginal benefits of the technologies over standard fare. The latter function can be achieved either by decreasing net cost through use of less expensive materials, or increase ef-

ficiency through use of more expensive materials. To avoid contradiction, designs of many materials are unavoidable.

One component that must necessarily be resolved in this manner is the refrigerant evaporator, which is applied to the cooled surface of the CPU in most low-temperature refrigeration systems. This part experiences significant thermal cycling, and while aluminum is preferable in this respect as a lightweight metal, as well as in material cost relative to copper, its poor thermal conductivity relative to copper and silver make it only suitable as part of the construction. The most cost-efficient configuration of materials to comprise an evaporator suitable for operation at 77K (the boiling point of the most inexpensive refrigerant, liquid nitrogen) is an A3003 body soldered to a sterling silver cold plate, which contacts the device being cooled and is the intermediate surface between heat load and working fluid — Fig. 3.

In previous work, a copper evaporator was used. It was placed at the surface of the central processing unit, while other components are cooled at different local temperatures within specific areas of the sealed subenvironment through automated refrigerant flow in prearranged tubing coils. Air condensation was prevented by enclosing all computer components in a sealed subenvironment wherein

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air was pumped out. As liquid nitrogen evaporated, it was circulated through this chamber (Ref. 12). Noncryogenic applications can also benefit from similar material combinations (Ref. 13).

Investigating Base Metal/Solder Combinations

The objective of this work was to gather the following data for copper or aluminum base metal/solder combinations: 1) Tensile strength of base materials before and after cryogenic cooling; 2) shear strength of soldered joints after soldering and after cryogenic cooling; and 3) microstructure analysis of soldered joints after soldering and after cryogenic cooling.

Conducting the Experiment

Copper C1010, sterling silver, and aluminum Alloy A3003 in the form of wrought tube and sheet were used as the base materials with the lead-free solder Sn-20 wt-% Zn. Standard single-lap shear test specimens of all these materials were manufactured according to specification AWS C3.2M/C3.2:2008* (Fig. 2 at the overlap 0.24 in. [6 mm]).

Prior to assembly of the joint, faying surfaces were cleaned with fine sandpaper and ethyl alcohol before soldering. Copper-to-silver joints were soldered with the acidic flux No. 71 supplied by Superior Flux Mfg. Co., Cleveland, Ohio. In order to join aluminum to silver, both base metal faying surfaces were pretinned with the Sn-20Zn solder by rubbing with a steel brush on the hot plate. Then, aluminum-to-silver joints were soldered without an additional solder portion but using the organic aluminum soldering flux ASF-40 (Ref. 14) supplied by Titanium Brazing, Inc., Columbus, Ohio.

Soldered joints were subjected to cryogenic cooling by submerging them into liquid nitrogen. Specimens were dipped into liquid nitrogen and held for 6 min to provide full cooling to the temperature -196°C . Following each cryogenic cooling, the specimens were dipped into water to return them to room temperature. The base materials were subjected to the same cryogenic treatments as joined specimens.

The specimens were subjected to tensile testing to determine ultimate shear strength of joints and tensile strength of base materials.

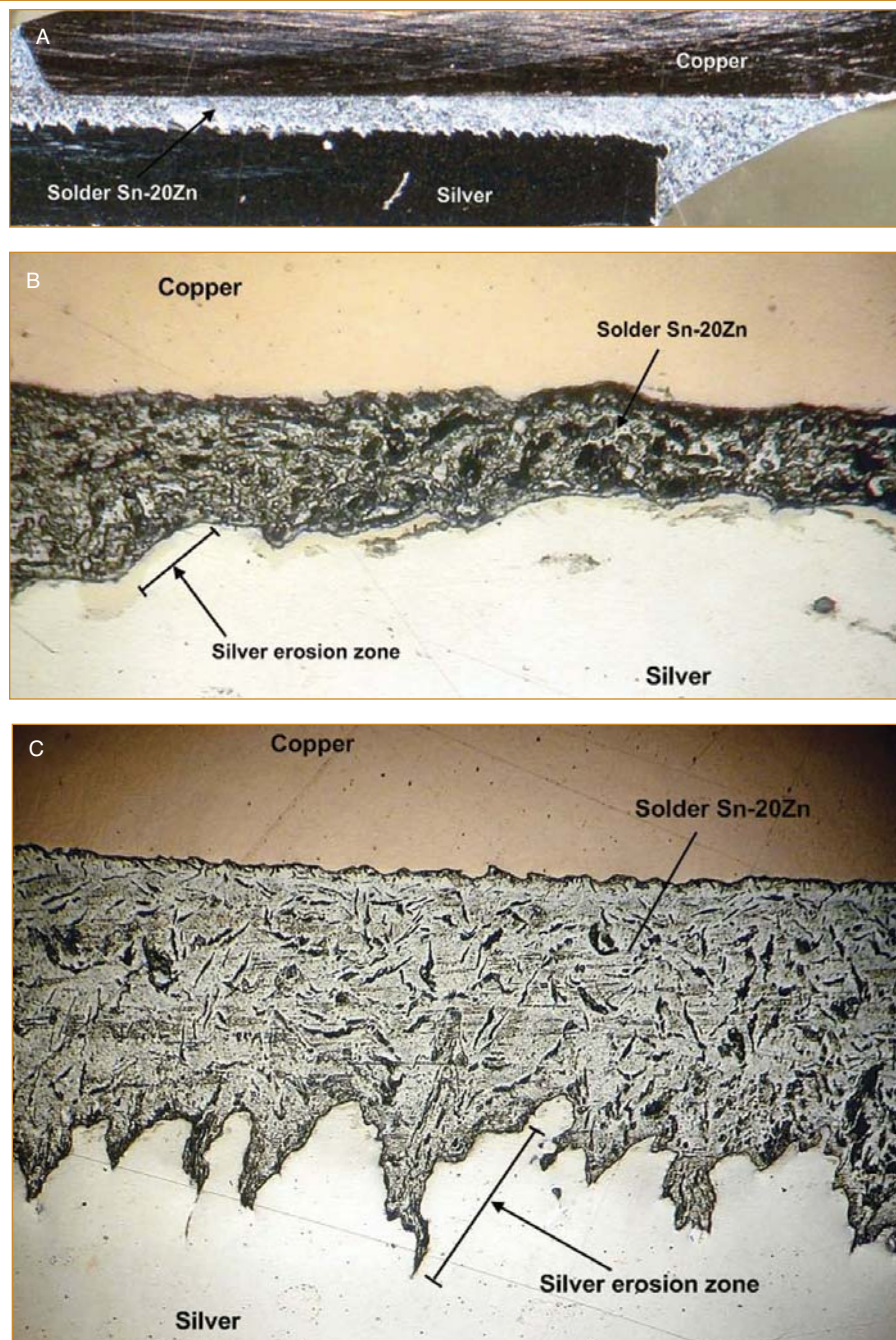


Fig. 4 — Structure of copper-silver soldered joints. A — Macrostructure after soldering, 2x; B — microstructure after soldering, 100x; C — after cryogenic treatment, 100x.

Results of the Investigation

Mechanical Properties

The results of the mechanical testing of base metals and soldered joints are presented in Table 1. The data in Table 1 are comprised of averages from the perform-

ance of 4–7 specimens tested for each combination of base metals.

The repeated cryogenic cooling does not affect tensile strength of copper and A3003 alloy unless another thermal treatment was done before contacting liquid nitrogen. After soldering, base metals that were subjected to cryogenic thermal cycling had a significant decrease in tensile strength by approximately 15% for

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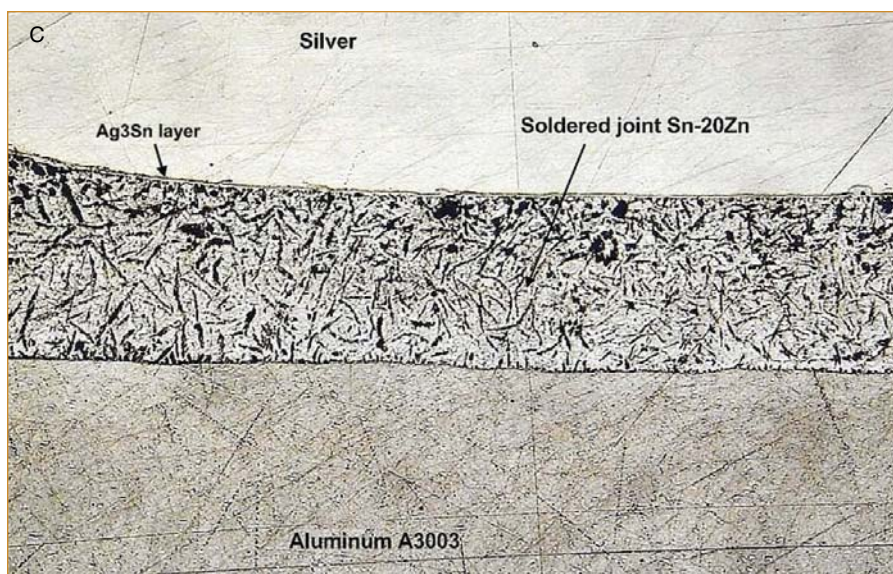
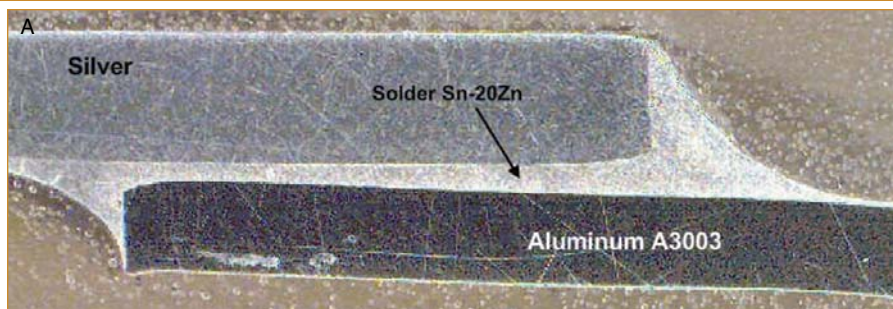


Fig. 5 — Structure of aluminum-silver soldered joints. A — Macrostructure after soldering, 2 $\times$; B — microstructure after soldering, 100 $\times$; C — after cryogenic treatment, 100 $\times$.

both aluminum and copper. This means that short-term heating during soldering to 270°–300°C (520°–570°F) affects the base metal strength more adversely than short-term thermal cycling at cryogenic temperatures.

The cryogenic thermal cycling decreased shear strength of aluminum-silver soldered joints by 14%, whereas the strength of copper-silver soldered joints was changed insignificantly — only by 4%. No cracks or microcracks were found in joints after soldering; therefore, a slight decrease of mechanical properties was accepted as noncritical for the application in electronics cooling, where structured soldered joints are not exposed to any stresses other than those arising from dissimilar expansion/contraction of joint materials during thermal cycling.

Microstructure of Soldered Joints

Microstructures of copper-silver joints soldered with the Sn-20Zn solder are presented in Fig. 4. The joint metal is dense, without voids and pores. Despite the formation of Ag₃Sn intermetallics was expected at the interface between silver base and solder, no intermetallics were found. However, the joints were characterized with significant erosion of silver by the solder — Fig. 4B, C. The joint microstructure was changed after cryogenic cooling. A eutectic type of solder microstructure after soldering was transformed into a quenching-type microstructure after on-and-off cryogenic cooling. This change did not result in a shear strength gain due to significant tin content in the solder, which causes low strength of the alloy independent of any structural changes.

Microstructures of aluminum-silver joints soldered with the Sn-20Zn solder are presented in Fig. 5. The joint metal is dense, without voids but with several small-size pores (Fig. 5B), which probably appeared due to organic flux application. This flux is characterized by considerable evaporation of gaseous products from the decomposition of organic amines. An expected intermetallic layer of Ag₃Sn phase was found at the silver-solder interface contrary to the previously mentioned microstructure of copper-silver joints. This can be explained by the fact that silver was pretinned before soldering with aluminum, while soldering of silver with copper was conducted in one thermal cycle.

The cryogenic treatment also trans-

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Table 1 — Effect of Cryogenic Treatment on Strength of Base Metals and Soldered Joints

Sample	Base metal at room temperature, MPa	Base metal, 6 min dipping in liquid nitrogen, MPa	Base metal after soldering, 6 min dipping in liquid nitrogen, MPa	Joint at room temperature, MPa	Joint, 6 min dipping in liquid nitrogen, MPa
Aluminum Alloy A3003	<u>169.2–176.6</u> 174.7	<u>162.2–175.1</u> 172.6	<u>147.7–150.1</u> 149.5		
Copper 1010	<u>271.4–279.1</u> 276.0	<u>273.6–283.1</u> 281.75	<u>229.9–237.4</u> 234.45		
Aluminum + Silver + (Sn-20Zn) Solder				<u>28.2–34.3</u> 31.63	<u>26.3–29.7</u> 27.32
Copper + Silver + (Sn-20Zn) Solder				<u>33.1–38.3</u> 37.36	<u>32.8–36.1</u> 35.77

formed the joint microstructure: needle-like structural aspects appeared as distinguishing features of a quenching structure. However, no cracks or microcracks were found in both the copper-silver and aluminum-silver soldered joints after cryogenic treatment. It is possible that thermal stresses are relaxed by relatively soft, plastic tin-zinc solder metal, as well as all the base metals, which also have good plasticity.

Conclusions

Soldered joints of A3003 and silver can be implemented, and are preferable in environments wherein they are expected to experience significant thermal-cycling-induced stress. The implication is that high-efficiency, low-cost components in electronics cooling can be assembled and applied, without a reduction in part life cycles, to intensive heat electronics cooling applications. Heat dissipation solutions dependent upon the relevant constructs are thereby made more competitive and brought nearer to market viability.

Cryogenic cooling resulted in a decrease in tensile strength for both copper and aluminum by about 15%, as well as shear strength reduction of soldered joints, but this can be considered as not critical or dangerous for this application. No cracks were found.

Significant erosion of silver by the Sn-

20Zn solder was found after soldering with copper, while a formation of Ag₃Sn intermetallic layer, due to pretinning, prevented this erosion when silver was soldered to aluminum.

Also, the cryogenic treatment resulted in changes in the solder joint microstructure, namely, an appearance of needle-like crystals characteristic of any quenching structure.

Acknowledgments

I am grateful to Dr. Alexander Shapiro of Titanium-Brazing, Inc., who provided valuable advice concerning methodology during joint strength testing, and to Dr. Boian Alexandrov of The Ohio State University Welding Engineering Program for help with metallographic work.

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BRAZING & SOLDERING TODAY

Testing Sinter Braze Integrity Using Resonant Inspection

The process proved effective in detecting defects commonly found in sinter brazed powder metal parts

BY RICHARD W. BONO

Powder metallurgy (PM) is the process of forming metal components by mixing elemental or metal alloy powders, die pressing at high force levels, and heating at temperatures just below the melting points of the particulate materials. This heating process, called sintering, takes place in a controlled-atmosphere furnace and bonds the particulate materials metallurgically. In recent years, the PM process has been shown to be a superior technique for manufacturing high-quality parts compared to forging or metal casting. Advantages include material utilization, shape complexity, and dimensional control, all yielding lower costs and greater flexibility.

Conventional PM, sometimes referred to as press and sinter, yields parts formed by compacting the powder in a single direction. The die forms the compacted shape, referred to as a green part. This shape is limited to definition in the compacting direction so that the green part can be removed from the die without damage.

Sinter brazing is a common joining process used by powder metal part manufacturers. It allows the formation of more complex parts while maintaining desirable levels of material strength. The technique involves assembling multiple powder metal parts, in the green state prior to sintering, adding a braze compound, and sintering at temperatures above the melting point of the brazing alloy. When processed properly, sinter brazing is cost effective and produces a strong joint. Several examples of brazed powder metal parts are shown in Fig. 1.

Certain defects are common among sinter brazed powder metal parts. These

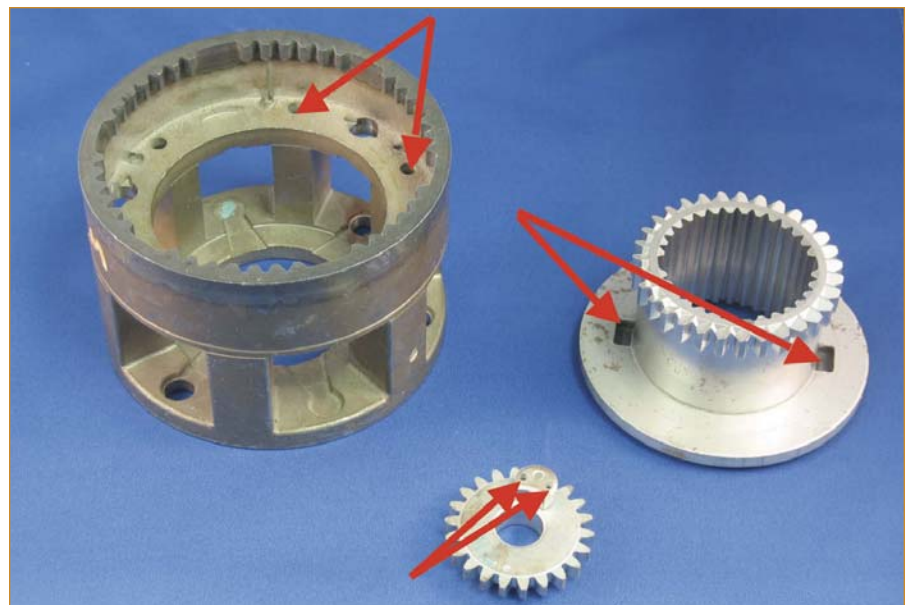


Fig. 1 — Examples of sinter brazed powder metal parts with braze plugs inserted as indicated.

include subcomponent misalignment during initial assembly and incomplete braze material infiltration. Inadequate infiltration is typically caused by using an improper braze alloy or damaged braze pellets (for example, a slug with 50% of its material broken away). Another likely root cause of poor sinter brazing is missing the braze pellet altogether. Other common process variances that can lead to inadequate braze joints include improper furnace settings and dewpoint. Several examples of these defects are shown in Fig. 2.

To ensure the formation of quality parts, the presence of potential defects

must be checked. Crack and chip defects, common to the root PM process, should also be tested. The consequences of shipping defective parts include expensive resorting, often at the customer's site, or contracting additional inspection to a third-party vendor. Ultimately, expensive end product recall costs could become the responsibility of the failed component manufacturer.

Given that typical PM parts are manufactured in medium to high volumes, performing these inspections in a reliable, automated, objective fashion is critical to maintain cost effectiveness. The Resonant Acoustic Method Of

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Nondestructive Testing (RAM NDT) from the Modal Shop, Cincinnati, Ohio, provides a technique for these demanding performance requirements.

Resonant inspection (RI), the general process on which the technique is based, measures the structural response of a part and evaluates it against the statistical variation from a control set of good parts to screen defects. Its volumetric approach tests the whole part, both for external and internal structural flaws or deviations, providing objective and quantitative results. This structural response is a unique and measurable signature, defined by a component's mechanical resonances. These resonances are a function of part geometry and material properties and are the basis for RI techniques. By measuring the resonances of a part, one determines the structural characteristics of that part in a single test.

The Resonant Acoustic Method technique performs RI by impacting a part and "listening" to its acoustic signature with a microphone. The controlled impact provides broadband input energy to excite the part, and the microphone allows for a noncontact measurement of the structural characteristic signature. The part's mechanical resonances amplify the broadband input energy at its specific resonant frequencies, indicated by peaks in the resulting frequency spectrum (shown graphically in Fig. 3) measured by the microphone. "Good" parts (structurally sound) have consistent spectral signatures (i.e., the mechanical resonances are the same among part samples) while "bad" parts are different (i.e., exhibit resonant frequency shifts from expected values). Deviations in peak frequencies or amplitudes constitute a structurally significant difference in the part's composition, providing a quantitative, objective, and repeatable part rejection. In simpler terms, just like a cracked bell sounds different when struck, flawed parts sound different and can be sorted accordingly.

The technique has proven effective for inspecting the structural integrity of sinter braze joints. In one such application, the structural integrity of a brazed powder metal carrier gear assembly was tested using the process, and the results correlated with destructive testing. Criteria templates with several critical resonant frequencies were established from a baseline set of parts. This initial set of parts was inspected with visual examination and microstructural analysis, and included acceptable production process variations in density, lot-to-lot powder, dimen-

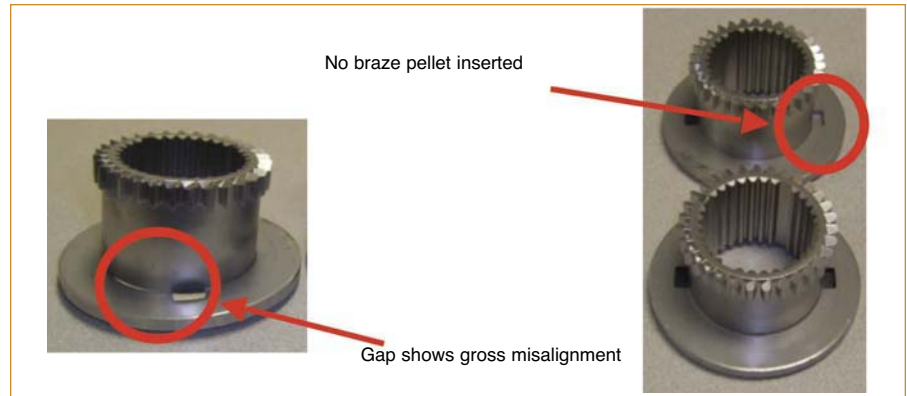


Fig. 2 — Examples of common defects found in sinter brazed powder metal parts, including the following: A — Gross misalignment; B — missed braze pellet (indicated by lack of discoloration).

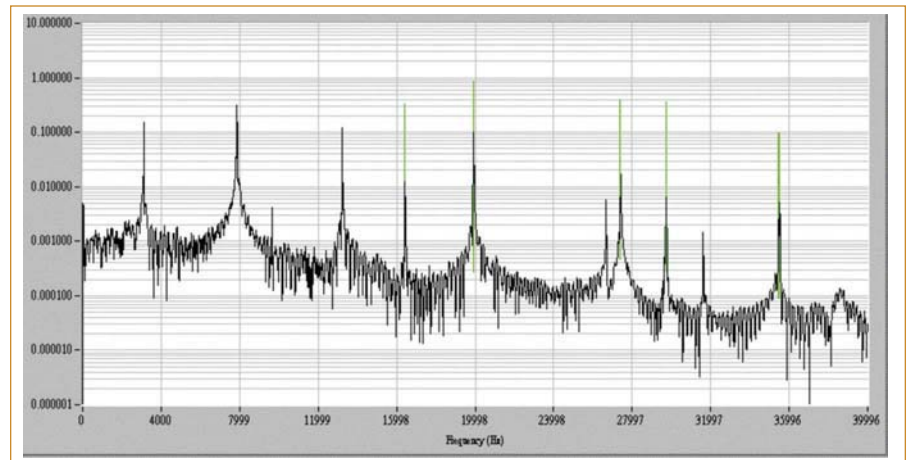


Fig. 3 — Typical acoustic signature frequency spectrum acquired using resonant imaging.

Table 1 — Results of a Tensile Test of a Brazed Joint with Induced Defects

Part Characterization/Induced Defect	Separation Force, lb (N)
Good parts	26,118 (116,180)
1 of 4 braze pellets missing	13,360 (59,430)
2 of 4 braze pellets missing	8,121 (36,124)
3 of 4 braze pellets missing	4,288 (19,074)
Misaligned subcomponents	8,129 (36,160)
Small braze pellet	8,812 (39,198)
Poor sinter	5,995 (26,670)

sions, and sintering effectiveness.

A tensile test of the braze joint was completed on this set of parts. The separation force was measured for a variety of groups of parts, with induced defects including misalignment, omitted braze pellets, small braze pellets, and poor sinter. The results are given in Table 1.

Within each of these groups of parts, certain resonant frequencies shifted that

allowed accurate and reliable 100% inspection via RAM NDT. Typically, these frequency shifts were on the order of 6–10% as compared to resonant frequency shifts due to acceptable process variation of less than 1%. As a result, it was concluded that the technique can easily and reliably detect poor sinter braze joints. ♦

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TECHNOLOGY NEWS

Novel Diffusion Brazing Technique for Joining Aluminum at 570°C Using Thin Films of Pure Copper and Al-Cu-Si Alloy

A new brazing technique was developed in the Institute of Materials Engineering, Technical University of Dortmund, Germany, to join aluminum alloys at 570°C (1058°F) by the transient liquid phase (TLP) process through pure copper thin films and Al-Cu-Si with a hypereutectic composition. Variations of the Al-Cu-Si layer composition showed a minor dependence on the melting points: 533°, 537°, and 541°C (Ref. 1). This work proved that ultrathin physical vapor deposition (PVD) films can be successfully utilized for brazing aluminum alloy parts.

Diffusion brazing of aluminum alloys precoated with filler metal components,

using an arc-PVD process, enables fluxless wetting, leading to high-strength braze joints at moderate brazing temperatures. During the subsequent diffusion brazing process, a transient liquid phase is formed based on the deposited thin film material. The filler alloy solidifies isothermally due to diffusion processes in the range of 560°–610°C (1040°–1130°F) within the brazing operation. Thereby, braze joints with higher remelting points than the actual brazing temperature can be obtained. The AA6060 alloy joints were fabricated in vacuum diffusion brazing processes after depositing filler metals of the systems Al-Cu and Al-Cu-Si. Alternatively, and for comparison purposes, conventional aluminum braze joints of the same aluminum alloy have been fabricated with the commercial BA1-4 (Al-12Si) filler metal of 0.2 mm thickness in a vacuum brazing process. Braze joints have been analyzed metallographi-

cally and by scanning electron microscopy (SEM). No voids or pores were found in the joint. Depending on the diffusion conditions, the diffusion brazed joints obtain a structure and composition very close to the base material.

Sealing Active Component of Brazing Alloy for Joining Solid Oxide Fuel Cell Ceramics with Metals in Air

Traditionally, ceramic joining using active brazing alloys (ABA) is carried out in a vacuum. However, some materials of the solid oxide fuel cell (SOFC) are not chemically stable in a vacuum, e.g., the perovskite-type cathode, and a vacuum brazing process is sometimes not feasible. An alternative brazing process in air was developed in Forschungszentrum Jülich, ZAT

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and RWTH Aachen University, Welding and Joining Institute, Aachen, Germany, in order to replace the active brazing process in a vacuum (Ref. 2). Titanium or zirconium films were applied directly on the ceramic surfaces (8YSZ) and sealed with an oxidation-resistant silver-based brazing alloy to prevent a premature oxidation of these Ti or Zr active components and improve wetting behavior.

The active components were deposited by the PVD technique on the solid electrolyte surface, and then coated with a silver brazing filler metal also using the PVD process. This allows the contact of Ti or Zr to the melted silver alloy during the brazing process and provides a wetting-promoting reaction with the ceramic surface. This method allows the dispensation of additional flux and also a reduced or inert furnace atmosphere. Successful joining of ceramic electrolyte 8YSZ with the ferritic chromium steel Crofer22APU

was made by brazing in air using zirconium or titanium film 1.25 microns thick on ceramic and fine silver film 15 microns thick deposited as the sealing layer on the Zr to protect it against oxidation. A silver foil 100 μm thick has been used for the wetting and joining tests. The joining and wetting tests were made in a muffle furnace at a brazing temperature of 1000°C (1832°F) and holding time of 10 min.

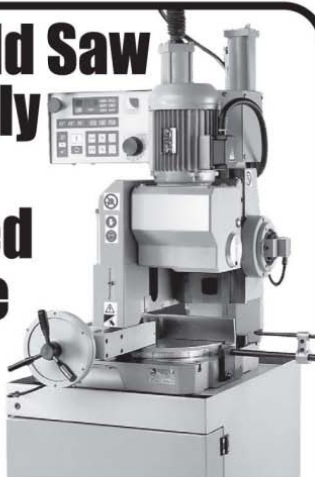
A zone with brownish discoloration has been observed on the 8YSZ ceramic surface coated with Ti or Zr. This is a sign of the oxygen removal by the Ti/Zr from the crystal lattice of the 8YSZ, which has a strongly reducing effect. The wetting angle of silver upon Ti film was ~35–40 and ~45–50 deg upon the Zr film, which is a significant improvement of the wetting behavior compared with pure silver that has the contact angle of ~73 deg in air. Some pore formation within the ZrO reactive layer was observed. The adhesion

to the 8YSZ surface was consistently good. The silver also showed uniform and good adhesion to the ZrO reactive layer.

Brazing Hot-Runner Nozzles Made of Three Dissimilar Materials: Hot-Work Steel, Copper, and Titanium Alloy

Multiple nozzles for hot-runner tools consisting of the material combination Cu-alloy, Ti-alloy, and hot-work steel are brazed successfully by Listemann AG, Eschen, Liechtenstein (Ref. 3). Preconditions for a reliable manufacturing process are keeping defined diameter tolerances, "frozen" process steps including cleaning, preparation, and assembling single parts as well as a consistent quality of the base materials. The material prop-

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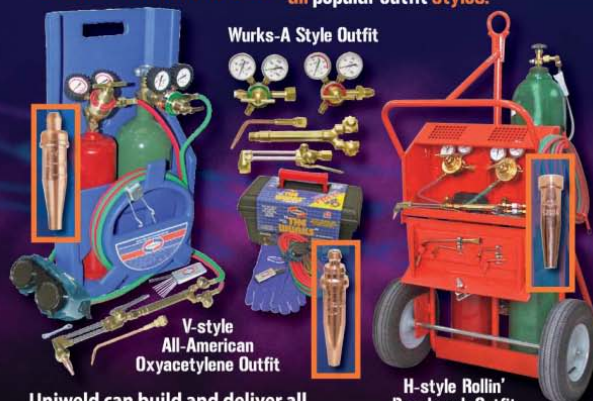
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erties of the joining partners and customer requirements partly generate an opposite impact on the brazing process by mismatch of the coefficient of thermal expansion, formation of intermetallics in the joint, and structure transformation at different temperatures, which did not correspond to the brazing cycle. Considering the boundary conditions, BVAg-8 and BVAg-30 filler metals were used for vacuum brazing at 840°C (1544°F) and a soak time of 5 min. Quenching should start at 780°C (1436°F) with a moderate N₂ pressure of 850 mbar.

A 840°C brazing temperature and 5-min soak time result in an intensive interaction between multiple nozzle (Cu alloy) and lower shaft (Ti alloy). As a consequence, cracks appear in the interface close to the lower shaft and joints fail during a pressure test at 300 bar. Palladium-containing BVAg-30 results more in pressure-tight joints than the silver-copper-eutectic BVAg-8 but with significantly reduced wetting and spreading behavior. Surprisingly, a brazed joint between the

Ti alloy and hot-work steel is not the weakest link.

It could be proved that keeping diameter tolerances as narrow as possible is of major importance to ensure consistent brazing joint clearances. In addition, it becomes evident that even moderate quenching conditions could result in crack formation. Obviously, this phenomenon is increased by the different shrinkage behavior of the materials used.

It could be proved that keeping diameter tolerances as narrow as possible is of major importance to ensure consistent brazing joint clearances. In addition, it becomes evident that even moderate quenching conditions could result in crack formation. Obviously, this phenomenon is increased by the different shrinkage behavior of the materials used. The quenching was modified to furnace cooling in a vacuum down to 500°C (932°F), followed by gas quenching with 850 mbar N₂ pressure. Still, the required hardness could be obtained although in the lower tolerance range. The joints proved to be

pressure tight, and as a result, serial production was released.

Pb-Free Solder Design to Promote Eutectic Solidification and Avoid Brittleness in Electronics Assembly Applications

Environmental regulations and market pressures create demand for the replacement of Pb-containing solders with Pb-free solders specifically for electronics assembly. Sn-Ag-Cu solders, replacements for Pb-containing solders, have been gaining ground. However, coarse intermetallic phases, which promote brittleness in joints produced with this solder, have been a substantial problem to overcome especially during slow cooling. Investigators at Ames Laboratory (USDOE) and Iowa State University, Ames, Iowa, have been considering single-element additions to the Alloy SAC3595 to improve eutectic solidification (Ref. 4).

Individual additions of Ni, Co, Fe, Mn, Zn, and Al at concentration levels 0.25, 0.20, 0.15, 0.10, and 0.05 wt-% were tested. It was found that individual additions of Zn ≥ 0.21 wt-%, Mn ≥ 0.10 wt-%, and Al ≈ 0.05 wt-% improved the control (suppression) of Ag₃Sn blades in the microstructure of soldered joints during slow cooling. SAC3595 modified with either Fe, Co, Ni, and Mn additions was found to be comparable to unmodified SAC3595 in shear strength terms, whereas slight shear strength degrading was observed for Zn and Al additions. But this degrading was not significant.

Thermal aging effects (at 150°C) on shear strength were tested on joints made with SAC3595 + X for X = 0.21 Zn, 0.10 Mn, 0.05 Al, 0.15 Fe, 0.10 Co, and 0.20 Ni. The shear strengths of SAC3595 joints with the Fe, Co, Ni, and Mn additions were typical of unmodified SAC3595 with high initial strength and a decreasing strength with aging time. In contrast, the initial shear strength of SAC3595 joints with 0.21 Zn and 0.05 Al was nearly the same as Sn-0.95Cu, but thermal aging for up to 500 h did not significantly degrade the shear strength. Consistent with this stability in strength retention, the main microstructure features of these Zn and Al modified joints (the Sn dendrite morphology and ternary eutectic) did not seem to coarsen on aging. This reduced but constant shear



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strength and high microstructural stability may be beneficial for subsequent board level impact testing.

Sn-Ag-Cu+X, whereby X is the addition, was found to be a suitable, if not drop-in, replacement for Pb-containing solders in electronics assembly applications. This was expected by the authors. Additional alloying was determined to be a generally successful strategy to improve microstructural stability.

Brazing Ceramics to Metals through a Porous Metal Interlayer to Compensate the Mismatch in Coefficients of Thermal Expansion and to Fill Wide Joint Clearances

A metal interlayer application between ceramic and metal parts to be brazed allows resolving three technological problems that occurred during joining of such dissimilar materials: 1) adjusting the joint clearance between long parts, 2) brazing assemblies with a wide (not capillary) joint clearance, and 3) compensating the mismatch in coefficients of thermal expansion. The effects of nickel cloth or copper porous interlayer on brazing stainless steel 304 and 316L pipes assembled with the wide clearance were studied in Tokai University, Kanagawa, and Tokyo Braze Co., Ltd., Tokyo, Japan, as well as brazing alumina to aluminum nitride ceramics and diamond-coated silicon wafers (Ref. 5). The eutectic Ag-Cu brazing filler metal BAg-8 was used for vacuum brazing all designs.

This method was effective to fill the continuously changed clearance (50 to 900 μm) set between pipes with the brazing filler metal. Moreover, it was possible to form the fillets in the joints. Also, the brazed joint's strength improvement was reached by dispersing the joint metal, which will stretch the nickel porous material. Brazing the wide clearance of 450 and 1500 μm between silicon wafers or ceramic and copper flat plates also was successful, which seemed to be impossible in the general brazing practice.

The nickel porous metal was also applied to braze shape-differed cooling channels on the stainless steel pipe surface. The good cooling channel was able to be formed when a metallic cloth was also similarly attached in the joint inter-

face. The attached Ni porous metal in the brazed joint interface was perfectly melted to the brazing filler metal. It is important to choose the brazing filler metal material compatible to the steel for the cooling channels good brazing on the pipe surface.

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All the papers listed below are from the *Proceedings of the 4th International Brazing and Soldering Conference*, cosponsored by AWS and ASM International, held April 26–29, 2009, in Orlando, Fla. In addition, these have all been edited by A. Rabinkin, R. Gourley, and C. Walker.

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Information provided by ALEXANDER E. SHAPIRO (ashapiro@titanium-brazing.com) and LEO A. SHAPIRO, Titanium Brazing, Inc., Columbus, Ohio.

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Q1: We are working with refrigeration equipment for special applications. During the installation process, a steel valve must be brazed or soldered to a copper pipe without “pinhole” leaks. We have contacted manufacturers of copper and steel parts, flux dealers, and condenser manufacturers. All have the same answer, “It is a standard procedure and we have no instructions.”

Q2: I want to braze 14-gauge cold-rolled steel onto some pieces of thin brass for decoration. Based on my Internet search, I used an oxyacetylene kit and flux-coated bronze brazing wire, but the brass is heating faster than the steel. It seems like it takes more heat to melt the brazing wire than the brass. What do you think?

A: Both questions can be attributed to the same limitation of heating temperature. Copper is characterized by fast grain growth above 900°C (1652°F) while the brass has a melting point in the area of 900°–930°C (1652°–1706°F). Therefore, the heating temperature in both cases must be below 900°C (1652°F). The use of an oxyacetylene torch is not necessary as propane torches or MAPP gas torches provide a sufficient and “softer” flame for heating of thin parts.

The answer to the second question has several options. You can use low-melting silver brazing wires such as BAg-1 or BAg-1a according to Table 1 of American Welding Society A5.8/A58M, *Specification for Filler Metals for Brazing and Braze Welding*. These filler metals contain about 50 wt-% silver and have brazing temperatures below 760°C (1400°F). Also, it is important that they contain only 16% zinc, while other low-melting silver brazing filler metals contain about 25–30 wt-% zinc or a higher amount of silver. You also can use more economical silver-based wire such as BAg-2a containing only 30 wt-% silver, but the brazing temperature will be higher, in the 710°–840°C (1300°–1550°F) range. If you would prefer a cadmium-free filler metal, there are several good choices such as BAg-28, which has the same brazing temperature but only 40% silver.

Thin brazing wire of 1/16-in. diameter is preferable in your case in order to avoid long heating for melting of the filler metal. Another approach is to use silver-free brazing filler metal such as P81 having a brazing temperature in the range of 680°–750°C (1256°–1380°F). This particular filler metal is supplied in the form of nonround rods. It does not have an AWS

BY ALEXANDER E. SHAPIRO

specification, but it is successfully used in Europe for joining steel to copper or steel to brass despite it containing phosphorus. Generally, the use of phosphorus is discouraged on steel due to the formation of brittle joints. It might be suitable if you are going to braze brass parts to steel for decoration purposes only.

Borate-fluoride fluxes of FB3-A, FB3C, and FB3-G according to AWS A5.31, *Specification for Fluxes for Brazing and Braze Welding*, are workable with all above-mentioned brazing filler metals. I would recommend so-called “black flux” — a borate-fluoride flux containing about 1% of boron powder as an activator. It provides good flow of both silver and silver-free brazing alloys. Flux residues are easily removed after brazing by washing in hot water and/or cleaning with a metal brush.

Evaporation and oxidation of zinc occurs during heating brass parts by flame of propane or oxyacetylene torches. Therefore, if your decorative brass parts have large areas, it is recommended to cover all surfaces to be brazed with the flux in order to diminish the formation of ZnO, which deteriorates wetting and spreading of the filler metal. Conversely, if the brass parts are small, you can place flux on the end of the brazing wire. The appearance of tiny pores at the surface of the braze joint should not surprise you. Porosity may result from evaporation of zinc from both the base metal and the filler metal. Thin brass base metal is vigorously dissolved in silver braze filler metals. It is important to avoid the contact of brass with molten braze longer than necessary. Remove the heat when you see that the filler metal has melted and flowed into the gap.

All of the above-mentioned combinations of brazing filler metals and fluxes are suitable for brazing a steel valve to a copper pipe as asked in the first question. However, I would recommend testing mechanical properties of the brazed joints if you are going to attempt using the silver-free P81 due to formation of iron phosphide at the steel-braze interface. It does not matter for brazing decoration pieces, but is reasonable for brazing structural parts.

Another option for silver-free brazing is the application of wire or rods of brass filler metal RBCuZn-B according to Table 4 of AWS A5.8/A58M. It has a melting point of 882°C (1620°F), and brazing is possible slightly above 900°C (1652°F). For this purpose, I would recommend you place the brazing wire inside the gap before heating. One or two grooves can be

machined either on the copper or the steel parts to place filler wire rings in. Placing the filler metal inside the gap will guarantee better filling of the joint along the overlap.

Other useful tips are to (a) cover the entire steel surface with the flux before brazing, especially if you braze stainless steel with copper. This allows for longer flux activity because the heating can be of sufficient duration to heat the structure of dissimilar metals; (b) heat the more massive part first. If the masses of both parts to be brazed are the same, heat the copper first due to its better heat conductivity against the steel; and (c) heat the joint with constant torch movement along the overlap in order to heat the joint uniformly.

Design of a braze joint using these dissimilar metals requires attention due to the big difference in their coefficients of thermal expansion (CTE). Copper’s CTE is about 10×10^{-6} in./in.·°F, while the CTE of carbon steel is only 6.5×10^{-6} in./in.·°F, and stainless steel is 8×10^{-6} in./in.·°F. This means that the copper pipe should be the outside part in the tube-in-tube joint structure, while the steel part should be the inside part. Assembling must be done almost without a gap between steel valve and copper pipe. A brazed joint designed in such a way will have the minimal width of the joint metal and will experience compressive residual stresses after cooling. Also, it is possible to avoid any defects in the joint or reduce a number of defects to a minimum. The leak-proofness (or airtightness) will also be good if the brazed structure is intended to work under gas or hydraulic pressure. The overlap is to be at least three thicknesses of the copper tube in order to provide sufficient shear strength of the brazed joint, but not longer than six thicknesses in order to avoid such defects as voids or flux residue inserts.

The emphasis of this article is focused on copper and brass because these base metals determine the specifications in brazing technology when they are joined to steel. The carbon or stainless steels have no limitation in brazing temperature as they can be heated or repaired by another heating cycle almost without a loss of strength. The oxide film formed on the surface of carbon steel is chemically unstable and is easily dissolved in all of the above-mentioned fluxes. Although the oxide film formed on the surface of stainless steel is significantly more stable, standard borate fluxes of the FB3 class (AWS A5.31-92), containing such active components as potassium fluoroborate, remove

this oxide film without problems. The steel part should be heated uniformly to a dark-red color as this is a good visual indicator of readiness to react with the molten filler metal. Neither copper nor brass give us such a clear indication of brazing temperature.

The last advice in the context of steel is, if you cannot provide a uniform, sufficient heating of the joint comprising dissimilar base metals having different heat conductivities (steel and copper alloys), it is reasonable to deposit a thin layer of silver filler metal on the steel surface as a first brazing operation with the flux. Then, remove the flux residues, and braze the "coated" steel part to the copper or brass part by a second heating with the addition of a new portion of the flux. This approach is especially helpful when brazing large surfaces of dissimilar metals. Small parts can be brazed directly without such complications.

My thanks to Prof. Igor N. Pashkov, Moscow University of Steel and Alloys, for his advice on silver-free brazing of steel to copper. ♦

This column is written alternately by TIM P. HIRTHE and ALEXANDER E. SHAPIRO. Both are members of the C3 Committee on Brazing and Soldering and several of its subcommittees, A5H Subcommittee on Filler Metals and Fluxes for Brazing, and the Brazing and Soldering Manufacturers Committee (BSMC). They are coauthors of the 5th edition of AWS Brazing Handbook.

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Deadline for Application : December 11, 2009

For Info go to www.aws.org/ad-index

Organized by The Japan Welding Engineering Society Sanpo Publications Incorporated



CONFERENCE ON WELDING CHROME MOLY STEELS

The welding of chrome-moly steel goes back to the days when tubing was oxyacetylene-welded to make up the fuselages of the early pre-aluminum airplanes. It required outstanding precision on the part of the welder. Even though the methods have changed, the welding of chrome-moly steel still requires utmost precision on the part of the welder and all involved parties.

Heat treatment and nondestructive testing are part and parcel of a successful weld. The 2 1/4Cr-1Mo steels are very popular materials for boilers and pressure vessels where the ASME Code is used. More recently, the modified 9Cr-1Mo steel, which was originally developed as the base metal for the Fast Breeder Reactor, is now widely specified in electric utilities and is moving into the oil and gas industry. To weld any of these steels for the first time, the engineer and the welder actually have to go back to school and start all over again.

Conventional arc welding processes are all used effectively on 4130, 2 1/4Cr-1Mo, and modified 9Cr-1Mo steels. Some newer processes like hybrid welding have also become popular. Proper administration of the preheat and postweld heat treat operations is most critical.

For the latest conference information, visit our website at www.aws.org/conferences or call 800-443-9353, ext. 455.

Tuesday, Nov. 17, 2009

Chicago (at the FABTECH INT'L & AWS Welding Show)

AWS Members: \$345

Nonmembers: \$480

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COMING EVENTS

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

SOUTH-TEC 2009. Oct. 6–8, Charlotte Convention Center, Charlotte, N.C. Visit www.sme.org/southtec.

♦ **Welding of Corrosion-Resistant Alloys Conf.** Oct. 6, 7, New Orleans, La. Contact American Welding Society, (800/305) 443-9353, ext. 229; or visit www.aws.org.

Power-Gen Asia and Renewable Energy World Asia Conf. and Expo. Oct. 7–9, IMPACT Exhibition & Convention Centre, Bangkok, Thailand. Visit www.powergenasia.com.

Lean Product Development Conf. Oct. 13–15, Motorola, Inc., Schaumburg, Ill. Visit www.sme.org/leanpd.

Canadian Manufacturing Technology Show. Oct. 19–22, Direct Energy Centre, Toronto, Ont., Canada. Visit www.cmts.ca.

The Aluminum Association Annual Meeting, “2010: Opportunities & Challenges.” Oct. 19, 20, Hotel Palomar & Waterview Conf. Center, Arlington, Va. Visit www.aluminum.org.

SNAME 2009, The Society of Naval Architects & Marine Engineers Annual Meeting and Expo. Oct. 21–23, Providence Convention Center, Providence, R.I. Visit www.snameexpo.com.

MACTECH 9th Int’l Expo for Machine Tools, Industrial Tools, Welding and Cutting Equipment. Oct. 22–25, Cairo Fair Ground, Cairo, Egypt. Visit www.ifg-eg.com.

MS&T 2009, Materials Science & Technology Expo. Oct. 25–29, David L. Lawrence Convention Center, Pittsburgh, Pa. Coorganized by ASM Int’l, ACerS, AIST, and TMS. Visit www.asminternational.org/mst.

National Robot Safety Conf. XXI. Oct. 26–29, Hyatt Regency, Dearborn, Mich. Contact Robotic Industries Assn. at ria@informz.net or ria@robotics.org.

2009 Shanghai Int’l Science Journals Summit. Oct. 27, 28, Shanghai, P. R. China. Visit www.sjs-sh.org.cn.

ICALEO®, 28th Int’l Congress on Applications of Lasers & Electro-Optics. Nov. 2–5, Hilton in the Walt Disney World Resort®, Orlando, Fla. Visit conferences@laserinstitute.org; or visit www.icaleo.org.

Metalworking and CNC Machine Tool Show 2009. Nov. 3–7, Shanghai New Int’l Expo Center, Shanghai, P. R. China. Visit www.messe.de.

17th Steelmaking Conf., 7th Ironmaking Conf, and 1st Cleaner Production Seminar (IAS-JICA). Nov. 10–12, Tenaris University, Buenos Aires, Argentina. Visit www.siderurgia.org.ar/conf09/index_english.html.

♦ **FABTECH International & AWS Welding Show** including **METALFORM.** Nov. 15–18, McCormick Place, Chicago, Ill. This show is the largest event in North America dedicated to showcasing the full spectrum of metal forming, fabricating, tube and pipe, welding equipment, and technology. Contact American Welding Society, call (800/305) 443-9353, ext. 455; or visit www.aws.org.

35th Int’l Symposium for Testing Failure Analysis (ISTFA). Nov. 15–19, San Jose, Calif. Visit www.asminternational.org.

♦ **Int’l Electron Beam Conf.** Nov. 16, 17, Chicago, Ill. Held during the FABTECH International & AWS Welding Show. Contact American Welding Society, call (800/305) 443-9353, ext. 455; or visit www.aws.org.

♦ **New Developments in Thermal Spray Coatings, Processes, and Applications Conf.** Nov. 16, Chicago, Ill. Held during the FABTECH International & AWS Welding Show. Contact American Welding Society, call (800/305) 443-9353, ext. 455; or visit www.aws.org.

♦ **Weld Cracking VII.** Nov. 16, Chicago, Ill. Held during the FABTECH International & AWS Welding Show. Contact American Welding Society, call (800/305) 443-9353, ext. 455; or visit www.aws.org.

♦ **Welding Chrome-Moly Steels Conf.** Nov. 17, Chicago, Ill. Held during the FABTECH International & AWS Welding Show. Contact American Welding Society, call (800/305) 443-9353, ext. 455; or visit www.aws.org.

♦ **Welding Corrosion-Resistant Alloys Conf.** Nov. 18, Chicago, Ill. Held during the FABTECH International & AWS Welding Show. Contact American Welding Society, call (800/305) 443-9353, ext. 455; or visit www.aws.org.

9th Int’l Welding Conf. and Expo. Dec. 1–3, World Trade Center, Yekaterinburg, Russian Federation. Visit www.uv2000.ru.

♦ **Power-Gen Int’l.** Dec. 8–10, Las Vegas, Nev. Contact American Welding Society, call (800/305) 443-9353, ext. 455; or visit www.aws.org.

Int’l Hardware Fair Cologne 2010. Feb. 28.–March 3, Cologne, Germany. Visit www.hardwarefair.com.

PICALO 2010, Pacific Int’l Conf. on Applications of Lasers and Optics. March 23–25, Shangri-La Hotel, Wuhan, P. R. China. Visit www.laserinstitute.org.

WESTEC 2010. March 23–25, Los Angeles Convention Center, Los Angeles, Calif. Visit www.westeconline.com.

Micromanufacturing & Nanomanufacturing Conf. and Exhibits. April 14, 15, Hilton Phoenix East/Mesa, Mesa, Ariz. Visit www.sme.org/micro and www.sme.org/nanomanufacturing.

The Japan Int’l Welding Show 2010. April 21–24, Tokyo Big Sight, Tokyo, Japan. Organized by The Japan Welding Engineering Society and Sampo Publications. Visit www.weldingshow.jp/english.

Montreal Manufacturing Technology Show. May 18–20, Place Bonaventure, Montreal, Que., Canada. Visit www.mmts.ca.

Rapid Conf. & Expo and 3D Imaging Conf. May 18–20, Disneyland Resort Anaheim, Anaheim, Calif. Visit www.sme.org/rapid.

EASTEC 2010. May 25–27, Eastern States Exposition, West Springfield, Mass. Visit www.easteconline.com.

♦ **LÖT 2010, 9th Int'l Conf. on Brazing, High-Temperature Brazing, and Diffusion Bonding.** June 15–17, Aachen, Germany. Sponsored by DVS (German Welding Society), cosponsored by AWS, ASM Int'l, and other societies. Visit www.dvs-ev.de/loet2010.

21st World Energy Congress. Sept. 12–16, 2010, Palais des Congrès, Montreal, Que., Canada. Visit <http://montreal2010.ca>.

EuroBLECH 2010, 21st Int'l Sheet Metal Working Technology Exhibition. Oct. 26–30, 2010, Exhibition Grounds, Hanover, Germany. Visit www.euroblech.com.

♦ **FABTECH International & AWS Welding Show including METALFORM.** Nov. 2–4, 2010, Georgia World Congress Center, Atlanta, Ga. This show is the largest event in North America dedicated to showcasing the full spectrum of metal forming, fabricating, tube and pipe, welding equipment, and technology. Contact American Welding Society, (800/305) 443-9353, ext. 455; or visit www.aws.org.

13th Int'l Symposium on Tubular Structures. Dec. 15–17, 2010, Hong Kong. Sponsored by the Subcommittee for Tubular Structures XV-E of the IIW. Visit www.hku.hk/civil/ISTS13.com.

♦ **Fray Int'l Symposium on Metals and Materials Processing in a Clean Environment.** Dec. 4–7, 2011, Hilton Cancun Golf & Spa Resort, Cancun, Mexico. Sponsored by the American Welding Society and many other technical organizations. Visit www.flogen.com/FraySymposium, or e-mail Chairman Florian Kongoli fkongoli@flogen.com.

Educational Opportunities

ASM Int'l Courses. Numerous classes on welding, corrosion, failure analysis, metallography, heat treating, etc., presented in Materials Park, Ohio, online, webinars, on-site, videos, and DVDs. Visit www.asminternational.org, search for “courses.”

Automotive Body in White Training for Skilled Trades and Engineers. Orion, Mich. A five-day course covers operations, troubleshooting, error recovery programs, and safety procedures for automotive lines and integrated cells. Contact Applied Mfg. Technologies, (248) 409-2000, www.appliedmfg.com.

Basics of Valves and Actuators Seminars and Expo. Oct. 29, Sheraton Houston Brookhollow Hotel, Houston, Tex. Sponsored by Valve Manufacturers Assn. Visit <http://vma.yourmembership.com/?valvebasics>.

Basic and Advanced Welding Courses. Cleveland, Ohio. Contact The Lincoln Electric Co. for schedules, www.lincolnelectric.com.

Boiler and Pressure Vessel Inspectors Training Courses and Seminars. Columbus, Ohio. Call (614) 888-8320; visit www.nationalboard.org.

CWI/CWE Course and Exam. Troy, Ohio. This is a ten-day program. Contact Hobart Institute of Welding Technology, (800) 332-9448, www.welding.org/technical/schedule2008.html.

CWI/CWE Prep Course and Exam and NDT Inspector Training Courses. An AWS Accredited Testing Facility. Courses held year-

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Visit www.welding.org for course dates



or call
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For info go to www.aws.org/ad-index

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round in Allentown, Pa., and at customers' facilities. Contact: Welder Training & Testing Institute, (800) 223-9884, info@wtti.edu; visit www.wtti.edu.

CWI Preparatory and Visual Weld Inspection Courses. Classes presented in Pascagoula, Miss., Houston, Tex., and Houma and Sulphur, La. Contact: Real Educational Services, Inc., (800) 489-2890, info@reaeducational.com.

Environmental Online Webinars. Free, online, real-time seminars conducted by industry experts. For topics and schedule, visit www.augustmack.com/Web%20Seminars.htm.

EPRI NDE Training Seminars. EPRI offers NDE technical skills training in visual examination, ultrasonic examination, ASME Section XI, and UT operator training. Contact Sherryl Stogner, (704) 547-6174; sstogner@epri.com.

Essentials of Safety Seminars. Two- and four-day courses are held at numerous locations nationwide to address federal and California OSHA safety regulations. Contact American Safety Training, Inc., (800) 896-8867, www.trainosha.com.

Fabricators and Manufacturers Assn. and Tube and Pipe Assn. Courses. Call (815) 399-8775; visit www.fmanet.org.

Firefighter Hazard Awareness Online Course. A self-paced, ten-module certificate course taught online by fire service professionals. Fee is \$195. Contact Industrial Scientific Corp., (800) 338-3287; www.indsci.com.

Gas Detection Made Easy Courses. Online and classroom courses for managing a gas monitoring program from gas detection to confined-space safety. Contact Industrial Scientific Corp., (800) 338-3287; www.indsci.com.

Geometric Dimensioning & Tolerancing Seminar. Nov. 30, Dec. 1, Chicago, Ill.; Dec. 3, 4, St. Louis, Mo. Visit www.hightechnologyseminars.com.

Hellier NDT Courses. Contact Hellier, 277 W. Main St., Ste. 2, Niantic, CT 06357; (860) 739-8950; FAX (860) 739-6732.

Inspection Courses on ultrasonic, eddy current, radiography, dye penetrant, magnetic particle, and visual at Levels 1-3. Meet SNT-TC-1A and NAS-410 requirements. Contact TEST NDT, LLC, (714) 255-1500, www.testndt.com.

Laser Safety Online Courses. Courses include Medical Laser Safety Officer, Laser Safety Training for Physicians, Industrial Laser Safety, and Laser Safety in Educational Institutions. Contact Laser Institute of America, (800) 345-3737, or visit www.laserinstitute.org.

Laser Safety Training Courses. Courses based on ANSI Z136.1, *Safe Use of Lasers*, presented in Orlando, Fla., or at customer's site. Contact Laser Institute of America, (800) 345-3737, www.laserinstitute.org.

Lyncole XIT™ Grounding Course. Training to protect facilities and equipment from power surges. Oct. 15, 16, Las Vegas, Nev. Contact: (800) 962-2610; Education@Lyncole.com; or visit www.lyncle.com.

Machine Safeguarding Seminars. Contact Rockford Systems, Inc., (800) 922-7533, www.rockfordsystems.com.

Machining and Grinding Courses. Contact TechSolve, www.TechSolve.org.

Motorsports Welding School Advanced Materials Courses. Cleveland, Ohio. Oct. 12-16, Dec. 7-11. Contact The Lincoln Electric Co., www.lincolnelectric.com.

Motorsports Welding School Basic Materials Courses. Cleveland, Ohio. Oct. 5-9, Nov. 9-13, Nov. 30-Dec. 4. Contact The Lincoln Electric Co., www.lincolnelectric.com.

NACE Int'l Training and Certification Courses. Contact National Assoc. of Corrosion Engineers, (281) 228-6223, www.nace.org.

NDE and CWI/CWE Courses and Exams. Allentown, Pa., and at customers' locations. Contact Welder Training and Testing Institute, (800) 223-9884, www.wtti.edu.

Pipe Welding. Cleveland, Ohio. Three-week-long course begins Oct. 26. Contact The Lincoln Electric Co., www.lincolnelectric.com.

Plastics Welding School. A two-day, hands-on course for certification to European DVS-approved plastics welding standards for hot gas and extrusion techniques. Contact Malcom Hot Air Systems, www.plasticweldingtools.com.

Protective Coatings Training and Certification Courses. At various locations and online. Contact The Society for Protective Coatings. Call (877) 281-7772, www.sspc.org.

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For info go to www.aws.org/ad-index

AWS Certification Schedule

Certification Seminars, Code Clinics and Examinations

Application deadlines are six weeks before the scheduled seminar or exam. Late applications will be assessed a \$250 Fast Track fee.

Certified Welding Inspector (CWI)

LOCATION	SEMINAR DATES	EXAM DATE
Atlanta, GA	Nov. 1-6	Nov. 7
Dallas, TX	Nov. 1-6	Nov. 7
Sacramento, CA	Nov. 1-6	Nov. 7
Spokane, WA	Nov. 1-6	Nov. 7
Corpus Christi, TX	EXAM ONLY	Nov. 21
St. Louis, MO	EXAM ONLY	Dec. 5
Syracuse, NY	Dec. 6-11	Dec. 12
Reno, NV	Dec. 6-11	Dec. 12
Miami, FL	Dec. 6-11	Dec. 12
Fresno, CA	Jan. 10-15, 2010	Jan. 16, 2010
Beaumont, TX	Jan. 10-15	Jan. 16
Corpus Christi, TX	EXAM ONLY	Jan. 23
Miami, FL	Jan. 24-29	Jan. 30
Albuquerque, NM	Jan. 31-Feb. 5	Feb. 6
Pittsburgh, PA	Jan. 31-Feb. 5	Feb. 6
Denver, CO	Jan. 31-Feb. 5	Feb. 6
Seattle, WA	Jan. 31-Feb. 5	Feb. 6
Miami, FL	EXAM ONLY	Feb. 25
Birmingham, AL	Feb. 21-26	Feb. 27
Long Beach, CA	Feb. 21-26	Feb. 27
Milwaukee, WI	Feb. 28-Mar. 5	Mar. 6
Atlanta, GA	Feb. 28-Mar. 5	Mar. 6
San Diego, CA	Feb. 28-Mar. 5	Mar. 6
Houston, TX	Mar. 7-12	Mar. 13
Norfolk, VA	Mar. 7-12	Mar. 13
Perrysburg, OH	EXAM ONLY	Mar. 13
Indianapolis, IN	Mar. 14-19	Mar. 20
Portland, OR	Mar. 14-19	Mar. 20
Miami, FL	EXAM ONLY	Mar. 18
Rochester, NY	EXAM ONLY	Mar. 20
Corpus Christi, TX	EXAM ONLY	Mar. 20
Boston, MA	Mar. 21-26	Mar. 27
Phoenix, AZ	Mar. 21-26	Mar. 27
Anchorage, AK	Mar. 21-26	Mar. 27
Chicago, IL	Mar. 21-26	Mar. 27
York, PA	EXAM ONLY	Mar. 27
Miami, FL	Mar. 28-Apr. 2	Apr. 3
Dallas, TX	Apr. 11-16	Apr. 17
Knoxville, TN	EXAM ONLY	Apr. 17
Springfield, MO	Apr. 18-23	Apr. 24
Mobile, AL	EXAM ONLY	Apr. 24
St. Louis, MO	EXAM ONLY	Apr. 24
Portland, ME	Apr. 25-30	May 1
Las Vegas, NV	Apr. 25-30	May 1
Waco, TX	EXAM ONLY	May 1
Baton Rouge, LA	May 2-7	May 8
San Francisco, CA	May 2-7	May 8
Nashville, TN	May 9-14	May 15
Jacksonville, FL	May 9-14	May 15
Baltimore, MD	May 9-14	May 15
Corpus Christi, TX	EXAM ONLY	May 15
Detroit, MI	May 16-21	May 22
Miami, FL	May 16-21	May 22
Albuquerque, NM	May 16-21	May 22
Long Beach, CA	EXAM ONLY	May 29
Spokane, WA	Jun. 6-11	Jun. 12
Oklahoma City, OK	Jun. 6-11	Jun. 12
Birmingham, AL	Jun. 6-11	Jun. 12

9-Year Recertification Seminar for CWI/SCWI

LOCATION	SEMINAR DATES	EXAM DATE
Miami, FL	Nov. 30-Dec. 5	NO EXAM
New Orleans, LA	Jan. 11-16, 2010	NO EXAM
Denver, CO	Feb. 22-27	NO EXAM
Dallas, TX	Mar. 15-20	NO EXAM
Miami, FL	Apr. 12-17	NO EXAM
Sacramento, CA	May 3-8	NO EXAM
Pittsburgh, PA	Jun. 7-12	NO EXAM

For current CWIs and SCWIs needing to meet education requirements without taking the exam. If needed, recertification exam can be taken at any site listed under Certified Welding Inspector.

Certified Welding Supervisor (CWS)

LOCATION	SEMINAR DATES	EXAM DATE
Long Beach, CA	Nov. 30-Dec. 4	Dec. 5
Atlanta, GA	Jan. 25-29, 2010	Jan. 30, 2010
New Orleans, LA	Apr. 19-23	Apr. 24
Miami, FL	Sept. 13-17	Sept. 18

CWS exams are also given at all CWI exam sites.

Certified Radiographic Interpreter (CRI)

LOCATION	SEMINAR DATES	EXAM DATE
Miami, FL	Feb. 1-5, 2010	Feb. 6, 2010
Miami, FL	Mar. 8-12	Mar. 13
Miami, FL	Apr. 19-23	Apr. 24
Miami, FL	Jun. 21-25	Jun. 26
Miami, FL	Jul. 26-30	Jul. 31

Radiographic Interpreter certification can be a stand-alone credential or can exempt you from your next 9-Year Recertification.

Certified Welding Sales Representative (CWSR)

LOCATION	SEMINAR DATES	EXAM DATE
Chicago, IL	Nov. 16-18	Nov. 18
Los Angeles, CA	Jan. 28-30, 2010	Jan. 30, 2010
Miami, FL	Feb. 25-27	Feb. 27
Houston, TX	Apr. 1-3	Apr. 3
Miami, FL	May 6-8	May 8
Chicago, IL	Jun. 10-12	Jun. 12
Miami, FL	Aug. 26-28	Aug. 28

CWSR exams will also be given at CWI exam sites.

Certified Welding Educator (CWE)

Seminar and exam are given at all sites listed under Certified Welding Inspector. Seminar attendees will not attend the Code Clinic portion of the seminar (usually first two days).

Senior Certified Welding Inspector (SCWI)

Exam can be taken at any site listed under Certified Welding Inspector. No preparatory seminar is offered.

Certified Welding Engineer (CWEEng)

Exam can be taken at any site listed under Certified Welding Inspector. No preparatory seminar is offered. Two exam days are necessary for this certification.

Certified Robotic Arc Welding (CRAW)

LOCATION	WEEK OF:	CONTACT
Lincoln Electric, Cleveland, OH	Oct. 19	(216) 383-8542
ABB, Inc., Auburn Hills, MI	Nov. 2	(248) 391-8421
Wolf Robotics, Ft. Collins, CO	Nov. 2	(970) 225-7736
ABB, Inc., Auburn Hills, MI	Dec. 14	(248) 391-8421
Wolf Robotics, Ft. Collins, CO	Dec. 14	(970) 225-7736

International CWI Courses and Exams

AWS training and certification for CWI and other programs are offered in many countries. For international certification program schedules and contact information, please visit http://www.aws.org/certification/inter_contact.html



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For information on any of our seminars and certification programs, visit our website at www.aws.org/certification or contact AWS at (800) 443-9353, Ext. 273 for Certification and Ext. 455 for Seminars. Please apply early to save Fast Track fees. This schedule is subject to change without notice. Please verify the dates with the Certification Dept. and confirm your course status before making final travel plans.

WELDING

WORKBOOK

Datasheet 309

Tips for Fusion Welding of Aluminum

- When loading “preweld cleaned” details or assemblies into welding fixtures, avoid contamination of the weld zone. For example, do not allow the clean weld edge to scrape the copper hold-down bars or fingers. Clean, lint-free or low-lint gloves should be used when touching weld zones.
- Just prior to welding, it is recommended to vacuum the weld zone with a shop vacuum cleaner fitted with a clean stainless steel tip. Do not clean by blowing air because besides producing potential contamination, the forced air may push contaminants into crevices or open joints.
- Minimize the number of tack welds. Each tack weld adds an additional start and stop area to the final weld. Starts and stops are prone to defects.
- Runoff weld tabs for starting and stopping butt joint welds should be utilized whenever possible. The tab material should be built into the details and may be removed after completion of the weld. If this is not possible, tabs may be added to the details by welding with the same quality procedures as the final weld. This will provide a uniform thermal transfer minimizing meltbacks and holes at the tab-to-part intersections — Fig. 1.
- Ideally, run-on/run-off weld tab material is provided as excess material on the details prior to welding, as shown in Fig. 1A. When this isn't practical, weld tabs can be added as shown in Fig. 1B–E. Remember the following:
 - 1) Preweld cleaning, scraping, and weld quality should be similar to that of the production part.
 - 2) Tab welds should be terminated on the tabs.
 - 3) Tab welds should have complete penetration if required on the production weld.
 - 4) Excess tab weld metal reinforcement should be flush to the detail surface so it won't interfere with production tooling and will provide thermal transfer.
 - 5) Weld tabs should not be removed until after the production weld is accepted.
- Soot removal from tack welds may be accomplished utilizing a clean, 18-8 stainless steel wire brush. Brushing should be performed manually. Do not use rotary brushing. Technique is critical. Use the stainless steel tipped vacuum while brushing. Manually brush from the beginning or end of the tack toward the center of the tack weld and vacuum tip, avoiding pushing the smut or dirt into the open joint — Fig. 2.
- Weld travel should be delayed until the desired penetration and surface weld width are achieved. Start diameters should not exceed the weld bead width. The current slope time of the amperage to welding current should be short. When filler metal is employed it should be fed into the leading edge of the weld pool and kept within the shielding of the torch gas.
- When terminating the weld, the molten pool should be solidified prior to terminating the arc.
- Extinguishing the arc at welding current will result in craters and crater cracks. When cold wire feed is used the wire feed speed should be down sloped while doing the same with the current, but stopped prior to final solidification of the weld pool to prevent freezing the wire in the solidified weld. At weld arc termination, the welding torch should remain over the stop area during solidification with sufficient postflow gas time to allow the electrode to cool down within the protection of the gas shield. If the tungsten electrode is discolored, it may be due to insufficient postflow time.

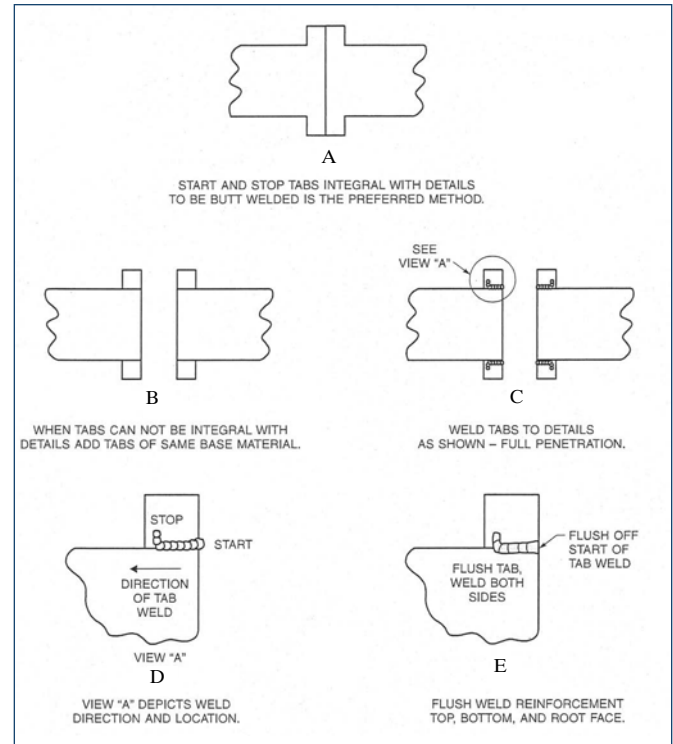


Fig. 1 — Start and stop run-on and run-off weld tabs.

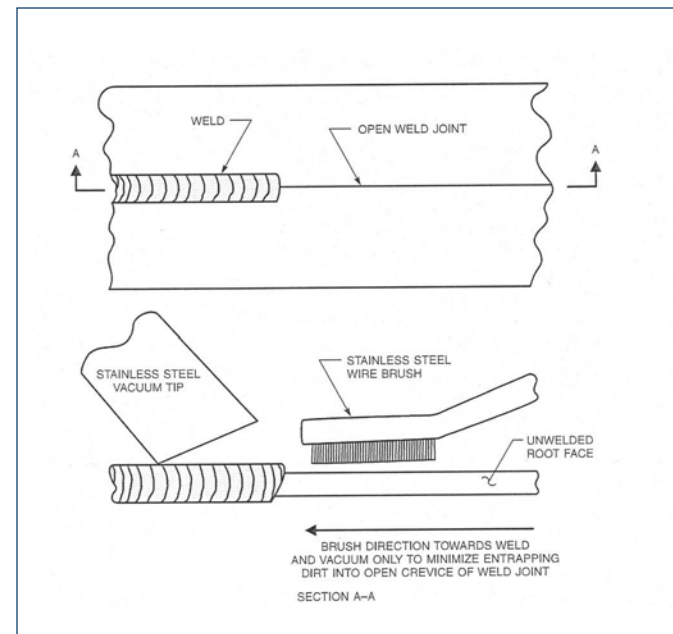


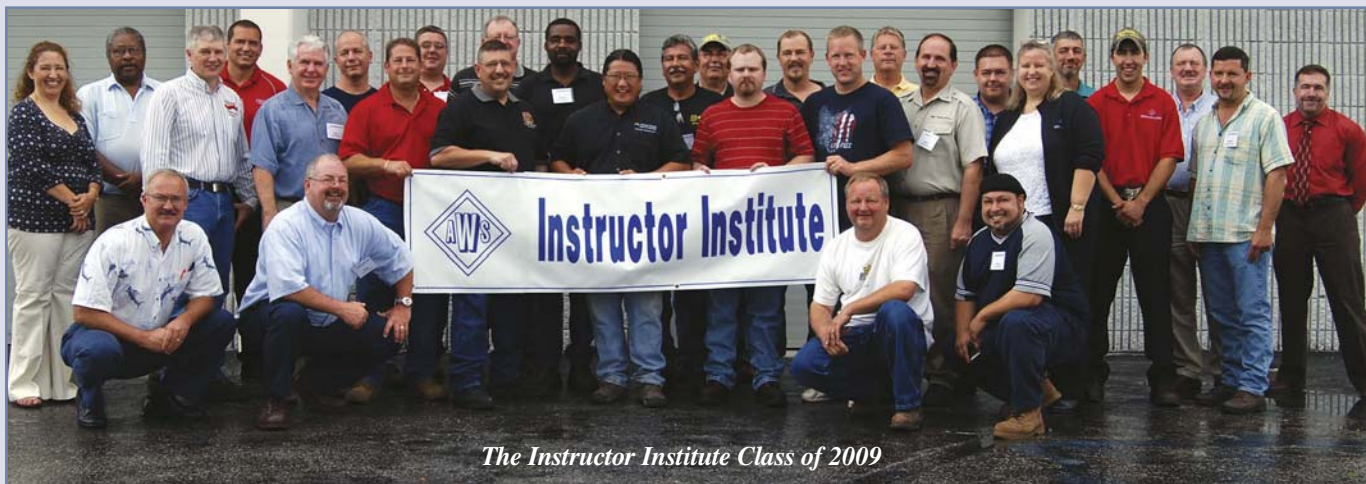
Fig. 2 — Method of utilizing an 18-8 stainless steel manual wire brush to remove soot and other debris from the surface of an open weld joint.

Excerpted from *The Practical Reference Guide for High-Quality Fusion Welding of Aluminum*.

SOCIETY NEWS

BY HOWARD M. WOODWARD

Educators Hone Skills at Annual Institute



The Instructor Institute Class of 2009

Welding educators nationwide met at AWS headquarters in Miami, Fla., July 29–31, for the 2009 Instructor Institute.

Conducting the training were Dr. **Ron Gilbert**, facilitator; past AWS President **Jim Greer**, who served as lab manager; and **Rick Polanin**, Dist. 13 director and a professor at Illinois Central College in East Peoria, Ill.

The manufacturers' representatives included **Jason Schmidt**, Lincoln Electric, Cleveland, Ohio; and **Jay Ginder** and **Tony Anderson**, ESAB Welding & Cutting Products, Florence, S.C.

The following welding educators participated in the event (their AWS District numbers are shown in parentheses): **John Morash** (1) Plymouth South High

School, Plymouth, Mass.; **Douglas Demarco** (2) NYC District Council Carpenters, Rethpage, N.Y.; **Daniel Millan** (3) Reading Muhlenberg CTC, Shillington, Pa.; **James Stallsmith** (5) Trident Technical College, Charleston, S.C.; **Shaun Lower** (6) UA #73, Oswego, N.Y.; **Brian Barnes** (7) Ivy Tech Community College, Bryan, Ohio; **Dale Kite** (9) George Stone Technical Center, Molino, Fla.; **Nick Baughman** (10) Coshocton County Career Center, Malvern, Ohio; **Tony Najor** (11) Lapeer Voc Tech Center, Emmett, Mich.; **Daniel Crifase** (12) Gateway Technical College, Silver Lakes, Wis.; **Mark Stevenson** (13) Kankakee Community College, Manteno, Ill.; **Rick Suria** (14) Hillsdale Fab-

ricators, St. Louis, Mo.; **Lee Larson** (15) North Dakota State College of Science, Fargo, N.Dak.; **Chris Beaty** (16) Metropolitan Community College, Omaha, Neb.; **Charles Credicott** (17) Tarrant County College, Benbrook, Tex.; **Hamp Drew** (18) St. Phillip's College, Sequin, Tex.; **Jeremy Dodge** (19) North Idaho College, Coeur d'Alene, Idaho; **Jeff Taniguchi** (20) Vernal, Utah; **Edward Hinajosa** (21) Wilmington Skills Center, San Pedro, Calif.; and **Melvin Johnson** (22) American River College, Sacramento, Calif.

AWS Educational Services supporting staff included **Dennis Marks**, managing director; **Paola Chacón**, event manager; and **Nichole Bradley**, manager.

Notice of Annual Meeting of the American Welding Society

The Annual Meeting of the members of the American Welding Society will be held on Monday, Nov. 16, 2009, beginning

at 9:00 AM at McCormick Place, Chicago, Ill. The regular business of the Society will be conducted, including election of offi-

cers and ten members of the Board of Directors. Any business properly brought before the membership will be considered.

Nominations Sought for National Officers

AWS members who wish to nominate candidates for President, Vice President, and Director-at-Large on the AWS Board of Directors for the term starting Jan. 1, 2011, may

1) Send their nominations electronically by Oct. 5, 2009, to Gricelda Manalich at gricelda@aws.org, c/o Gene E. Lawson, chairman, National Nominating Commit-

tee, or

2) Present their nominations in person at the open session of the National Nominating Committee meeting scheduled for 2:00 to 3:00 PM, Tuesday, November 17, 2009, at McCormick Place, Chicago, Ill., during the 2009 FABTECH International & AWS Welding Show. Nominations must be accompanied by biographical material

on each candidate, including a written statement by the candidate as to his or her willingness and ability to serve if nominated and elected, letters of support, plus a 5×7-inch head-and-shoulders color photo. Note: Persons who present their nominations at the Show must provide 20 copies of the biographical materials and written statement.

Member-Get-A-Member Campaign

Listed are the members participating in the 2009–2010 Member-Get-A-Member Campaign. See page 69 in this *Welding Journal* for campaign rules and prize list, or visit www.aws.org/mgm. These standings are as of July 21, 2009. Call the AWS Membership Dept. (800/305) 443-9353, ext. 480, if you have questions about your status.

Winner's Circle

Sponsored 20+ new members.

The superscript indicates the number of times the member has achieved Winner's Circle status since June 1, 1999.

J. Compton, San Fernando Valley⁷
E. Ezell, Mobile⁷
J. Merzthal, Peru²
G. Taylor, Pascagoula²
L. Taylor, Pascagoula²
S. Esders, Detroit¹
M. Haggard, Inland Empire¹
M. Karagoulis, Detroit¹
S. McGill, NE Tennessee¹
B. Mikeska, Houston¹

W. Shreve, Fox Valley¹
T. Weaver, Johnstown/Altoona¹
G. Woomey, Johnstown/Altoona¹
R. Wray, Nebraska¹

President's Guild

Sponsored 20 or more new members.

V. Craven, Pascagoula — 29

President's Roundtable

Sponsored 9–19 new members.

H. Thompson, New Orleans — 9

President's Club

Sponsored 3–8 new members.

R. Ellenbecker, Connecticut — 8
S. Keskar, India — 4
E. Ravelo, International — 4

President's Honor Roll

Sponsored 2 new members.

J. Barber, Connecticut
G. Burrion, South Florida
J. Compton, San Fernando Valley
R. Davis, Utah
G. Euliano, Northwestern Pennsylvania
M. Haynes, Niagara Frontier

J. Hope, Puget Sound
D. Mandina, New Orleans

Student Member Sponsors

C. Rogers, San Antonio — 29
J. Morash, Boston — 27
S. Burdge, Stark Central — 20
R. Evans, Siouxland — 20
E. Norman, Ozark — 20
V. Facchiano, Lehigh Valley — 19
A. Duron, New Orleans — 18
D. Berger, New Orleans — 17
G. Seese, Johnstown-Altoona — 16
A. Stute, Madison-Beloit — 15
R. Munns, Utah — 14
S. Kuntz, Pittsburgh — 10
R. Rummel, Central Texas — 10
W. Garrett, Olympic — 7
D. Vranich, North Florida — 5
J. Fitzpatrick, Arizona — 4
D. Kowalski, Pittsburgh — 4
S. MacKenzie, Northern Michigan — 4
N. Carlson, Idaho/Montana — 3
R. Hutchison, Long Beach/Or. Cty. — 3

2009 District and Section Awardees Announced

Section Meritorious

District — Awardee — Section Name

2 Ken Messemer, Long Island
3 Justin Heistand, Lancaster
4 Roger Snider, SW Virginia
4 Bill Rhodes, SW Virginia
4 Craig Streif, Charlotte
4 Russell Wahrman, Triangle
6 Fred Schmidt, Niagara Frontier
6 Ken Hammond, Niagara Frontier
6 Robert Christoffe, Northern New York
6 Robert Davis, Syracuse
8 Bill Warwick, NE Tennessee
8 Tim Singleton, NE Tennessee
9 Mike Barnett, Mobile
9 Travis Moore, New Orleans
9 Anthony Blakeney, Baton Rouge
9 Tom Shelton, Baton Rouge
9 Gary Owens, Baton Rouge
9 Darren Haas, Pascagoula
9 Charles Everett, Pascagoula
9 Jim Cooley, Birmingham
9 Charles Lewis, Acadiana
10 Bob Brenner, Stark Central
10 Ward Kiser, Drake Well
14 Curt Eggen, St. Louis
14 Scott Zimmer, St. Louis
14 John Myers, Indiana
14 Tim Neubauer, Sangamon Valley
15 Dan Johnson, Northwest
15 Paul Carter, Northwest
16 Jim King, Eastern Iowa
16 Wayne Burns, Iowa
17 Virginia Fagan, Ozark
17 Chris Wright, North Texas
17 Chris Layton, Central Arkansas
17 Angela Harrison, Central Arkansas
17 Aaron Campbell, Central Arkansas
17 Kevin Sava, Central Arkansas
17 Dan Bricker, East Texas
18 James Bobo, Lake Charles

18 Christopher Long, Corpus Christi
18 Rick Yniguez, Corpus Christi
18 Mike Huelskamp, Corpus Christi
18 Derek Stelly, Houston
18 Danny Castro, Houston
18 Sudhanshu Ogale, Sabine
18 Richard Salinas, Rio Grande Valley
18 George Baldree, Rio Grande Valley
18 Howard Thomas, San Antonio
18 Hamp Drew, San Antonio
19 Jerry Hope, Puget Sound
20 David Drake, Albuquerque
20 John Morrison, Idaho/Montana
20 Tim McJunkin, Idaho/Montana
20 Richard Dean, Idaho/Montana
20 Adam Johnson, Utah
20 Paul Dowling, Utah
20 Robert McGee, Wyoming
22 Jerry Azzaro, San Francisco
22 Sharon Jones, San Francisco
22 Don Robinson, Sacramento
22 Matt Wysocki, Sacramento
22 Alex Gutierrez, Santa Clara Valley

District Meritorious

2 Brian Cassidy, Long Island
4 Gary Stilner, Tidewater
4 Lynn Showalter, Tidewater
5 Norman Zappa, Atlanta
6 Neal Chapman, Syracuse
6 William Brooks, Chattanooga
8 Wallace Honey, NE Mississippi
8 Bob Fellers, Western Carolina
9 Cynthia Harris, Pascagoula
12 Rob Stinson, Madison-Beloit
12 John F. Hinrichs, Milwaukee
14 Richard Alley, Indiana
14 Gailyn Cornell, St. Louis
15 Todd Bridgum, Northwest
15 Ike Oguocha, Saskatoon
16 Jim King, Eastern Iowa

16 Wayne Burns, Iowa
17 Robert White, Central Texas
17 Adam Esminger, Tulsa
18 Saty Sagu, Houston
18 Derek Stelly, Houston
18 Glynn Savage, Sabine
19 Jerry Hope, Puget Sound
20 Bruce Madigan, Idaho/Montana
20 Patrick Mulville, Southern Colorado
21 Stan Luis, California Central Coast
22 Kerry Shatell, Sacramento Valley
22 Tom Smeltzer, San Francisco

Section Educator

4 Lori Safrit, Charlotte
4 Ray Sosko, Charlotte
4 Jon Cookson, Tidewater
4 Russell Wahrman, Triangle
6 Don Schucknecht, Niagara Frontier
6 Tom Bryant, Syracuse
6 Tim Howell, Syracuse
8 Bobby Graham, NE Mississippi
8 Robin Dykes, Chattanooga
9 Larry Porter, Pascagoula
9 Chevis Necaie, Pascagoula
9 Darren Haas, Pascagoula
9 Chris Weber, New Orleans
9 William Wilson, New Orleans
9 Lane Beard, Baton Rouge
9 Dawn Dowling, Baton Rouge
9 Kevin Crovetto, Baton Rouge
9 Arthur Savoy, Acadiana
9 Tommy Smith, Acadiana
9 Roy Ledford, Birmingham
11 Nick Regets, Detroit
11 Jay Jezzylo, Upper Peninsula
13 Curt Rippey, Peoria
13 Shane Seals, Peoria
14 John Crager, Indiana
14 Steve Wilson, St. Louis
18 Edwin Riveva, Rio Grande Valley

18 Mike Mylnar, Corpus Christi
 18 John McKeehan, Sabine
 20 John Steele, Colorado
 20 Kevin Fox, Wyoming
 20 Carl Schiner, Wyoming
 20 Kyle Gillespie, Idaho/Montana
 20 Jeremy Phillipson, Utah
 20 Roger Wolfe, Southern Colorado
 21 Mary Means, L.A./Inland Empire
 21 Ray Snowden, California Central Coast
 21 George Moore, San Diego
 22 Mark Feuerbach, Sacramento Valley
 22 Emmanuel Ezenwa, Sacramento Valley
 22 David Noret, San Francisco

District Educator

1 John Fusco, Boston
 1 Jonathan Theberge, Maine
 4 Ed Dupree, Tidewater
 4 Teresa Williams, Northeastern Carolina
 4 Roy Lanier, Northeastern Carolina
 4 Chris Overfelt, SW Virginia
 4 James Stump, SW Virginia
 5 Curtis Warren, N. Central Florida
 8 Gary Gammill, NE Mississippi
 8 Jeff Hankins, NE Tennessee
 9 Dale Box, Pascagoula
 9 Tony Hopper, Mobile
 11 Jeff Carney, Western Michigan
 11 Larry Blake, NW Ohio
 12 Larry Bowers, Madison-Beloit
 12 Bob Ellenbecker, Fox Valley
 13 Mark Stevenson, J.A.K.
 14 Rick Ferguson, Indiana
 14 John Biama, St. Louis
 15 Todd Hankel, Northwest
 15 Loren Kantola, Arrowhead
 16 Kyle Kopsa, Kansas
 17 Paul Staglin, North Texas
 17 Jim Bridwell, Ozark
 18 Wayne Knuppel, Houston
 20 Mike Tryon, Utah
 20 Henry Wahl, Wyoming
 21 Ray Snowden, California Central Coast
 21 Jack Compton, San Fernando Valley
 22 Frank Ramos, Sacramento Valley
 22 Mark Reese, Sacramento Valley

Section CWI of the Year

4 Marvin Tyler, Triangle
 6 Vincent Carnifax, Syracuse
 8 Jason West, Chattanooga
 8 Randy Hammond, Greater Huntsville

9 Chevis Necaise, Pascagoula
 9 Perry Theriot, Baton Rouge
 9 Duran Denham, Baton Rouge
 9 John Pajak, New Orleans
 9 Aldo Duron, New Orleans
 10 Dan Feuerstein, Cleveland
 11 Dick West, NW Ohio
 14 Daniel L. Wiegand, St. Louis
 14 Charles W. Wandling, St. Louis
 14 Tony Brosio, Indiana
 15 Doug Mroz, Arrowhead
 16 Rick Guffey, Iowa
 16 Dennis Wright, Kansas City
 16 T. A. Bischoff, Kansas
 17 Jimmy Brewer, Central Arkansas
 17 John Marx, Oklahoma City
 17 Howard Record, East Texas
 18 Richard Marslender, Corpus Christi
 18 Mike Rollins, Corpus Christi
 18 Jose Delgado, Rio Grande Valley
 18 Grant Peltier, Houston
 19 Sidney Capouilliez, Puget Sound
 20 Wade Lutz, Colorado
 20 Michael Rinow, Colorado
 20 Kim Despain, Utah
 20 Reece McFadden, Utah
 20 Kelly Bennett, Utah
 20 Craig Bush, Wyoming
 20 Sherman Butler, Idaho/Montana
 20 Alma Olsen, Idaho/Montana
 22 Brian Rogers, San Francisco
 22 David Aultman, San Francisco

District CWI of the Year

1 Kevin DeSousa, Boston
 2 Harland W. Thompson, Long Island
 4 Jeff Martin, Charlotte
 4 Kevin Schafer, Triangle
 5 Carl Matricardi, Atlanta
 6 Bill Davis, Syracuse
 6 Doug Tanner, Northern New York
 6 Stewart Harris, Triangle
 8 Bob O'Neal, Nashville
 9 Dawn Dowling, Baton Rouge
 9 Forrest Schoop, Baton Rouge
 9 Mark Kevin Spencer, Baton Rouge
 9 Larry Porter, Pascagoula
 10 Huck Hughes, Mahoning Valley
 10 Ken Kasnyik, Cleveland
 12 Dale Holschbach, Lakeshore
 14 Bruce Craig, Indiana
 14 Michael Kamp, St. Louis
 14 Tony Brosio, Indiana

16 Rick Guffey, Iowa
 16 Dennis Wright, Kansas City
 17 Tom Moffitt, Tulsa
 18 Justin Gordy, Houston
 18 Kevin Hebert, Lake Charles
 18 John Husfeld, Houston
 19 Sidney Capouilliez, Puget Sound
 20 Michael Thomas, Albuquerque
 20 Jim Eubanks, Colorado
 21 George Rolla, L.A./Inland Empire
 21 Mark Bell, San Diego
 21 Mark Hayes, Nevada
 22 Frank Ramos, Sacramento Valley
 22 Mark Reese, Sacramento Valley

Section Private Sector Instructor

1 Thomas Ferri, Boston
 2 Thomas Gartland, Long Island
 4 Jesse O'Neal, Triangle
 8 Rodney Patterson, Nashville
 9 Carey Addison, New Orleans
 9 Ed Dixon, New Orleans
 9 Linda Taylor, Pascagoula
 9 Gerald Taylor, Pascagoula
 10 Lon Damon, Cleveland
 14 Jeff Cooper, Sangamon Valley
 14 Larry Elms, St. Louis
 16 Wayne Seitz, Nebraska
 17 Aaron Campbell, Central Arkansas
 17 Gene Norwood, Tulsa
 18 Thomas Solano, Corpus Christi
 18 Rick Ford, Corpus Christi
 18 Morris Weeks, Sabin
 20 Alan Barber, Colorado
 20 David Murphy, Colorado
 22 Liisa Pine Schoonmaker, San Francisco

District Private Sector Instructor

4 Steve Gore, Charlotte
 5 Michael Bannister, N. Central Florida
 9 James Smith, Mobile
 9 Roy Lerille, New Orleans
 10 Travis Crate, Drake Well
 10 Scott Burdge, Stark Central
 12 Dan Crifase, Racine-Kenosha
 12 Jim Renner, Upper Peninsula
 13 William Enright, Chicago
 14 Gary Dugger, Indiana
 14 Frank Slinkard, St. Louis
 17 Jamie Pearson, North Texas
 17 Robert Warke, East Texas
 20 Todd Anderson, Utah
 20 Mark Trevithick, Colorado

District Director Awardees Named

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

Roy Lanier, District 4 director, nominated the following for this award:

Stewart Harris, Triangle
 Jesse O'Neal, Triangle
 Marvin Tyler, Triangle
 Russell Wahrman, Triangle
 Kevin Shaffer, Triangle
 Jon Cookson, Tidewater

Ed Dupree, Tidewater
 Lynn Showalter, Tidewater
 Steve Gore, Charlotte
 Jeff Martin, Charlotte
 Lori Safrin, Charlotte
 Ray Sosko, Charlotte
 Gary Stiltner, Charlotte
 Roy Lanier, NE Carolina
 Teresa Williams, NE Carolina
 James A. Stump, SW Virginia

Richard Harris, District 10 director, nominated the following for this award:
 Mike Owens, Drake Well

Jason Fry, Drake Well
 Chuck Moore, Mahoning Valley
 Harry Sadler, Cleveland
 Mark Demchak, Cleveland

Neil Shannon, District 19 director, has nominated the following for this award:

Mike Yung, Portland
 Jerry Hope, Puget Sound
 Peter Macksey, Alaska

Dale Flood, District 22 director, has nominated the following for this award:
 Tom Smeltzer, San Francisco.

Tech Topics

Errata A5.12

AWS A5.12M/A5.12:2009 (ISO 6848:2004 MOD), *Specification for Tungsten and Oxide Dispersed Tungsten Electrodes for Arc Welding and Cutting*

The following errata have been identified and incorporated into the current reprint of this document.

Page 3, Table 1 — Chemical composition requirements for tungsten electrodes — Changed Principal oxide in second column from “La₂O₂” to “La₂O₃” at three places.

Page 13, Subclause B6.1, seventh line — Changed “Table A.1” to Table A.2”.

Page 14, Subclause B6.4, third line Changed “Table A.1” to Table A.2”.

Page 14, Subclause B7.2, fourth line — Changed “CeO” to “CeO₂”.

Official Interpretations D1.1

Subject: CVN and Tables 4.5, 4.6

Code Edition: D1.1:2006

Code Provision: Tables 4.5, 4.6

AWS Log: D1.1-06-06

Inquiry 1: Does Variable 27) of Table 4.5 supersede Variable 6) of Table 4.6 for all applications?

Response: No, see Clause 4.35.3

Inquiry 2: Does Variable 6) of Table 4.6 supersede Variable 27) of Table 4.5 only for WPSs tested with impacts?

Response: No, the supplementary essential variables are in addition to Table 4.5. See 4.35.3.

Subject: Welder Six Month Requirement

Code Edition: D1.1:2006

Code Provision: Subclause 4.1.3.1

AWS Log: D1.1-06-I08b

Inquiry 1: What specifically does the term a given process mean?

(a) Is a given process for D1.1 any welding process inclusive of other codes (e.g., D1.2, ASME code welding, etc.)?

(b) Is a given process inclusive of welding on other base metals (e.g., aluminum, stainless steels, etc.) using similar WPSs?

(c) Is a given process inclusive of any welding performed in the six month window including welding not done to recognized standards or codes or not done under some form of quality control?

Response: A given process of welding is the same welding process or processes used by the welder or welding operator for the original performance qualification.

(a) No. It is not “any process,” but only the process for which the welder or welding operator was qualified (e.g., SMAW, FCAW, etc.) and it may include welding with that qualified process to other codes.

(b) Yes, however a given process of welding means the physical act of welding by the welder or welding operator. It is not required that the welder or welding operator performs welding to the original qualification WPS or original base material.

(c) No. It is not “any welding,” but welding with the same process (e.g., SMAW, FCAW, etc.) for the employer regardless of the code or standard employed.

Inquiry 2: What specifically does engaged mean?

Response: To be engaged in a given process of welding means the physical act of welding by the welder or welding operator.

Subject: Fillet Weld Mechanical Properties

Code Edition: D1.1:2006

Code Provision: Clause 4.11

AWS Log: D1.1-06-I15b

Inquiry 1: Is it the intent of Clause 4.11 to require all welding consumables employed for fillet welds to be proven by the mechanical testing of a CJP or consumable verification weld?

Response: No, provided the welding consumable(s) complies with the Filler Metal Requirements listed in Table 3.1.

Inquiry 2: If the design of the structure requires Charpy V-notch impact testing is it a requirement to prove that fillet weld metal is compliant by impact testing a CJP or consumable verification weld?

Response: Yes. When contract documents require CVN impact testing, a procedure qualification by test including CVN tests is required. See AWS D1.1:2006 4.1.1.3 and 2.2.2. For qualification of fillet welds under Clause 4.11, this may be satisfied by CVN tests taken from consumable verification coupons.

Inquiry 3: Does Clause 4.11.3 also require supplementary essential variables (Table 4.7) to apply to fillet weld metal where the design requires impact testing?

Response: Yes, when contract documents require CVN impact testing. See 4.11.3(4) and 4.7.1.

Subject: Qualifying Two Processes on One Plate

Code Edition: D1.1:2006

Code Provision: Tables 4.2, 4.11

AWS Log: D1.1-06-I18b

Inquiry 1: Can I qualify two welding processes on one test plate?

Response: Yes.

Inquiry 2: Do I use the deposited weld metal thickness for each weld process to establish the range of thickness qualified?

Response: AWS D1.1:2006 does not address the range of qualified deposit thicknesses where more than one process is combined within the same test plate.

Subject: Limitation of Prequalified WPS Variables

Code Edition: D1.1:2008

Code Provision: Clause 3.6, Table 4.5

AWS Log: D1.1-08-I01

Inquiry 1: If the 4 variables are listed on the Prequalified WPS without qualification testing how does one select the value to be used to generate the required range?

Response: Selection of the parameters listed in AWS D1.1:2008 Clause 3.6(1), (2), (3), and (4) for use on the WPS is at the discretion of the contractor. The parameters listed on the WPS shall be within the recommendations of the electrode manufacturer and any other limits put forth by Clause 3 and Clause 5 of this code.

Inquiry 2: Should a mean value be selected based on the wide ranges given by the electrode manufacturer, and known by the user to produce sound welding performance in their shop, after which the ranges required by Table 4.5 may be developed and listed on the prequalified WPS?

Response: A range may be established as described in Inquiry 2 or a narrower range may be specified.

Inquiry 3: Or may we use the full range recommended by the manufacture for a given size electrode and list that on our prequalified WPS and allow the shop to determine how to apply those wide ranges to the welding applications?

Response: It is not the intent of AWS D1.1:2008 Clause 3.6 that a single entry on the WPS include the full range recommended by the manufacturer for a given size electrode. Multiple entries, each including compatible welding parameter ranges in compliance with Table 4.5 and within the manufacturer's recommendations, may be necessary.

**NEW PRIZES.
NEW CAMPAIGN.
START SPONSORING
MEMBERS TODAY!**

Win Great Prizes in the **2009-2010 AWS Member-Get-A-Member Campaign***

ABOUT: AWS is looking for individuals to become part of an exclusive group of AWS Members who get involved and win. Give back to your profession, strengthen AWS and win great limited-edition prizes by participating in the 2009-2010 Member-Get-A-Member Campaign. By recruiting new members to AWS, you're adding to the resources necessary to expand your benefits as an AWS Member. Year round, you'll have the opportunity to recruit new members and be eligible to win special contests and prizes. Referrals are our most successful member recruitment tool. Our Members know first-hand how useful AWS Membership is, and with your help, AWS will continue to be the leading organization in the materials joining industry.

To recruit new Members, use the application on the reverse, or visit www.aws.org/mgm

PRIZE CATEGORIES

President's Honor Roll: Recruit 1-2 new Individual Members and receive an AWS key chain.

President's Club: Recruit 3-8 new Individual Members and receive an AWS hat and an AWS key chain.

President's Roundtable: Recruit 9-19 new Individual Members and receive an AWS polo shirt, hat and an AWS key chain.

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

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

SPECIAL PRIZES

Participants will also be eligible to win prizes in specialized categories. Prizes will be awarded at the close of the campaign (June 2010).

Sponsor of the Year: The individual who sponsors the greatest number of new Individual Members during the campaign will receive a plaque, a trip to the 2010 FABTECH International & AWS Welding Show, and recognition at the AWS Awards Luncheon at the Show.

Student Sponsor Prize: AWS Members who sponsor two or more Student Members will receive an AWS key chain.

The AWS Member who sponsors the most Student Members will receive a free, one-year AWS Membership, an AWS polo shirt, hat and an AWS key chain.

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

LUCK OF THE DRAW

For every new member you sponsor, your name is entered into a quarterly drawing. The more new members you sponsor, the greater your chances of winning. Prizes will be awarded in November 2009, as well as in February and June 2010.

Prizes Include:

- ★ Complimentary AWS Membership renewal
- ★ AWS t-shirt
- ★ AWS hat

SUPER SECTION CHALLENGE

The AWS Section in each District that achieves the highest net percentage increase in new Individual Members before the June 2010 deadline will receive special recognition in the *Welding Journal*.

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

*The 2009-2010 MGM Campaign runs from June 1, 2009 to May 31, 2010. Prizes are awarded at the close of the campaign.



American Welding Society

Visit www.aws.org

SPECIAL OFFER FOR NEW AWS INDIVIDUAL MEMBERS – TWO YEARS FOR \$135 (a \$25 savings)

★ PLUS... Get a popular welding publication for only \$25 (\$192 value)

AWS MEMBERSHIP APPLICATION

4 Easy Ways to Join or Renew:

- ☐ Mail this form, along with your payment, to AWS
- ☐ Call the Membership Department at (800) 443-9353, ext. 480
- ☐ Fax this completed form to (305) 443-5647
- ☐ Join or renew on our website <www.aws.org/membership>

☐ Mr. ☐ Ms. ☐ Mrs. ☐ Dr. Please print • Duplicate this page as needed

Last Name _____

First Name _____ M.I. _____

Title _____ Birthdate _____

Were you ever an AWS Member? ☐ YES ☐ NO If "YES," give year _____ and Member # _____

Primary Phone () _____ Secondary Phone () _____

FAX () _____ E-Mail _____

Did you learn of the Society through an AWS Member? ☐ Yes ☐ No

If "yes," Member's name: _____ Member's # (if known): _____

From time to time, AWS sends out informational emails about programs we offer, new Member benefits, savings opportunities and changes to our website. If you would prefer not to receive these emails, please check here ☐

ADDRESS

NOTE: This address will be used for all Society mail.

Company (if applicable) _____

Address _____

Address Con't. _____

City _____ State/Province _____ Zip/Postal Code _____ Country _____

PROFILE DATA

NOTE: This data will be used to develop programs and services to serve you better.

- ① Who pays your dues?: ☐ Company ☐ Self-paid ② Sex: ☐ Male ☐ Female
- ③ Education level: ☐ High school diploma ☐ Associate's ☐ Bachelor's ☐ Master's ☐ Doctoral

PAYMENT INFORMATION (Required)

ONE-YEAR AWS INDIVIDUAL MEMBERSHIP\$80
TWO-YEAR AWS INDIVIDUAL MEMBERSHIP†~~\$160~~ \$135



New Member? ☐ Yes ☐ No

If yes, add one-time initiation fee of \$12\$ _____

International Members add \$50 for optional hard copy of *Welding Journal* (note: digital delivery of *WJ* is standard)†††\$50 (Optional)

{ Domestic Members add \$25 for book selection (\$192 value), and save up to 87%††.....\$ _____ (Optional)

{ International Members add \$75 for book selection (note: \$50 is for international shipping) ††.....\$ _____ (Optional)
(Note: Book Selection applies to new Individual Members only – Book selections on upper-right corner)

TOTAL PAYMENT\$ _____

AWS STUDENT MEMBERSHIP †††

- ☐ Domestic (Canada & Mexico incl.)\$15
☐ International\$50

TOTAL PAYMENT\$ _____

NOTE: Dues include \$18.70 for *Welding Journal* subscription and \$4.00 for the AWS Foundation.

Payment can be made (in U.S. dollars) by check or money order (international or foreign), payable to the American Welding Society, or by charge card.

- ☐ Check ☐ Money Order ☐ Bill Me
☐ American Express ☐ Diners Club ☐ Carte Blanche ☐ MasterCard ☐ Visa ☐ Discover ☐ Other

Your Account Number _____ Expiration Date (mm/yy) _____

Signature of Applicant: _____ Application Date: _____

Office Use Only

Check # _____ Account # _____

Source Code **WJ** _____ Date _____ Amount _____



American Welding Society

P.O. Box 440367
Miami, FL 33144-0367
Telephone (800) 443-9353
FAX (305) 443-5647
Visit our website: www.aws.org

Member Services Revised 12/12/08

†Two-year Individual Membership Special Offer: applies only to new AWS Individual Members. ††Discount Publication Offer: applies only to new AWS Individual Members. Select one of the six listed publications for an additional \$25; International Members add \$75 (\$25 for book selection and \$50 for international shipping); Multi-Year Discount: First year is \$80, each additional year is \$75. No limit on years (not available to Student Members). †††Student Member: Any individual who attends a recognized college, university, technical, vocational school or high school is eligible. Domestic Members are those students residing in North America (incl. Canada & Mexico). This membership includes the *Welding Journal* magazine. Student Memberships do not include a discounted publication. ††††International hard copy *Welding Journal* option: applies only to International AWS Welder Members (excludes Canada and Mexico). Digitized delivery of *WJ* is standard

BOOK/CD-ROM SELECTION

(Pay Only \$25... up to a \$192 value)

NOTE: Only **New Individual Members** are eligible for this selection. Be sure to add \$25 to your total payment.

ONLY ONE SELECTION PLEASE.

- ☐ *Jefferson's Welding Encyclopedia (CD-ROM only)*
- ☐ *Design and Planning Manual for Cost-Effective Welding*
- ☐ *Welding Metallurgy*
- ☐ *Welding Handbook (9th Ed., Vol. 3)*
- ☐ *Welding Handbook (9th Ed., Vol. 2)*
- ☐ *Welding Handbook (9th Ed., Vol. 1)*

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- A ☐ Contract construction
- B ☐ Chemicals & allied products
- C ☐ Petroleum & coal industries
- D ☐ Primary metal industries
- E ☐ Fabricated metal products
- F ☐ Machinery except elect. (incl. gas welding)
- G ☐ Electrical equip., supplies, electrodes
- H ☐ Transportation equip. — air, aerospace
- I ☐ Transportation equip. — automotive
- J ☐ Transportation equip. — boats, ships
- K ☐ Transportation equip. — railroad
- L ☐ Utilities
- M ☐ Welding distributors & retail trade
- N ☐ Misc. repair services (incl. welding shops)
- O ☐ Educational Services (univ., libraries, schools)
- P ☐ Engineering & architectural services (incl. assns.)
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- 07 ☐ Inspector, tester
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- 14 ☐ Technician
- 09 ☐ Welder, welding or cutting operator
- 11 ☐ Consultant
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Technical Interests (Check all that apply)

- A ☐ Ferrous metals
- B ☐ Aluminum
- C ☐ Nonferrous metals except aluminum
- D ☐ Advanced materials/Intermetallics
- E ☐ Ceramics
- F ☐ High energy beam processes
- G ☐ Arc welding
- H ☐ Brazing and soldering
- I ☐ Resistance welding
- J ☐ Thermal spray
- K ☐ Cutting
- L ☐ NDT
- M ☐ Safety and health
- N ☐ Bending and shearing
- O ☐ Roll forming
- P ☐ Stamping and punching
- Q ☐ Aerospace
- R ☐ Automotive
- S ☐ Machinery
- T ☐ Marine
- U ☐ Piping and tubing
- V ☐ Pressure vessels and tanks
- W ☐ Sheet metal
- X ☐ Structures
- Y ☐ Other
- Z ☐ Automation
- 1 ☐ Robotics
- 2 ☐ Computerization of Welding

Standard for Public Review

A5.29/A5.29M:200X, *Specification for Low-Alloy Steel Electrodes for Flux Cored Arc Welding*. Revised — \$26.00. Expired 9/21/09.

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 standard was submitted for public review. Contact Rosalinda O'Neill, roneill@aws.org; (800/305) 443-9353, ext. 451, to order a draft copy.

ISO Draft Standards for Public Review

ISO/DIS 25239-1.2 — *Friction stir welding — Aluminium — Part 1: Vocabulary*

ISO/DIS 25239-2.2 — *Friction stir welding — Aluminium — Part 2: Design of weld joints*

ISO/DIS 25239-3.2 — *Friction stir welding — Aluminium — Part 3: Qualification of welding operators*

ISO/DIS 25239-4.2 — *Friction stir welding — Aluminium — Part 4: Specification and qualification of welding procedures*

ISO/DIS 25239-5.2 — *Friction stir welding — Aluminium — Part 5: Quality and inspection requirements*

Copies of the above draft standards are available for review and comment through your national standards body, which in the United States is ANSI, 25 W. 43rd St., 4th Fl., New York, NY 10036; (212) 642-4900. Send comments regarding ISO documents 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, adavis@aws.org, (305) 443-9353, ext. 466.

Technical Committee Meetings

All AWS technical committee meetings are open to the public. To attend a meeting, call the staff committee secretary, (800/305) 443-9353, at the extension shown in parentheses.

Oct. 6-8, B2 Committee on Procedure and Performance Qualification. Pittsburgh, Pa. S. Morales (313).

Oct. 7, SH1 Subcommittee on Fumes and Gases. Columbus, Ohio. S. Hedrick (305).

Oct. 13, B2F Subcommittee on Plastic Welding Qualifications, and G1A Subcommittee on Hot Gas Welding and Extrusion Welding. Dallas, Tex. S. Hedrick (305).

Oct. 14-16, A2 Committee and Subcommittees on Definitions and Symbols. Wheeling, W.Va. A. Alonso (299).

Oct. 22, C4 Committee on Oxyfuel Gas Welding and Cutting. Cleveland, Ohio. A. Alonso (299).

The Following Meetings Will Be Held at the FABTECH International & AWS Welding Show in Chicago, Ill.

Nov. 15, C7 Committee on High Energy Beam Welding and Cutting. R. Starks (304).

Nov. 15, C7B Subcommittee on Electron Beam Welding and Cutting. R. Starks (304).

Nov. 16, D14B Subcommittee on General Design and Practices. M. Rubin (215).

Nov. 16, D14G Subcommittee on Welding of Rotating Equipment. M. Rubin (215).

Nov. 16, D14I Subcommittee on Hydraulic Cylinders. M. Rubin (215).

Nov. 16, D15C Subcommittee on Track Welding. R. Starks (304).

Nov. 16, D16 Committee on Robotic and Automatic Welding. M. Rubin (215).

Nov. 17, A5H Subcommittee on Filler Metals and Fluxes for Brazing. S. Borrero (334).

Nov. 17, B1 Committee on Methods of Inspection. B. McGrath (311).

Nov. 17, B1B Subcommittee on Visual Examination of Welds. B. McGrath (311).

Nov. 17, B1C Standing Task Group on the Welding Inspection Handbook. B. McGrath (311).

Nov. 17, C2 Committee on Thermal Spraying. R. Starks (304).

Nov. 17, C6 Committee on Friction Welding. R. Starks (304).

Nov. 17, D14 Committee on Machinery and Equipment. M. Rubin (215).

Nov. 17, D14C Subcommittee on Earthmoving and Construction Equipment. M. Rubin (215).

Nov. 17, D14E Subcommittee on Welding of Presses and Industrial and Mill Cranes. M. Rubin (215).

Nov. 17, D17D Subcommittee on Resistance Welding. M. Rubin (215).

Nov. 17, D17K Subcommittee on Fusion Welding. M. Rubin (215).

Nov. 17, G2C Subcommittee on Nickel Alloys. S. Borrero (334).

Nov. 18, A5K Subcommittee on Titanium and Zirconium Filler Metals. S. Borrero (334).

Nov. 18, D17 Committee on Welding in the Aircraft and Aerospace Industries. M. Rubin (215).

Nov. 18, G2D Subcommittee on Reactive Alloys. S. Borrero (334).

Nov. 18, 19, C3 Committee and Subcommittees on Brazing and Soldering. S. Borrero (334).

Nov. 18, 19, D15A Subcommittee on Freight Cars and Their Materials. R. Starks (304).

Nov. 19, D15 Committee on Railroad Welding. R. Starks (304).

Summary of Changes in ASME Section IX, 2007 Edition, 2009 Addenda

BY WALTER J. SPERKO

Readers are advised that the opinions expressed in this article are those of the author and not the official opinions of ASME Standards Committee IX. These changes become mandatory Jan. 1, 2010.

Changes to QW/QB-422, P-Number Table

If you work with Section IX regularly, the first thing you noticed when you inserted the blue pages was that QW/QB-422 is different: The columns for S-numbers are gone. S-numbers, you may recall, were assigned to certain materials that were permitted by the ASME B31 Code and select Code Cases but were not adopted as Boiler Code materials (i.e., S-

number materials were not "SA" or "SB" materials). Previous ASME policy was that only materials that were SA or SB materials were allowed to be assigned P-numbers. That policy changed recently, and Standards Committee IX made life easier for everyone by converting all materials with S-numbers designations to P-number designations.

A parallel but more subtle and expansive change was made in QW-420. Previously, materials were manufactured to the ASTM version of a specification could be considered as having the same S-number as the corresponding SA or SB material's assigned P-number (i.e., ASTM A-312 TP304 could be considered S-8 since

ASME SA-312 TP 304 was assigned to P-8), this revision allows all materials that have the same UNS number as any material that is assigned a P-number to be considered as having the same P-number as the listed material. That is, ASME SA-312 TP 304 is listed as UNS S30400; therefore, all materials manufactured to any specification in which the material is identified as UNS S30400 may be considered as P-8. This provision also applies to group number assignments.

When taking advantage of this change, however, the materials used for the test coupon have to be materials that are as-

— ASME IX continued on next page.

WALTER J. SPERKO (sperko@asme.org) is president, Sperko Engineering, Greensboro, N.C., and vice chair, ASME Subcommittee IX.

— ASME IX continued from previous page

signed P-numbers by Section IX; continuing with the above example, readers should use ASME SA-312 TP304 (which is listed) and not ASTM A-312 TP304 (which is not listed) for test coupons. For materials not assigned a UNS number and not listed in QW/QB-422, QW-424.1 applies.

These changes, of course, do not mean that you can construct ASME boilers, pressure vessels, or nuclear components with former S-number materials or with materials assigned a P-number using the UNS number; they still have to be constructed using materials that are listed in ASME Section II, Part D, i.e., they have to be built from materials that are made to SA or SB specifications, and piping has to be constructed using materials that are permitted by the applicable section of the ASME B31 Code for Pressure Piping.

For purposes of reducing the number of procedure qualifications when materials were similarly weldable, base metals were assigned P-numbers in the first edition of Section IX published in 1941. In those days, a welding power supply (motor-generator) was known as a “welder,” and the person who did the welding was known as a “welding operator.” For purposes of reducing the number of operator qualifications when materials were similarly weldable, base metals were assigned O-numbers. The Operator grouping system was dropped in the early 1950s, leaving only P-numbers, which are used today for both procedure and performance qualification purposes. Both P-numbers and O-numbers were just numbers in the old days; however, by the 1960s, Subcommittee IX started using alphanumeric designations such as P-9A, P-10C, P-11A, etc., and the rules typically required that separate qualifications were required for each number-letter combination. In these addenda, QW-420 specifically states that P-numbers are considered alphanumeric designations even though they are called “P-numbers.” This means that P-11A and P-11B are considered separate P-numbers without further identifying them as such in the variables, the tables, and in other locations throughout Section IX. This allowed deletion of QW-403.13, which addressed P-5, 9, and 10 with their separate alpha designations, and it eliminated the need to address alpha designations in a new P-number family, P-15.

Creep-Strength-Enhanced Ferritic Alloys: P-number 15

The power industry has been using a creep-strength-enhanced ferritic alloy (CSEFA) identified as “Grade 91” for el-

evated-temperature service for more than two decades. Although Grade 91 is based on Cr-Mo steels that have been used for decades, industry has discovered that its microstructure and associated creep behavior is far more sensitive to fabrication and installation practices than predecessor Cr-Mo steels such as 2½ Cr-1Mo. As the result of some failures in Grade 91 installations, special rules have been written for this material such as the postweld heat treatment requirements for P-5B, Group 2, in Section I, paragraph PW-39, and in B31.1, Table 136. While the industry has learned to deal with Grade 91’s idiosyncrasies, more CSEFAs are on the way: Grades 92, 911, 122, 23, 24, and others. It is anticipated that they will exhibit similar idiosyncrasies to Grade 91 and possibly some of their own. In order to make it easier for the construction codes to deal with these idiosyncrasies as they arise, Section IX has designated a new P-number family for CSEFAs – P-15. Assignments will be as follows:

P-15A	Open
P-15B	1¼Cr
P-15C	2¼Cr (e.g., 23, 24)
P-15D	Open
P-15E	9Cr (e.g., 91, 92, 911)
P-15F	12Cr (e.g., 122, VM12)

Grade 91 materials currently assigned to P-5B, Group 2, will become P-15E. Existing WPS and supporting PQRs that permit welding P-5B Group 2 materials must be reviewed to see if the WPSs are still qualified for welding materials under P-15E. If a PQR shows that the test coupon base metal was one of those assigned to P-No. 15E, the WPS may be revised to allow welding of P-15E. If a PQR shows that the test coupon base metal was not one of those assigned to P-No. 15E, the WPS may only permit welding of materials currently assigned that P-number.

When the PQR shows that the test coupon base metal was one of those assigned to P-15E, the PQR may be revised to P-15E, or it may remain as P-5B, Group 2, since 1) the base metal that was welded was P-5B, Group 2, at the time that the test coupon was welded, and 2) it is the base metal that was welded that determines the P-number that may be specified on the WPS, not the historically assigned P-number shown on the PQR.

In the writer’s experience, however, not changing PQRs to the new P-number will result in negative comments from reviewers of WPSs who are not aware of the above subtlety. If you choose to revise PQRs to show the new P-number assignments, be sure to recertify the record and annotating that the base metal P-number assignment was revised due to a code change.

The old WPS and PQR are still valid for ongoing and repair work to previous

editions of the Code where the applicable construction code assigned Grade 91 to P-5B, Group 2.

Readers may note that the above description of how to deal with reassigned P-numbers is slightly different from my previous advice that said that the PQR had to be revised. Due to feedback from some readers, this matter was recently vetted in committee and the above is consistent with recent interpretations. This advice is applicable not only to the CSEFAs but also to other materials such as those base materials with revised P-numbers in the nickel-base family.

Corresponding changes were also made in various paragraphs and tables where ranges such as “P-1 through P-11” have been changed to “P-1 through P-15F.” This means that, since QW-423 was revised as described above, welders who were previously qualified to weld on P-1 through P-11 base metals are now qualified to weld on P-1 through P-15F base metals. Although Section IX does not specifically address revisions to welder qualification records, the provisions of QW-200.3, which address revisions to PQRs, could reasonably be applied to welder qualification records, allowing PQRs to be revised when there is a relevant code change; accordingly, one could revise previous welder qualification records by changing the base metal range qualified from P-1 through P-11 to P-1 through P-15F, recertifying the record and annotating that the base metal range qualified was revised due to a code change.

ISO Material Grouping Assignments

After you received your Addenda sheets, you should have been notified that revised QW/QB-422 tables should be downloaded from the ASME Web site: <http://cstools.asme.org/csconnect/pdf/CommitteeFiles/29447.pdf>.

When you downloaded that table, you saw that there were more changes to the table. A new column “ISO/TR 15608 group” was added. This column lists assignments of materials to group numbers in accordance with the criteria of ISO/TR 15608:2005, *Welding — Guidelines for a metallic materials grouping system*, and it is consistent with the assignments found in ISO/TR 20173:2008, *Grouping systems for materials — American materials*. While this listing is provided as a convenience to users worldwide, it is provided for information only. Section IX does not refer to this grouping as a basis for establishing the range of base metals qualified for either procedure or performance qualification. There are two other ISO standards that assign ISO 15608 group numbers to European and Japanese materials, ISO/TR-20172 and ISO/TR-20174 respec-

tively. The availability of the ISO base metal grouping assignments will make it easier to evaluate the similarity of materials for welding purposes.

'Condition(s)'

While there appear to be a lot of revisions when reviewing the listing of changes, most are editorial and the rest are simplifications. Biggest number changes were associated with an action in which a senior SC IX member examined how the word "condition" and its variants were used. It turns out there were many ways the term was used, and some were inappropriate. Some examples: QW-100.3, "conditions" was changed to "rules"; and in QW-321, "conditions" was changed to "provisions"; QW-322.2(a), "conditions" was changed to "requirements"; QW-322.1, "conditions" was deleted; QW-407.1, "conditions" was deleted (several of these); and in QW/QW-492, "conditions" was changed to "parameters" for active fluxes.

So, if you are reading a paragraph marked with "09" in the margin and the change is not obvious, look it up in the change summary and you will probably find that "condition" was modified.

Welding Procedure (QW-200) Changes

Beyond the changes in S-numbers and addition of P-15, there were a couple of changes to the procedure qualification rules worth noting.

QW-442, the A-number table, changes rarely. In these addenda, the transition point for chromium between A-4 and A-5 was changed from 5 to 4% so that the transition in chromium content matched the same transition between base metals assigned to P-5A (2% Cr and 3% Cr-Mo) and those assigned to P-5B (nominally 5 through 12% Cr-Mo steels). This allows WPSs qualified using any P-5B base metal to be written so that the chemical composition of the filler metal can match that of any other P-5B base metal, whereas previously, a PQR showing that a 5% Cr-Mo steel was used for both the test coupon and the filler metal could only support a WPS written for welding 5% Cr-Mo base metals using 5% Cr-Mo filler metals. Readers might want to review their existing P-5B WPSs to see if they can take advantage of this change.

QW-404.23, which is an essential variable for GTAW and PAW for both procedure and performance qualification, was modified to add use of flux-coated rod in addition to requiring separate qualification when using flux cored, powder, metal cored, and solid wires. The most commonly used filler metal product form qualified with either process is solid wire, and

when solid wire is used to weld a test coupon, that also qualifies metal cored wires and vice versa, but no other product form. Flux cored and flux covered rods are most commonly used as an alternate to using gas backing when welding stainless steel, and this variable requires separate qualification of both WPSs and welders when these product forms are used. The use of separately applied backing flux is not addressed by Section IX; readers who use such fluxes would be wise to run a procedure qualification test to satisfy themselves that these fluxes do not affect the properties of the weld and advise their customers that there may be residual flux in the piping.

Welder Qualification (QW-300) Changes

There were no significant changes to welder qualification other than those resulting from P-number changes discussed above.

Base Metals and Filler Metals

Beyond the extensive changes described above regarding S-numbers and P-15, the regular collection of new base metals was added and editorial corrections were made. One notable addition was the addition of ASME B16.50, *Wrought Copper and Copper Alloy Braze-Joint Pressure Fittings*, as brazing P-number 107. Fittings made to this specification are made from the same copper alloys as B16.22 solder-joint fittings, but B16.50 permits the fittings to have shallower cups that are more suitable for brazed joints than the deep cups that are needed for soldered joints.

Brazing (QB) Changes

Other than the addition of B16.50, two small changes were made to clarify the variables associated with overlap length of brazed joints.

QB-408.1 says, for lap or socket joints, the brazer is qualified to braze using an overlap length up to 25% greater than that used on the performance qualification test coupon. This recognizes that, as the overlap length increases, it becomes more difficult to make a sound braze joint, but it says nothing about decreasing the overlap. To clarify that decreasing the overlap from that used on the test coupon was acceptable, a parenthetical clarification was added saying that a decrease in overlap is permitted without requalification.

QB-408.4 says, for lap or socket joints, the BPS is qualified to braze using an overlap length no greater than that used on the procedure qualification test coupon. This recognizes that, as the over-

lap length decreases, the unit stress through the joint increases, but it says nothing about increasing the overlap. To clarify that increasing the overlap from that used on the test coupon was acceptable, a parenthetical clarification was added saying that an increase in overlap is permitted without requalification since that decreases the unit stress through the joint.

Inquiries

It was a pretty dull year for inquiries. One curious inquiry was IX-07-11 that asked if a person making adjustments of the volts, amps, wire feed speed, or other settings at the direction of a qualified welder or welding operator had to also be a qualified welder or welding operator. The reply was "no." It's always reassuring to know that if a welder hollers, "Joe, give me five more amps," that Joe does not have to be qualified to weld.

Coming Attractions

Over the last several decades, electronic controls have moved into welding power supplies and controls. Motor-generators that produced nearly pure DC current were replaced with transformers and rectifiers. Most of these power supplies produced DC current with some waveform ripples, but the waveform was highly regular, and ordinary volt and ammeters could be used to measure the energy accurately. Modern power supplies use inverters and electronic controls to control volts and amps independently; this allows the power supply to control the volts and amps waveforms to minimize spatter, control penetration, bridge gaps, and the like to make welding easier and more consistent; these controls operate at 5 to 10 MHz, and the heat input used to make a weld cannot be measured correctly using either averaging or RMS meters to determine the heat input. Conveniently, the electronics that control the waveform can also be used to measure the arc energy accurately by sampling the volts and amps at the same frequency as the controls operate, and those measurements can be integrated over time to provide a meter reading of cumulative Joules over the time the arc is on or Joules/s (watts). When such a reading is recorded along with the travel speed, heat input can be accurately recorded on the PQR and controlled during welding. How this will be incorporated into Section IX will be revealed next year in the *Welding Journal* and will appear in the 2010 edition.

Note ASME Code Committee meetings are open to the public. The meeting schedule is posted on www.asme.org and www.sperkoengineering.com. ♦

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AWS Membership

Member Grades	As of 9/01/09
Sustaining.....	504
Supporting.....	313
Educational.....	502
Affiliate.....	467
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Total corporate members.....	1,834
Individual members.....	52,248
Student + transitional members.....	5,720
Total members.....	57,968

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UNESP
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Porto Alegre, RS 90410-001, Brazil

Walker Career Center
9651 E. 21st St.
Indianapolis, IN 46229

Life Members Offered Perks at FABTECH International & AWS Welding Show

AWS Life Members are urged to take advantage of their complimentary free admission to the upcoming FABTECH International & AWS Welding Show, including MetalForm, plus free registration to the entire Professional Program (a \$325 value).

The event will take place Nov. 15-18, 2009, at McCormick Place in Chicago, Ill.

The free Professional Program registration entitles AWS Life Members to attend any of the technical sessions occurring during the three-day period.

The registration form is part of the *Advance Program* mailed to all members with the September issue of *Welding Journal*; or call the Membership Dept., (800) 443-9353,

ext. 260, to have the form mailed to you.

To obtain your free registration, be sure to mark "AWS Life Member: Free Registration" at the top of the form. Then fax both sides of the form to (305) 443-7559, Attn.: Ruben Lara, accounting director, or mail the form to AWS c/o Ruben Lara, 550 NW LeJeune Rd., Miami, FL 33126.

Name Your Candidate for the Prof. Masubuchi Award

November 2 is the deadline for submitting nominations for the 2010 Prof. Koichi Masubuchi Award, sponsored by the Dept. of Ocean Engineering at Massachusetts Institute of Technology.

This award is presented each year to one person who has made significant contributions to the advancement of materials joining through research and development. The

award includes an honorarium of \$5000.

The candidate must be 40 years old or younger, may live anywhere in the world, and need not be an AWS member. The nomination package should be prepared by someone familiar with the research background of the candidate. It should include the candidate's résumé listing background, experience, publications, honors, and awards, plus

at least three letters of recommendation from fellow researchers.

This award was established to recognize Prof. Koichi Masubuchi for his numerous contributions to the advancement of the science and technology of welding, especially in the fields of fabricating marine and outer space structures. E-mail your nominations to Prof. John DuPont at jnd1@lehigh.edu.

SECTION NEWS



Shown at the New Jersey Section meeting at the Ironworker District Council are (from left) William Lawson, Ed Mironski, Ron Savasta, Bill Kolfenbach, Jim Creegan, and Section Chairman Seann Bradley.



The District 5 conference met in Savannah, Ga., headed by Steve Mattson, District 5 director, shown seated at the head of the table.

District 1

Russ Norris, director
(207) 604-9262
russ.norris@airgas.com

NEW JERSEY

MARCH 17

Activity: The Section members met at Ironworker District Council Northern New Jersey in Edison, N.J., for a presentation on the careers available to graduates of the Ironworker apprenticeship and journeyman training programs. The meeting concluded with a tour of the facilities. The presenters included **William Lawson**, **Ed Mironski**, **Ron Savasta**, **Bill Kolfenbach**, and **Jim Creegan**.

NEW YORK

JULY 27

Activity: The Section's executive board members met at Buckley's Restaurant in Brooklyn, N.Y., to plan the coming year's schedule of events. Treasurer **Alan Zibitt** received the District Directors award for his contributions to the Society.



Shown at the New York Section board meeting are (from left) Education Chair Doug DeMarco, Treasurer Alan Zibitt, and Chairman Dominick Colasanto.

District 2

Kenneth R. Stockton, director
(908) 412-7099
kenneth.stockton@pseg.com

District 3

Michael Wiswesser, director
(610) 820-9551
mike@welderinstitute.com



At the Atlanta Section activity are (from left) Rick Oliver, Paul Rose, Branden Muehlbrandt, Cajun Seeger, Ronnie Jackson, Joe Young, George Head, Ron Weatherred, and Nick Peterson.



Shown at the Atlanta Section event at Local Union 72 are (from left) Cajun Seeger, District 5 Director Steve Mattson, Greg Webster, Robbie Zappa, Mike Cockerham, and Branden Muehlbrandt.



The Atlanta Section executive board members are (clockwise from front-left) David Ennis, Chair Robbie Zappa, Rene Engeron, Carl Matricardi, and Tom Rieger.

Activity: The Atlanta Section members participated in the grand opening of the new Welding Technology Center training facility operated by The Plumbers and Pipefitters Local Union 72 of the United Association (UA) of Journeymen and Apprentices of the Plumbing and Pipefitting Industry of the United States and Canada, Mechanical Trades Institute, in Lithia Springs, Ga., to augment its skilled trades apprenticeship program. Its students, from beginners to advanced welders, earn college credits while at the center and working in the five-year apprenticeship on-the-job training program. The facility will graduate highly skilled tradespeople trained to fill the requirements of the local contractors with welders certified to the UA Welder Certification Program *Quality Systems Manual*. Officiating was **Cajun Seeger**, UA welding director, with welding instructors **Greg Webster**, **Mike Cockerham**, and **Branden Muehlbrandt** — all qualified AWS CWIs and CWEs. **Steve Mattson**, District 5 director, attended the event.

AUGUST 13

Activity: The Atlanta Section's executive committee met to set the upcoming year's activities. Plans include sponsoring a student to compete in the SkillsUSA contest, fund-raising, and possible meetings at Mechanical Trades Institute, Miller Electric, Praxair, and Lanier Tech. Announced was the Section's new Web site www.awsatlantasection.com. Attending were Chair **Robbie Zappa**; **Carl Matricardi**, vice chair; **Rene Engeron**, secretary; **David Ennis**, education chair; and **Tom Rieger**, Image of Welding chair. The meeting was held at Boudreaux's Restaurant in Duluth, Ga.

District 4

Roy C. Lanier, director
(252) 321-4285
rlanier@email.pittcc.edu

District 5

Steve Mattson, director
(904) 260-6040
steve.mattson@yahoo.com

District 5 Conference

JUNE 5, 6

Activity: The annual District 5 conference was held in Savannah, Ga. **Steve Mattson**, District 5 director, conducted the program. The presenters included **Robbie Zappa**, **David Ennis**, and **Carl Matricardi**.

ATLANTA

JULY 23

District 6

Kenneth Phy, director
(315) 218-5297
kenneth.phy@gmail.com



Attending the Pittsburgh Section executive board meeting are (from left) John Menhart, Carl Ott, Chairman Dave Daugherty, Dave McQuaid, and Carl Spaeder.

District 7

Don Howard, director
(814) 269-2895
howard@ctc.com

PITTSBURGH

AUGUST 11

Activity: The Section executive board met at Rockefeller's Grille in McKees Rocks, Pa., to plan the upcoming season's activities. Attending were Chair **Dave Daugherty**, **John Menhart**, **Carl Ott**, **Dave McQuaid**, and **Carl Spaeder**.

District 8

Joe Livesay, director
(931) 484-7502, ext. 143
joe.livesay@ttcc.edu

District 9

George D. Fairbanks Jr., director
(225) 473-6362
fitts@bellsouth.net

District 9 Conference

JUNE 21

Activity: **George Fairbanks**, District 9 director, presided over the conference hosted by Cei Fabricators, Inc., in St. James, La., and the Baton Rouge Section. A highlight was a boiled crawfish dinner. **George Shaheen**, Cei Fabricators owner, was presented a plaque in recognition of his support over the years to the Southeastern Louisiana University AWS Student Chapter.

MORGAN CITY

AUGUST 4

Activity: The Section's executive committee met to install new board members and make plans to revitalize the Section. The Section draws attendees from the Morgan City, Houma, Thibodaux, and sur-



Shown at the District 9 conference are (from left) Anthony Blakeney, Michael Beaveau, George Shaheen, and George Fairbanks, District 9 director.



Attending the Morgan City Section executive board meeting are (from left) **Joey Rentrop**, **Bill New**, Chairman **John Derrick**, **Tim Theiss**, District 9 Director **George Fairbanks**, and **Renesse Landry**.

rounding areas. The board set its first Section meeting for September 8, to be hosted by outgoing Chair **Bill New** at his fabrication shop in Morgan City. The incoming board members are **John Derrick**, chairman; **Renesse Landry**, first vice chair; **Joey**

Rentrop, second vice chair and secretary; and **Tim Theiss**, treasurer. Attending the meeting were **Bill New** and District 9 Director **George Fairbanks**. The meeting was held at Atchafalaya Club House in Patterson, La.



The Central Michigan Section team members proudly display the Quiz the Experts traveling trophy they earned the right to keep for the second year in a row. Shown are (from left) Jim Farmer, Roy Bailiff, and Bill Eggleston.



Detroit Section Chair Mark Rotary (left) and Jim Kline, a fellow Ironman Triathlon competitor, get ready for the big challenge.

first vice chair; **Roy Bailiff**, second vice chair; and **Jim Farmer**, treasurer. **Jim Farmer** received his Life Membership Certificate for 35 years of service to the Society and an appreciation plaque for serving as treasurer of the Central Michigan Section for 27 years. The awards were presented by Chairman **Jeff Seelye**, the Section's board members, and District 11 Director **F. T. Siradakis**.

DETROIT

AUGUST 1

Activity: Chairman **Mark Rotary** took the plunge and competed in the Whirlpool Ironman 70.3 Steelhead Triathlon 2009 in Benton Harbor, Mich., finishing in six hours and 21 minutes. The three-part competition included a 1.3-mile swim, 56-mile bike course, and a 13-mile run. For the occasion, AWS Director-at-Large **Don DeCorte** presented Rotary with a custom-made T-shirt emblazoned with the AWS logo to wear during his competition. Rotary said several people inquired about the AWS logo giving him the opportunity to tell them about the Society and his Section's activities.

NORTHWEST OHIO

JULY 10

Activity: The Section hosted its annual AWS scholarship fund-raising golf outing at South Toledo Golf Club in Toledo, Ohio. The event is named in honor of **Donald J. Leonhardt**, a welding instructor at Owens Community College, and a supervisor of the Section's CWI exams. Coordinating the event were **Mike Rogers**, **Tony Duris**, and **Mark Scalise**. Fifteen, four-man teams competed.

District 12

Sean P. Moran, director
(920) 954-3828
sean.moran@hobartbrothers.com



Shown at the Quiz the Experts event are (from left) Jeff Seelye, District 11 Director F. T. Siradakis, awardee Jim Farmer, Roy Bailiff, and Bill Eggleston.



Mark Rotary displays the attention-getting T-shirt he wore in the Whirlpool Ironman Triathlon. The logo reads, "American Welding Society, Building Iron Men."

District 10

Richard A. Harris, director
(440) 338-5921
richaharris@windstream.net

District 11

Eftihios Siradakis, director
(989) 894-4101
ft.siradakis@airgas.com

CENTRAL MICHIGAN

APRIL 20

Activity: The annual Quiz the Experts event took center stage for this program attended by members of the Detroit, Saginaw Valley, Central Michigan, and Western Michigan Sections, and members of the Ferris State University Student Chapter. Taking top honors was the Central Michigan team of experts **Bill Eggleston**,



Shown at the Chicago Section executive meeting are (seated, from left) Chair Hank Sima, Craig Tichelar, and Pete Harris; (standing, from left) Pete Host, Eric Krauss, Cliff Iftimie, Jim Greer, Marty Vondra, and Chuck Hubbard.



Eldon Lafevre (left) received the District 13 Private Sector Educator Award from John Willard, J.A.K. Section chair, in July.



Attending the 2009 Leadership Symposium are (from left) Lee Kvidahl, an AWS past president; Cassie Burrell, AWS deputy executive director; Alfred Nieves, senior coordinator; Rhenda Mayo, director, member services; Chicago Section Secretary Eric Krauss; Gailyn Cornell, representing the St. Louis Section; and facilitator Ron Gilbert.

District 13

W. Richard Polanin, director
(309) 694-5404
rpolanin@icc.edu

CHICAGO

JULY 13

Activity: Secretary **Eric Krauss** participated in the 2009 Leadership Symposium held July 12–15 at AWS headquarters in Miami.

AUGUST 12

Activity: The Section held its executive board meeting at Bailey's Restaurant in Westmont, Ill. Attending were Chair **Hank Sima**, **Craig Tichelar**, **Pete Harris**, **Pete Host**, **Eric Krauss**, **Cliff Iftimie**, **Jim Greer**, **Marty Vondra**, and **Chuck Hubbard**.

J.A.K.

JULY 13

Activity: The Joliet-Aurora-Kankakee Section made an awards presentation as

part of the Ironworkers Local 444 regular meeting in Joliet, Ill. **Eldon Lafevre**, recently retired Ironworkers Apprenticeship Coordinator, received the District 13 Private Sector Educator Award from Chairman **John Willard**. Lafevre was involved in the Local's training program for more than 20 years with an emphasis on training and certifying welders for the structural steel industry. Lafevre continues to mentor its welders and instructors.

District 14

Tully C. Parker, director
(618) 667-7795
tparke@millerwelds.com

District 15

Mace V. Harris, director
(612) 861-3870
macevh@aol.com



Ben Johnson (left) accepts his golf awards from Northern Plains Section Chair **Brent Smith**.

NORTHERN PLAINS

JULY 25

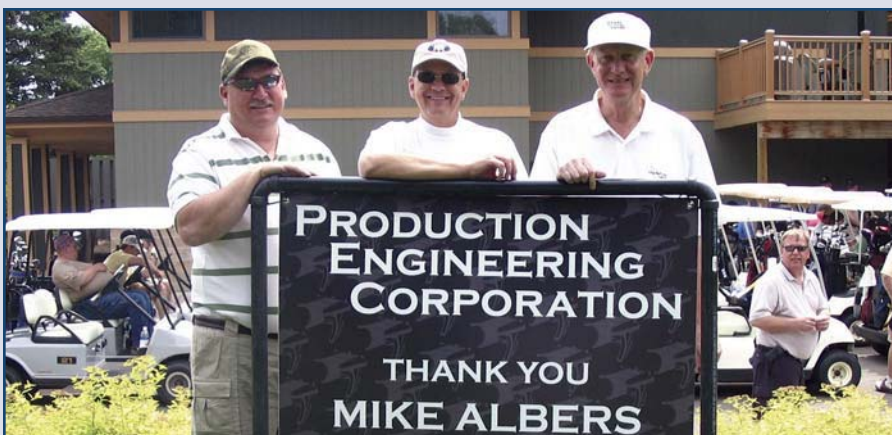
Activity: The Section hosted its annual golf outing at Sandhill Golf Club in Fertile, Minn. The scholarship fund-raising event attracted 45 golfers that ended in a three-way-tie for first place. After the tie-breaking run, the winning team included **Travis Effhauser**, **Ben Johnson**, **Scott Langlie**, and **Lonnie Thompson**.



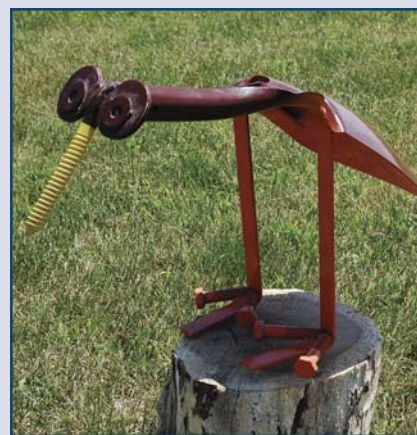
The Northern Plains Section golf winners are (from left) Travis Effhauser, Ben Johnson, Scott Langlie, and Lonnie Thompson.



Darrell Byram (left), the long-putt champ, is shown with Brent Smith, Northern Plains Section chairman.



Shown at the Northwest Section golf outing fund-raising event are (from left) Clint Emmert, Bob Sands, and Bob Keilty.



'Devon's Duck' came to life from a handful of scrap metal under the steady welding hands of Devon Severson coached by her father, Bruce, for an Iowa 4-H project.



Iowa Section member Bruce Severson and daughter Devon worked together on a 4-H welding project in the summer.

Ben Johnson took the longest-drive and closest-to-the-pin honors, and **Darrell Byram** earned the prize for the longest putt. **Brent Smith**, chairman, presented the awards.

NORTHWEST

JUNE 15

Activity: The Section hosted its annual scholarship fund-raising golf outing at New Prague Golf Club in New Prague, Minn. The Section members formally recognized Production Engineering Corp. (PEC) for its support and making a \$1000 contribution each year for the past ten years to the fund. Attending were PEC representatives **Mike Albers**, president; **Clint Emmert**, vice president of manufacturing; and **Bob Sands**.

District 16

David Landon, director
(641) 621-7476
dlandon@vermeermfg.com

IOWA

SUMMER

Activity: **Bruce Severson** participated in a 4-H "reuse, recycle, reclaim" project with his daughter, AWS Student Member **Devon**, age 10. He taught her what she needed to know to use welding and other shop skills to create art pieces from scrap metal parts.

District 17

J. Jones, director
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jjones@thermadyne.com

District 18

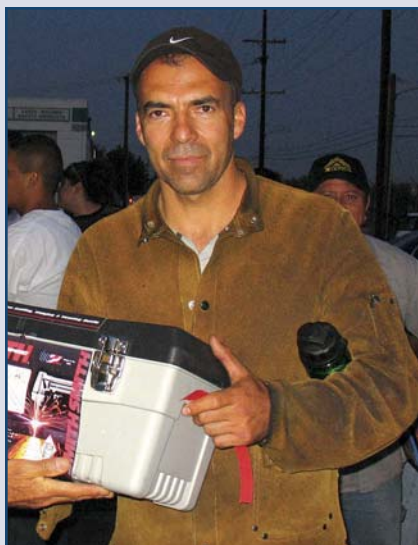
John Bray, director
(281) 997-7273
sales@affiliatedmachinery.com

District 19

Neil Shannon, director
(503) 419-4546
neilshnn@msn.com

District 20

William A. Komlos, director
(801) 560-2353
bkoz@arctechllc.com



Jose Luis won the raffle prize at the Los Angeles/Inland Empire Section meeting.

District 21

Nanette Samanich, director
(702) 429-5017
Nan07@aol.com

L.A./INLAND EMPIRE

MAY 29

Activity: The Section members participated in a company tour and welding competition held at Red-D-Arc Welderentals in Rancho Cucamonga, Calif. The attendees saw demonstrations of various machines, then 30 contestants competed in an entry-level welding contest. The assignment was to complete a ¼-in. fillet weld using ⅜-in. E7018 electrode on low-carbon steel. The procedure involved welding a 3 × 3 × ⅜-in. angle to a ¼-in.-thick horizontal plate using



Shown at the L.A./Inland Empire Section welding contest are (from left) Chair George Rolla, Miguel Bonilla, and Mary Means, education chair.



George Rolla (left), L.A./Inland Empire Section chair, gives a helping hand to Carlos Vasquez who totes the prize he won for taking first place in the welding competition.

shielded metal arc welding. The judges included two engineers, two CWIs, and two welding instructors. The top scorers were Carlos Vasquez and Miguel Bonilla. Jose Luis won the raffle prize.

District 22

Dale Flood, director
(916) 288-6100, ext. 172
flashflood@email.com

Share Your Expertise with the World — Join an AWS Technical Committee

Thermal Spraying

Volunteers are invited to participate on the C2 Committee on Thermal Spraying. Its documents include **C2.16**, *Guide for Thermal-Spray Operator Qualification*; **C2.18**, *Guide for the Protection of Steel with Thermal Sprayed Coatings of Aluminum and Zinc and their Alloys and Composites*; **C2.19**, *Machine Element Repair*; **C2.20**, *Thermal Sprayed Coating for Reinforced Concrete*; **C2.21**, *Specification for Thermal Spray Equipment Acceptance Inspection*; **C2.23**, *Specification for the Application of Thermal Spray Coatings (Metallizing) of Aluminum, Zinc, and Their Alloys and Composites for the Corrosion Protection of Steel*; **C2.25**, *Specification for Thermal Spray Feedstock — Solid and Composite Wire and Ceramic*

Rods. Contact Reino Starks, rstarks@aws.org, (800/305) 443-9353, ext. 304, for information, or visit www.aws.org/IUQ4 to submit your application online.

Welding Sales Representatives

AWS established a new certification program for welding sales representatives in 2009. Volunteers are invited to be part of the technical subcommittee responsible for setting the qualification requirements, **AWS B5.14**, *Specification for the Qualification of Welding Sales Representatives*, that this program is based on. For complete information about this committee's work, contact John Gayler, gayler@aws.org, (800/305) 443-9353, ext. 472; or submit a technical committee application online at www.aws.org/IUQ4.

Robotic and Automatic Welding

Volunteers are sought to participate on the D16 Committee on Robotic and Automatic Welding. Its documents include **D16.1**, *Specification for Robotic Arc Welding Safety*; **D16.2**, *Guide for Components of Robotic and Automatic Arc Welding Installations*; **D16.3**, *Risk Assessment Guide for Robotic Arc Welding*; **D16.4**, *Specification for Qualification of Robotic Arc Welding Personnel*. Persons engaged in robotic welding operations and suppliers of equipment who want to contribute their expertise to the preparation of one or more of these documents are urged to contact Matt Rubin, mru-bin@aws.org; (800/305) 443-9353, ext. 215, or visit www.aws.org/IUQ4 to submit your member application online.

Guide to AWS Services

American Welding Society
550 NW LeJeune Rd., Miami, FL 33126
www.aws.org; (800/305) 443-9353; FAX (305) 443-7559
Staff telephone extensions are shown in parentheses.

AWS PRESIDENT

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vic_matthews@lincolnelectric.com
The Lincoln Electric Co.
7955 Dines Rd., Novelty, OH 44072

ADMINISTRATION

Executive Director
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Executive Assistant for Board Services
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IT Network Director
Armando Campana.. acampana@aws.org(296)

Director
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Natalia Swain.. nswain@aws.org(245)

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Luisa Hernandez.. luisa@aws.org(266)

Director, Human Resources
Dora A. Shade.. dshade@aws.org(235)

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Senior Coordinator
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GOVERNMENT LIAISON SERVICES

Hugh K. Webster.. hwebster@wc-b.com
Webster, Chamberlain & Bean, Washington, D.C., (202) 785-9500; FAX (202) 835-0243. Identifies funding sources for welding education, research, and development. Monitors legislative and regulatory issues of importance to the welding industry.

CONVENTION and EXPOSITIONS

Senior Associate Executive Director
Jeff Weber.. jweber@aws.org(246)

Corporate Director, Exhibition Sales
Joe Krall.. jkrall@aws.org(297)
Organizes the annual AWS Welding Show and Convention, regulates space assignments, registration items, and other Expo activities.

Brazing and Soldering Manufacturers' Committee

Jeff Weber.. jweber@aws.org(246)

RWMA — Resistance Welding Manufacturing Alliance

Manager
Susan Hopkins.. susan@aws.org(295)

WEMCO — Welding Equipment Manufacturers Committee

Manager
Natalie Tapley.. tapley@aws.org(444)

PUBLICATION SERVICES

Department Information(275)
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Welding Journal

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National Sales Director

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Society and Section News Editor

Howard Woodward.. woodward@aws.org(244)

Welding Handbook

Welding Handbook Editor
Annette O'Brien.. aobrien@aws.org(303)
Publishes *Welding Journal*, the Society's monthly magazine, *Inspection Trends*, *Welding Handbook*, and books on general welding subjects.

MARKETING COMMUNICATIONS

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Public Relations Manager
Cindy Weihl.. cweihl@aws.org(416)

Webmaster
Angela Miller.. amiller@aws.org(456)

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Director

Rhenda A. Mayo.. rhenda@aws.org(260)
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CERTIFICATION SERVICES

Department Information(273)

Managing Director, Certification Operations
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Managing Director, Technical Operations
Peter Howe.. phowe@aws.org(309)
Manages and oversees the development, integrity, and technical content of all certification programs.

Director, Int'l Business & Certification Programs
Priti Jain.. pjain@aws.org(258)
Directs all int'l business and certification programs. Is responsible for oversight of all agencies handling AWS certification programs.

EDUCATION SERVICES

Managing Director
Dennis Marks.. dmarks@aws.org(449)

Director, Education Services Administration and Convention Operations
John Ospina.. jospina@aws.org(462)

AWS AWARDS, FELLOWS, COUNSELORS

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Coordinates AWS awards and AWS Fellow and Counselor nominees.

TECHNICAL SERVICES

Department Information(340)

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Int'l Standards Activities, American Council of the Int'l Institute of Welding (IIW)

Director, National Standards Activities
John L. Gayler.. gayler@aws.org(472)
Personnel and Facilities Qualification, Computerization of Welding Information

Manager, Safety and Health
Stephen P. Hedrick.. steveh@aws.org(305)
Metric Practice, Safety and Health, Joining of Plastics and Composites, Welding Iron Castings

Technical Publications
AWS publishes about 200 documents widely used throughout the welding industry.
Senior Manager
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Staff Engineers/Standards Program Managers
Annette Alonso.. aalonso@aws.org(299)
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Stephen Borrero.. sborrero@aws.org(334)
Joining of Metals and Alloys, Brazing and Soldering, Brazing Filler Metals and Fluxes, Brazing Handbook, Soldering Handbook

Rakesh Gupta.. gupta@aws.org(301)
Filler Metals and Allied Materials, Int'l Filler Metals, Instrumentation for Welding, UNS Numbers Assignment

Brian McGrath.. bmcgrath@aws.org(311)
Methods of Inspection, Mechanical Testing of Welds, Welding in Marine Construction, Piping and Tubing

Selvis Morales.. smorales@aws.org(313)
Welding Qualification, Structural Welding

Matthew Rubin.. mrubin@aws.org(215)
Aircraft and Aerospace, Machinery and Equipment, Robotics Welding, Arc Welding and Cutting Processes

Reino Starks.. rstarks@aws.org(304)
Welding in Sanitary Applications, High-Energy Beam Welding, Friction Welding, Railroad Welding, Thermal Spray

Note: Official interpretations of AWS standards may be obtained only by sending a request in writing to the Managing Director, Technical Services, Andrew R. Davis, at adavis@aws.org.

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.

Nominees for National Office

Only Sustaining Members, Members, Honorary Members, Life Members, or Retired Members who have been members for a period of at least three years shall be eligible for election as a director or national officer.

It is the duty of the National Nominating Committee to nominate candidates for national office. The committee shall hold an open meeting, preferably at the Annual Meeting, at which members may appear to present and discuss the eligibility of all candidates.

To be considered a candidate for the 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 a District director.

Interested persons should submit a letter stating which office they seek, including a statement of qualifications, their willingness and ability to serve if nominated and elected, and a biographical sketch.

E-mail the letter to gricelda@aws.org, c/o Gene Lawson, chair, National Nominating Committee.

The next meeting of the National Nominating Committee is scheduled for November 2009. The terms of office for candidates nominated at this meeting will commence January 1, 2011.

profession, or to one who is accredited with exceptional accomplishments in the development of the welding art, upon whom the Society deems fit to confer an honorary distinction. Honorary Members have full rights of membership.

National Meritorious Certificate Award

This certificate award recognizes the recipient's counsel, loyalty, and dedication to AWS affairs, assistance in promoting cordial relations with industry and other organizations, and for contributions of time and effort on behalf of the Society.

International Meritorious Certificate Award

This honor recognizes recipients' significant contributions to the welding industry for service to the international welding community in the broadest terms. The awardee is not required to be an AWS member. Multiple awards may be given. The award consists of a certificate and a one-year AWS membership.

Honorary Meritorious Awards

The Honorary Meritorious Awards Committee makes recommendations for the nominees presented to receive the Honorary Membership, National Meritorious Certificate, William Irrgang Memorial, and the George E. Willis Awards. These honors are presented during the FABTECH International & AWS Welding Show held each fall. The deadline for submissions is December 31 prior to the year of the awards presentations. Send candidate materials to Wendy Sue Reeve, secretary, Honorary Meritorious Awards Committee, wreeve@aws.org; 550 NW LeJeune Rd., Miami, FL 33126. Descriptions of these awards follow.

William Irrgang Memorial Award

Sponsored by The Lincoln Electric Co. in honor of William Irrgang, the award, administered by AWS, is given each year to the individual who has done the most over the past five years to enhance the Society's goal of advancing the science and technology of welding. It includes a \$2500 honorarium and a certificate.

George E. Willis Award

Sponsored by The Lincoln Electric Co. in honor of George E. Willis, the award, administered by AWS, is given each year to an individual who promoted the advancement of welding internationally by fostering cooperative participation in technology transfer, standards rationalization, and promotion of industrial goodwill. It includes a \$2500 honorarium and a certificate.

Honorary Membership Award

The honor is presented to a person of acknowledged eminence in the welding

AWS Publications Sales

Purchase AWS standards, books, and other publications from **World Engineering Xchange (WEX), Ltd.**
orders@awspubs.com; www.awspubs.com
Toll-free (888) 935-3464 (U.S., Canada)
(305) 824-1177; FAX (305) 826-6195

Welding Journal Reprints

Copies of *Welding Journal* articles may be purchased from Ruben Lara.
(800/305) 443-9353, ext. 288; rlara@aws.org

Custom reprints of *Welding Journal* articles, in quantities of 100 or more, may be purchased from

FosteReprints

Claudia Stachowiak
Reprint Marketing Manager
866-879-9144, ext. 121
claudia@fostereprints.com

AWS Foundation

AWS Foundation, Inc., 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.

Chairman, Board of Trustees
Gerald D. Uttrachi

Executive Director, AWS
Ray Shook, ext. 210, rshook@aws.org

Executive Director, Foundation
Sam Gentry, ext. 331, sgentry@aws.org

Solutions Opportunity Squad (SOS)

Corporate Director
Monica Pfarr, ext. 461, mpfarr@aws.org

Director
Connie Bowling, ext. 308, cbowling@aws.org

General Information
(800) 443-9353, ext. 689; vpinsky@aws.org
550 NW LeJeune Rd., Miami, FL 33126

AWS Mission Statement

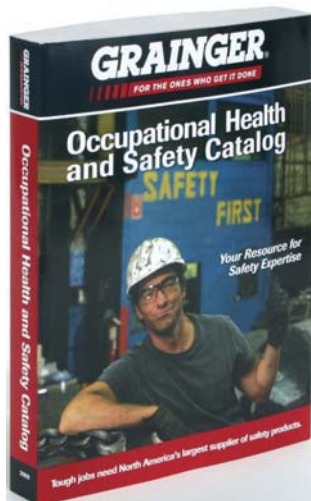
The mission of the American Welding Society is to advance the science, technology, and application of welding and allied processes, including joining, brazing, soldering, cutting, and thermal spraying.

It is the intent of the American Welding Society to build AWS to the highest quality standards. Your suggestions are welcome. Please contact any staff member or AWS President Victor Y. Matthews, as listed on the previous page.

NEW

LITERATURE

Occupational Safety Products Catalog Updated



The *Occupational Health and Safety Catalog* offers all of the products and resources businesses need to keep their employees and facilities safe. This edition

doubles the offerings from the previous catalog, including a larger selection of safety footwear, clothing, and training and reference materials. It is organized by key safety issues and OSHA standards, making it easier for readers to select the right solutions for their safety-related needs. The catalog can be viewed online or ordered in printed format.

W. W. Grainger, Inc.
www.grainger.com/safetyinfo
(800) 323-0620

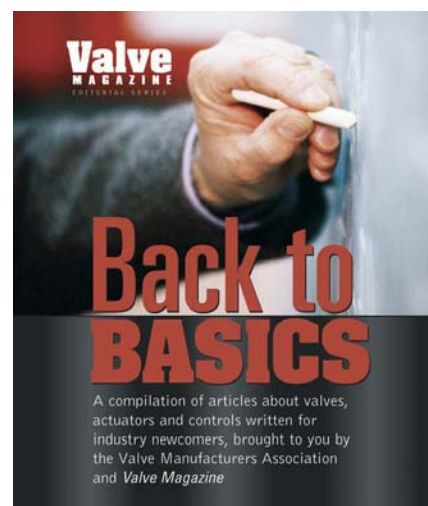
Hybrid Laser-Arc Welding Reference Released

The reference book, *Hybrid Laser-Arc Welding Report*, features twelve technical papers on the title subject written by researchers in the United States, Japan, Germany, China, Finland, Denmark, and Austria, divided into three parts. Part one reviews the characteristics of the process, including the properties of joints produced and ways of assessing weld quality. Part two concerns applications using mag-

nesium alloys, aluminum, steel, and dissimilar metals in the shipbuilding and automotive industries. Part three has a paper on hybrid laser-arc welding of steel. Edited by F. O. Olsen, Technical University of Denmark, the price is \$245, including shipping and handling.

Research and Markets
www.researchandmarkets.com/reports/991980
FAX: (646) 607-1907

Valve Back to Basics Compilation Released



The book *Back to Basics* is a compilation of 17 articles previously published in *Valve Magazine* between 2004 and 2009. The 80-page, full-color, spiral-bound book addresses the major valve categories plus actuator fundamentals and selection, valve specifying for beginners, and a primer on materials. The valve types detailed include gate, globe, check, pressure-seal, plug, hydrant, ball, butterfly, diaphragm and pinch, safety relief, and control valves and systems. Written by valve industry experts, the book is part of the association's new educational and training initiative. The list price is \$79, \$69 for VMA members, plus shipping. A free copy is provided for every five copies ordered.

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Free Guide Addresses Packaging Automation

The eight-page guide, *Packaging Automation Trends: Using Small Assembly Ro-*

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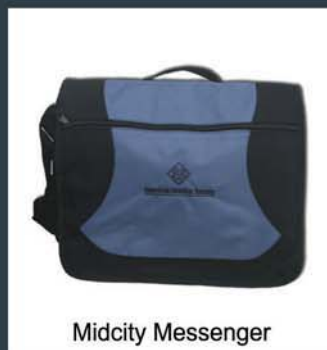
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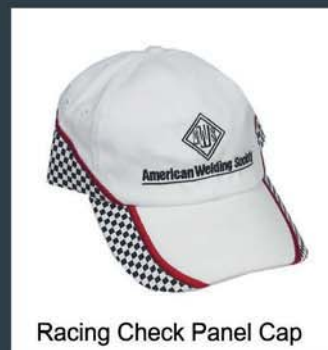
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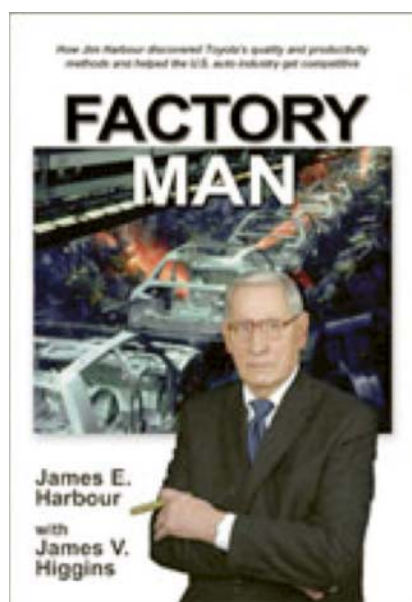
— continued from page 84

bots in Upstream Packaging Processes, is written for manufacturers, packaging engineers, machine builders, and system integrators. Explored are the advantages of using small assembly robots in the processes that take place before final cartoning and palletizing, which usually require larger robots. Illustrated and compared are high-speed, pick-and-place, four-axis SCARA robots and six-axis articulated robots that offer added flexibility of movement. One section deals with robot automation basics, calculating payload capacity, necessary reach, cycle time, programming, etc. Another section details the ten things to look for when choosing a robot. The free guide can be downloaded from the Web site.

DENSO Robotics

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Factory Man Bios Auto Expert James E. Harbour



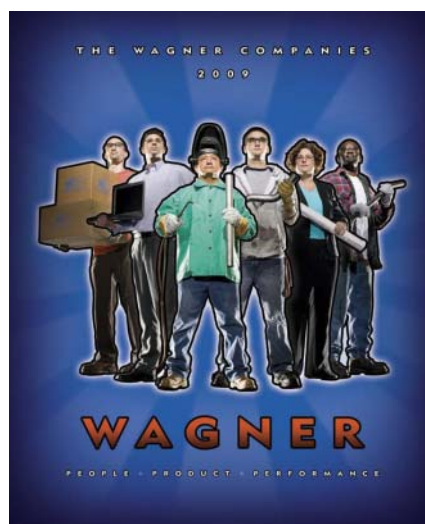
The recently released James E. Harbour autobiography, *Factory Man*, details how he discovered Toyota's quality and productivity methods on the factory floor and helped the U.S. auto industry get competitive, and why Detroit's Big Three still need help. Harbour is recognized as a leading automotive industry analyst and founder of *The Harbour Report*, a study of original equipment manufacturers' manufacturing performance. In nontechnical terms, the book discusses "common-based" manufacturing to reduce investment for design and product develop-

ment, and the use of common platforms and architectures including such components as seat tracks, horns, lumbar supports, sensors, bearings, lock sets, door handles, etc. The net savings of such implementations, he explains, has the potential to conservatively save \$2000 per vehicle. The book is coauthored by James V. Higgins, an auto industry reporter, columnist, and editor, primarily for *The Detroit News*, for more than 25 years. The book lists for \$30, \$26 for SME members.

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Master Catalog Illustrates Railing Systems



The 304-page master catalog includes 7800 items in the company's lines of aluminum and stainless steel railing systems. Complete information is presented on spiral stairs, cable railing, glass railings, connectors, woven wire mesh panels, flanges, slip-on fittings, balusters, brackets, architectural shapes, and stamped ornaments. Included is an expanded technical information section providing installation instructions and current code summaries. New products include the PanelGrip™ dry glaze system for the installation of structural glass railing, Kee Access® galvanized malleable iron slip-on fittings, Speed Rail® aluminum slip-on fittings, and numerous other products.

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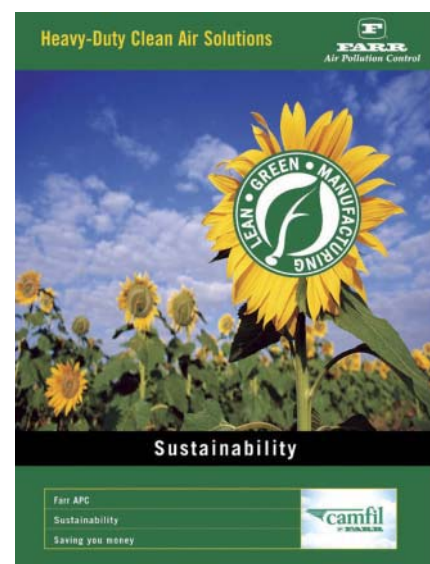
The 2009 editions of *Aluminum Standards and Data* and *Aluminum Standards*

and *Data* — *Metric SI* provide information and data pertaining to nominal and specified chemical compositions of alloys; typical mechanical and physical properties of commonly used commercial alloys; mechanical property limits; information on comparative characteristics and applications; definitions; and dimensional tolerances for semifabricated products. Included are the latest information from the 2009 American National Standards for wrought aluminum and aluminum alloys, and the reorganized Terminology Section now harmonizes with international definitions. Available in print or CD, either individually or as a set of both documents, the list prices are \$125 each, and \$190 for the set. Aluminum Association member prices are \$65 each, and \$95 for the set. To order, visit the Web site and click on "What's New."

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Heavy-Duty Air Pollution Control Systems Pictured



A four-page, full-color brochure illustrates and describes the features of the company's "green" Gold Series heavy-duty air pollution control systems for industrial applications. Shown are the HEMIpleat® filter with Gold Cone™ filter technology, and the DURApleat® washable and reusable model for more rigorous applications and temperatures. A number of photographs show the equipment installed in a variety of customized industrial settings.

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PERSONNEL

Lincoln Makes Executive Management Changes



David LeBlanc



George Blankenship



Richard Seif



Gretchen Farrell

Lincoln Electric Holdings, Inc., Cleveland, Ohio, has named **David LeBlanc** to the newly created position of senior vice president, president of Lincoln Electric International; **George Blankenship** has been promoted to senior vice president and president, Lincoln Electric North America; **Richard Seif** has been named senior vice president, global marketing and automation; and **Gretchen Farrell** has been named senior vice president, human resources and compliance. LeBlanc, with the company since 1995, has served since 2005 as president, Lincoln Electric Europe. Blankenship previously was president, Lincoln Cleveland and senior vice president of global engineering. Seif, with the company since 1971, most recently was vice president, sales and marketing U.S.A. Prior to this promotion, Farrell served as vice president, human resources.

Airgas Names Presidents

Airgas, Inc., Radnor, Pa., has named **Pamela M. Swanson** president of Airgas North Central. She replaces **Ronald J. Stark** who has joined the company's corporate management team as senior vice president — sales and marketing. **Edward A. Richards** was named Airgas Nor Pac president, succeeding **Dan L. Tatro** who has joined the Airgas Core Strategy II team as director — CS². Since 2004, when



Pamela Swanson



Ronald Stark



Edward Richards



Dan Tatro

Swanson joined the company, she has served as vice president for Airgas North Central's northeast division. With the company since 2005, Richards most recently served as vice president — operations for Airgas Nor Pac, based in Vancouver, Wash.

Director of Sales Appointed at Wagner Companies



Anthony Goodings

Wagner Companies, Milwaukee, Wis., has appointed **Anthony R. Goodings** to the newly created position of director of sales. Goodings brings 22 years of experience in the sales and account management field gained from affiliations with Herman Miller, McGraw-Hill Construction, Johnson Controls, and Olon Industries. Wagner, a metal products manufacturer, is a supplier to the architectural and industrial markets.

Operations Manager Named at Saint-Gobain

Saint-Gobain Technical Fabrics, Grand

Island, N.Y., has appointed **Ron Franklin** glass mat operations manager, overseeing operations in Charleston, S.C., and Russellville, Ala. Prior to joining the company, Franklin was general manager for glass mat operations at GAF Materials Corp.

President Named at Northwire



Michael Conger



Mark Kravik

Northwire, Inc., Technical Cable, Osceola, Wis., has named **Michael Conger** president, succeeding **Mark Kravik** who has transitioned to chairman of the board. Prior to joining the company, Conger, an AWS Certified Welding Inspector with the Fox Valley Section, served in senior management roles in the railway and truck manufacturing industry, most recently with a company in Paris, France.

Business Director Named at Bluewater Thermal



Terry Brown

Bluewater Thermal Services, Buffalo, N.Y., operating 15 certified heat treating facilities in nine states and Canada, has appointed **Terry Brown** to the new position of director — business development. Before joining the company, Brown served with Lindberg Heat Treating Co. in a variety of positions, most recently as director — sales and marketing.

PTM Hires Military Contract Specialist

PTM Corp. and its Modified Technology

— continued on page 90



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American Welding Society

PERSONNEL

— continued from page 88

gies Advanced Engineering and Tooling Group, Fair Haven, Mich., has hired **Samra Weindl** as military defense specialist to explore the military sector for contracts and other related business. Weindl previously worked at Cypress Manufacturing for three years where she served as defense contract specialist.

KUKA Robotics Canada Appoints Sales Director



Yarek Niedbala

KUKA Robotics Canada, Ltd., Toronto, has appointed **Yarek Niedbala** director of sales for the Canadian marketplace. Niedbala has 12 years' experience in the field with 8 years at KUKA Robotics Corp. U.S.

NEW PRODUCTS

— continued from page 25



cutting, and similar operations. It employs a negative-pressure system that exhausts all fumes quickly to the outside or into existing ductwork. Four models are available with fume extraction capacities from 400 to 1150 ft³/min. Accessories include flexible goose-neck hood support arms.

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NEWS OF THE INDUSTRY

— continued from page 13

ATI Industrial Automation Holds Open House, Technology Training Fair



ATI Industrial Automation, an engineering-based developer of robotic peripheral equipment, hosted its 3rd Annual Open House and Technology Training Fair at the Detroit, Mich., sales office on August 20. As shown above, guests take a first-hand look at the company's latest robotic end-effector products. Account managers and engineers discussed existing and potential applications. Demonstrations of the company's robotic tool changers, collision sensors, and deburring tools as well as compliance devices ran all day. Also, training sessions were held for robotic deburring applications, industrial fieldbus systems, and new product developments.

Eberspaecher Expanding Production in Michigan



At Eberspaecher North America's manufacturing plant in Brighton, Mich., a multimillion-dollar renovation of the facility has been finished. Production Associate Dawnn Anderson is pictured here.

Production of new commercial-vehicle exhaust aftertreatment systems is scheduled to begin later this year at Eberspaecher North America's manufacturing facilities in Brighton, Mich.

Recently, the company completed a multimillion-dollar renovation of the facility, retooling 80% of the 120,000-sq-ft plant floor

space with automated welding equipment for the final assembly of new aftertreatment systems.

Eberspaecher has also installed manufacturing technology at a new facility in Wixom, Mich. The 100,000-sq-ft plant houses roll-forming and new patented sizing equipment for the production of canning used in its aftertreatment systems.

Designed to meet new Environmental Protection Agency commercial-vehicle emissions standards for 2010, the company's selective catalytic reduction technology has the ability to reduce critical heavy-truck emissions.

Machinery Added to Manufacturing Technology's Contract Welding Services



Part of the growth experienced by Manufacturing Technology Inc.'s Contract Welding Services, South Bend, Ind., includes more than \$3 million in machinery. Three new friction stir welding machines were added as well as a linear friction welding machine. This expansion has provided more than a 40% increase in capacity and reduced turnaround time. Among its equipment is a large contract rotary friction welding machine. Displayed is the Contract Welding area where welding, heat treat, and pre/post processing are conducted. Several other specialized machines are scheduled to join the lineup later this year.

Industry Notes

- Eight winners were chosen for the **North American Die Casting Association's 2009 International Die Casting Design Competition**. These were on display at the 113th Metalcasting Congress in Las Vegas, Nev. Two honorable mention winners were also awarded. Categories were grouped by material.
- **OKI Electric Industry** developed static pressure soldering technology for lead-free soldering of large, high-density products. Using it, the company and **Nihon Dennetsu** jointly developed a soldering machine enabling lead-free (Sn-3.0Ag-0.5Cu) soldering for products sized up to 490 x 510 mm and 6 mm thick.
- A memorial endowment scholarship for welding students attending **Aims Community College**, Colorado, has been established by family and friends of the late **Dale Majors**, a welder who played a role in developing the school's vocational programs.
- **Walker Corp.**, Ontario, Calif., acquired **Specialty International de Mexico**, a metal fabricating, welding, assembly, and powder coating operation that will become Walker Specialty International de Mexico.

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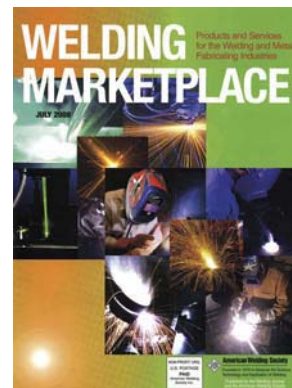
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Transient High-Frequency Welding Simulations of Dual-Phase Steels

Numerical and experimental simulations were used to investigate high-frequency welding of advanced high-strength steels

BY R. BAUMER AND Y. ADONYI

ABSTRACT

Continued development of advanced high-strength steel (AHSS) requires a corresponding improvement in joining technology. One promising joining method is high-frequency butt joint welding. Seeking to validate the utility of this process for joining AHSS flat sheet specimens for steel mill processing lines, high-frequency butt joint welding of flat sheet steel was investigated through a combined numerical and experimental simulation methodology. Simulated welds were produced and pre-Curie and post-Curie temperature heating rate differences were observed with infrared radiation (IR) imaging. Good correlations were found between numerical predictions and actual heating rates. Final metallographic analysis revealed complete coalescence of faying surface, with only minor hardening at the weld interface. It was concluded that high-frequency welding shows good potential for coil joining in steel processing lines.

Introduction

Modern steel coil processing lines (such as pickling and galvanizing) benefit greatly from a continuous feed of steel strip, a process that requires coil end joining (Ref. 1). As is shown in Fig. 1, continuous processing is achieved through the combined use of an accumulator (Fig. 1B) (Ref. 2) and a coil end welding machine

(Fig. 1C). Due to the finite capacity of the accumulator, one main constraint on welding process selection is welding speed. Additional constraints, such as material thickness, result in a variety of welding processes being used for coil end joining, including gas tungsten arc welding (GTAW), gas metal arc welding (GMAW), flash welding (FW), resistance (mash) seam welding (RSEW-MS), and laser beam welding (LBW) (Ref. 3). Note that the last two are mostly used on tin coating and recoiling lines, where the sheet thickness is less than 1 mm.

Joining of advanced high-strength steel (AHSS) coil ends brings additional challenges to coil end joining due to inherent high strength, prompting difficulties in end shearing, and faying surface alignment, and a propensity for localized hardening in welding microstructures. Indeed, excessive hardness in the fusion and heat-affected zones has been reported in the case of laser beam welding of dual-phase (DP) and transformation-induced plasticity (TRIP) steels (Ref. 4). The presence of such excessive hardness can provide a metallurgical notch, precipitating joint failure during subsequent mill operations. To eliminate potential problems stemming from the as-cast microstructures found in fusion welding, a solid-state welding process is desired for joining AHSS coil ends. While resistance welding (RW) and flash welding (both solid-state processes) are currently widely employed in coil joining, RW is slow and is limited to small thicknesses (Ref. 1) while FW can be difficult to control because it is susceptible to irregular arcing and incom-

plete fusion on the strip edges. Even resultant strip breaks of 0.2% are not acceptable, as equipment is damaged and production lost. Therefore, an improved solid-state joining process is desired for joining AHSS coil ends.

Previous work has demonstrated that a coupled high-frequency induction heating/pressure welding (termed hyper-interfacial bonding) operation can produce faying surface coalescence in butt joint configurations and minimize thermally induced changes in grain size of ultrafine-grained steel (Ref. 5). Heating times for $5 \times 5 \times 30$ -mm specimens were shown to be very rapid (0.2 s to 1600°C at 1 MHz and 50–59 kW) (Ref. 5), indicating that high-frequency welding can satisfy the time constraints associated with coil end joining.

Additionally, previous research demonstrated that high-frequency welding could produce good welds in AHSS specimens (Fig. 2), as evidenced by successful limited dome height formability testing (Ref. 6). The long history of successful high-frequency induction welding (HFIW) of joints in tubular products and structural shapes (Ref. 7) also suggests the usefulness of high-frequency welding for coil end joining.

This present work builds on this foundation by developing numerical and experimental techniques for simulating high-frequency welding of dual-phase steel coil ends, thereby 1) providing insight into fundamental high-frequency heating/material interactions, 2) establishing operating parameters, and 3) demonstrating the feasibility of joining DP steel coil ends with high-frequency welding.

Physical Simulation Overview

High-frequency induction heating/pressure welding of dual-phase steels was performed at small scale through induction heating using a solid-state-controlled, state-of-the-art 100-kW variable-frequency (250–400 kHz) induction welding power supply. After heating specimens to forging

KEYWORDS

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Dual-Phase Steels
FEA Modeling
Heating Rates

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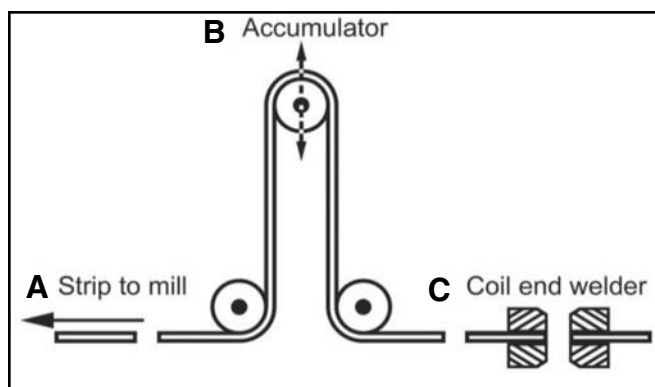


Fig. 1 — Schematic representation of accumulator and coil end welding machine utilized in continuous steel strip processing mills. A — Strip to mill; B — accumulator — moving vertical rollers allow for a varying amount of strip to be stored, enabling the stored strip to be fed to the mill line while keeping the coil end stationary; C — welding machine utilized to join the end of the coil in the mill and the lead end of the next coil. (Fig. 1B reproduced after Ref. 2 with permission from MetalForming/PMA Services, Inc.)

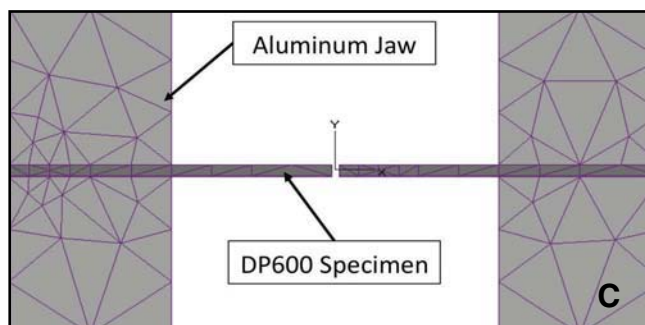
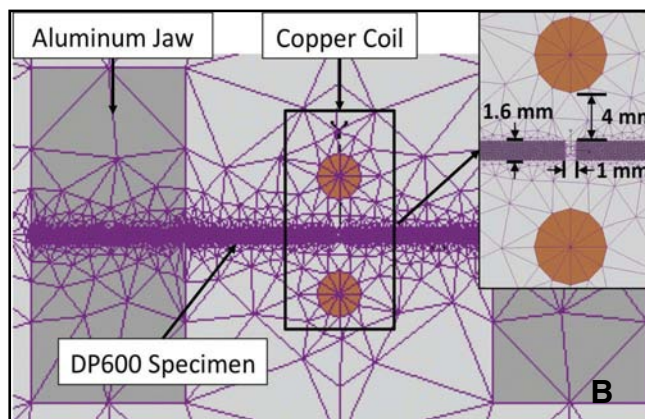
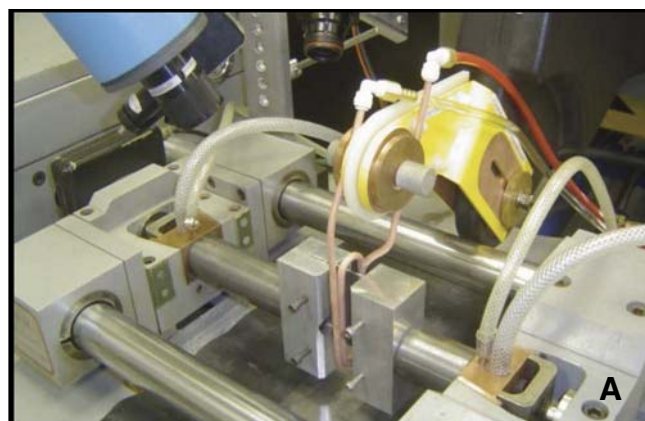


Fig. 3 — A — Physical simulation setup. Note results reported in this present investigation utilized a single-turn induction coil and did not use the two-turn coil shown above; B — electromagnetic model simulation geometry with representative mesh density; C — thermal model simulation geometry with representative mesh density.



Fig. 2 — High-frequency welds made in advanced high-strength steels (different composition than the DP600 but still possessing near 600 MPa ultimate tensile strength). A — As-welded specimens; B — transverse micrograph. Previously published in Ref. 6. Used with permission from US Steel Research Europe, Kosice, Slovak Republic.

temperatures and turning off the induction coil power supply, controlled deformation was delivered by the hydraulic ram system of a connected Gleeble 1500® thermomechanical simulator. All heating and deformation timing was precisely controlled via a LabVIEW control program connecting the two systems. Small-scale welding specimens ($1.5 \times 44 \times 89$ mm) were rigidly constrained in aluminum jaws and heated by a water-cooled, copper induction coil — Fig. 3A. Atmospheric shielding was accomplished by flooding the welding chamber with argon.

As compared to the industry standard high-frequency resistance welding (HFRW) often employed in tube welding

(Ref. 7), the experimental simulation technique reported here is distinguished by 1) a transient process unable to reach the steady-state operating condition characteristic of HFRW, 2) controlled relative motion between faying surfaces (i.e., not dependent upon the speed or V angle of the advancing pipe), and 3) variable frequency between 250 and 400 kHz using the latest solid-state power control technology.

Fundamentals of the Heating Mechanisms

Heating of welding specimen edges prior to forging is the consequence of both eddy current heating, accentuated by the skin effect, and hysteresis heating (ferro-

magnetic materials only). Eddy current heating occurs due to resistive heating losses accompanying induced current flow in a material. By consequence of the skin effect, current distributions are restricted to shallow penetration depths on faying surfaces, leading to rapid heating and high efficiencies (Ref. 8). For ferromagnetic materials, hysteresis heating also occurs, a direct consequence of inelastic magnetization/demagnetization (represented by the area enclosed by the BH curve of a material) (Ref. 9). Naturally, hysteresis heating ceases when the Curie temperature (approximately 1033 K for ferromagnetic materials) (Ref. 10) is reached and materials become paramagnetic.

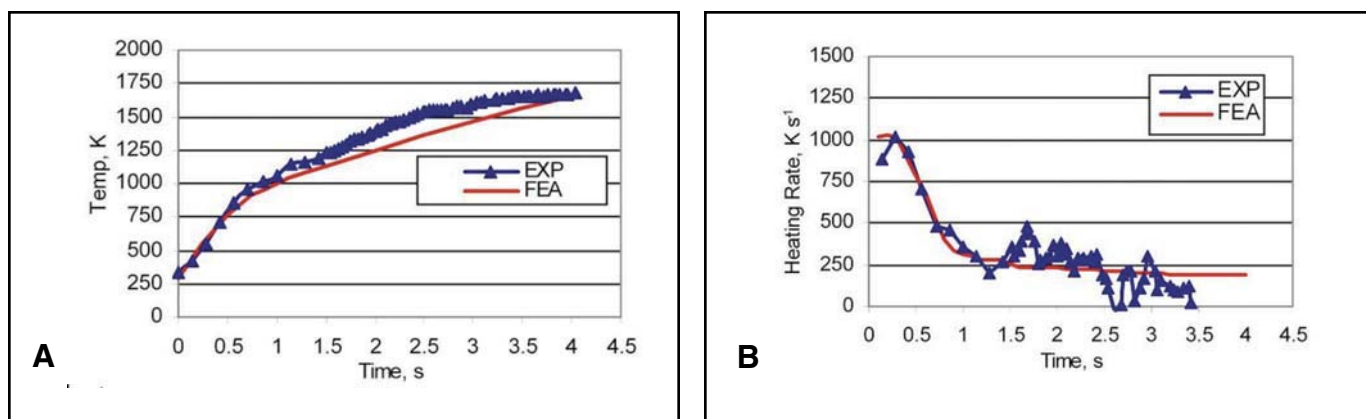


Fig. 4 — A — Comparison of numerical and experiment temperatures; B — heating rates vs. time at the faying surface (weld interface center). Numerical simulation results for DP600 heated with a 1750-A induction coil current input (315 kHz). Physical experimental results shown for DP600 welded at 315 kHz and 40 kW.

Table 1 — Material Input Parameters for Numerical Simulations of High-Frequency Induction Heating of DP600 Sheet Steel

Temp. K	Thermal Conductivity W·m ⁻¹ ·K ⁻¹	Temp. K	Specific Heat J·kg ⁻¹ ·K ⁻¹	Temp. K	Resistivity μΩ·m	Magnetic Loss W·kg ⁻¹	B Field T	H Amp·m ⁻¹	293 K μ _r	523 K μ _r	773 K μ _r	1023 K μ _r
273	59.5	323	450	273	0.3	0.00	0	0	0.0	0.0	0.0	0.0
373	57.8	473	520	373	0.38	5512	0.015	100	11.0	9.2	6.7	1.9
473	53.2	573	565	473	0.44	22050	0.03	200	16.6	13.8	10.0	2.9
573	49.4	623	590	573	0.42	49612	0.045	300	20.3	17.0	12.3	3.6
673	45.6	723	650	673	0.65	88200	0.06	400	23.2	19.4	14.1	4.2
773	41	823	730	773	0.78	137812	0.075	500	25.5	21.3	15.5	4.7
873	36.8	973	825	873	0.92	198450	0.09	1000	35.2	29.5	21.6	6.8
973	33.1	1023	1100	973	1.11	270112	0.105	2000	44.8	37.7	27.9	9.4
1073	28.5	1073	875	1073	1.34	352800	0.12	3000	50.7	42.9	31.9	11.4
1273	27.6	1123	846	1173	1.55	446512	0.135	4000	55.2	46.8	35.2	13.2

Note: Thermal conductivity values were taken from SAE 1008 carbon steel (Ref. 18); specific heat capacity values were taken from SAE 1010 (323–1023 K) and SAE 1008 (1073–1123 K) (Ref. 16). Resistivity values were determined using DP980 (Ref. 17). Magnetic loss was determined at 280 kHz using Equation 9. Relative magnetic permeability was determined using Equation 10.

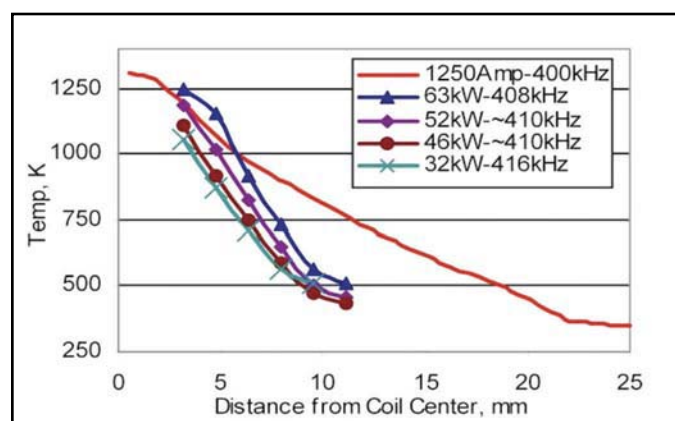


Fig. 5 — Comparison of numerical and experiment temperature distributions. Experimental data obtained through static heating trials of DP600.

Fundamentals of the Deformation Mechanisms

Weld quality in high-frequency welding is strongly dependent upon the nature of deformation at the faying surface. Pre-

vious research indicates that control of deformation input parameters of total faying surface upset, deformation strain rate, and forging operation temperatures can improve coalescence of faying surfaces during high-frequency welding of high-performance steels (HPS) (Ref. 11). While the significance of these mechanisms is certainly recognized in this present research, neither total upset nor deformation rates were considered as primary variables in this initial process development, as fundamental heating parameters were of primary concern.

Objectives

The purpose of this numerical and physical simulation study was to understand and characterize the thermal phenomena governing the bond quality in transient high-frequency joining of DP steels. The study was also intended to validate the concept of designing a steel coil joining prototype and provide means to link parametric effects found at small scale to future full-scale implementation.

Methodology

Induction Heating Simulation Overview

Induction heating is modeled by solving both the electromagnetic response to current flow through the heating coil and the thermal response of the specimen to eddy current and hysteresis heating. The electromagnetic regime is described by Maxwell's equations and associated constitutive relations (as given by Ref. 15)

$$\vec{\nabla} \cdot \vec{B} = 0 \quad (1)$$

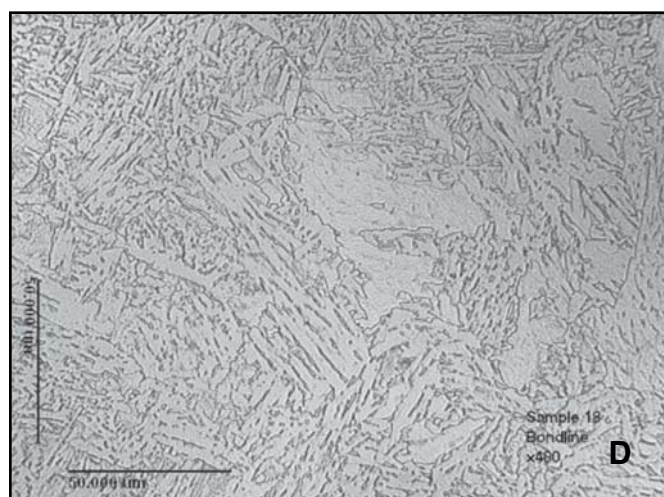
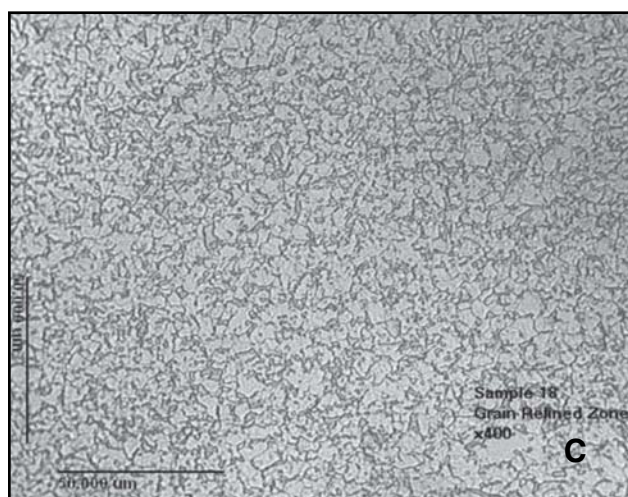
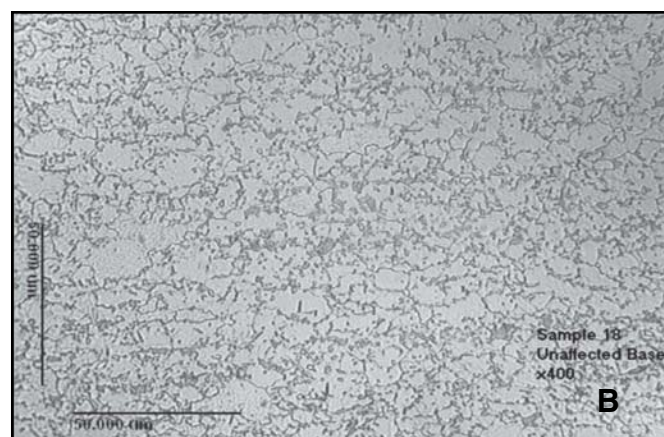


Fig. 6 — Sample 18: DP 600, 42 kW, 315 kHz, 4 s heating. A — Welded sample; B — base metal; C — grain-refined zone; D — weld interface.

$$\vec{\nabla} \cdot \vec{D} = 0 \quad (2)$$

$$\vec{\nabla} \times \vec{E} = -\frac{\partial \vec{B}}{\partial t} \quad (3)$$

$$\vec{\nabla} \times \vec{H} = \vec{J} + \frac{\partial \vec{D}}{\partial t} \quad (4)$$

$$\vec{D} = \epsilon \vec{E} \quad (5)$$

$$\vec{B} = \mu \vec{H} \quad (6)$$

$$\vec{J} = \sigma \vec{E} \quad (7)$$

where B is magnetic induction, D is electric flux density, E is electric field strength, H is magnetic field strength, μ is magnetic permeability, ϵ is dielectric constant, and σ is conductivity.

Solutions in the electromagnetic regime yield eddy current and hysteresis power losses, which comprise the thermal generation term in the generalized heat equation (Refs. 12, 15)

$$\vec{\nabla} \cdot (k \nabla T) + \dot{Q} = \rho C \frac{\partial T}{\partial t} \quad (8)$$

where $\dot{Q}$ is internal heat generation (in this problem, coming from hysteresis and eddy current power losses), k is thermal conductivity, ρ is density, and C is specific heat.

Solving the heat equation yields the resulting temperature distribution in the specimen. Due to the temperature dependence of all material properties, coupling between the governing equations is highly nonlinear, requiring a numerical solution method. (Refer to Refs. 9 and 12–15 for detailed explanations of the governing equations and associated numerical solutions.)

In this present work, a systematic numerical simulation of induction heating of flat sheet DP steels was conducted using the commercial finite element analysis (FEA) software MagNet and ThermNet from Infolytica Corp. MagNet enables a user to model components and current-carrying conductors (using a CAD-type interface) and solve for the resulting electromagnetic field interaction between the two via an FEA-based solution method. Solutions include static, time-harmonic, and transient responses in two or three dimensions. Similarly, ThermNet provides

an FEA-based solution to the transient thermal response of a component subject to heating or cooling phenomenon. Solutions include static and transient responses in two or three dimensions. Induction heating is modeled by solving electromagnetic and thermal systems together.

Numerical Simulation: Specimen Geometry, Mesh, and Boundary Conditions

Model geometry was defined in two dimensions only, operating under the assumption that edge heating effects were negligible. Dual-phase steel welding specimens were each said to be 1.6 mm thick and 43.5 mm in length, with a 1-mm root opening between faying surfaces. The induction coil was modeled as a solid copper conductor of 6.35 mm diameter with a liftoff of 4 mm. Aluminum jaws utilized to contain specimens during physical trials were also included in the model — Fig. 3B. Simulations were conducted in a simulation cell (referred to as the AirBox) of dimensions 176 × 176 mm.

Following the definition of specimen

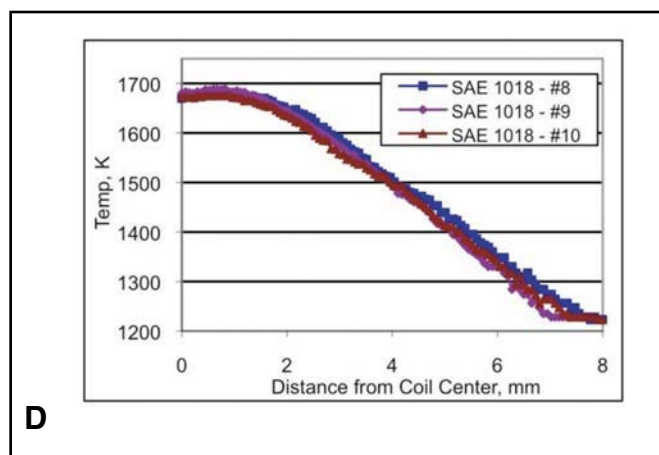
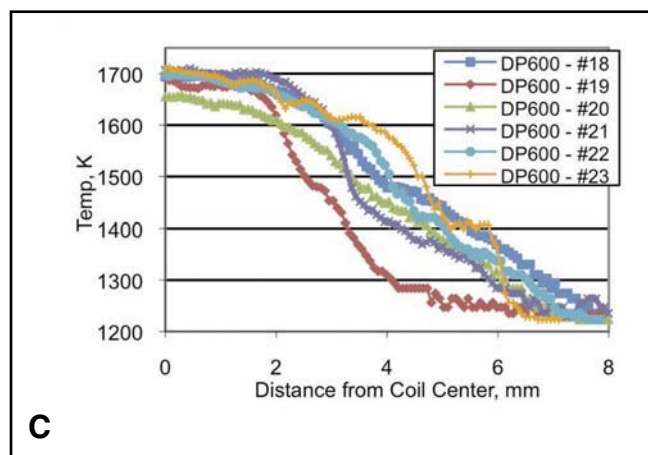
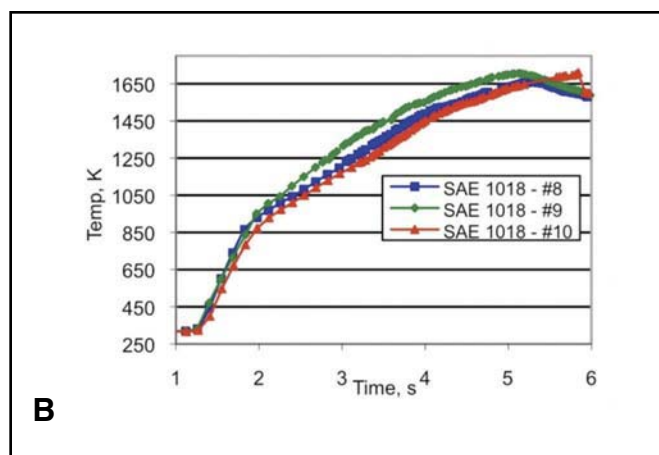
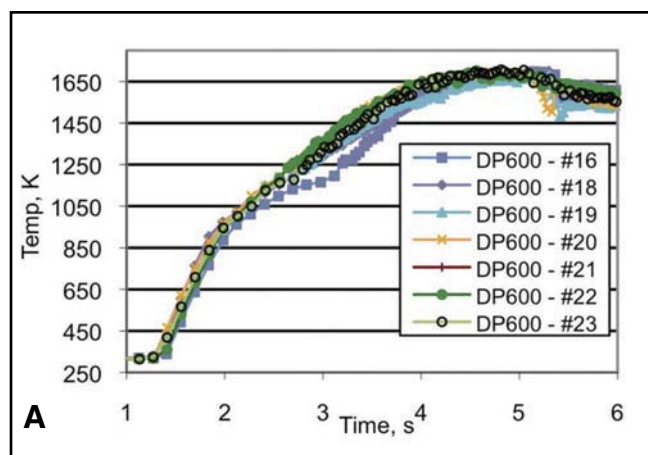


Fig. 7 — A — Temperature evolution at the weld interface for DP600; B — temperature evolution at the weld interface for SAE 1018; C — temperature distribution at time of maximum temperature (immediately prior to upset) of DP600; D — temperature distribution at time of maximum temperature (immediately prior to upset) of SAE 1018.

Table 2 — Representative Physical Simulation Input Parameters for DP600 and SAE 1018

Material	Frequency kHz	Power kW	Gap mm	Liftoff mm	Upset mm	Disp. Rate mm s ⁻¹	Trial Time s
SAE 1018	316	42	1	4	-1	10	4
DP 600	315	42	1	4	-2	100	4
SAE 1018	403	42	1	4	-2	20	4
DP 600	398	42	1	4	-2	20	4

Note: See Appendix 1 for all data.

geometry, the second step in FEA implementation was spatial discretization. In the electromagnetic model, due to the rapidly changing electromagnetic fields, the maximum element size (MES) in the sample was to be no larger than 0.25 mm. No MES was specified for the AirBox or the coil, and the computer generated one appropriate to the geometry — Fig. 3C. For the thermal model, no maximum element size was set for any part of the model, and an appropriate mesh was automatically generated — Fig. 3C. A polynomial order of two was set for all element equations.

The electromagnetic boundary condi-

tions were set to have flux lines tangential to the AirBox perimeter and at the intersection of the AirBox with the sheet specimen. This facilitated the approximation that the sheet specimen was being inductively heated in an infinitely large volume. In the thermal regime, the adiabatic boundary condition was applied to all surfaces, assuming that radiative and convective heat losses were small compared to conduction of heat within the specimen.

Numerical Simulation: Material Properties

Material properties requiring defini-

tion for successful FEA simulation of induction heating are mass density, thermal conductivity, specific heat, electrical resistivity (or conductivity), magnetic loss (hysteresis loss), magnetic permeability, and electric permittivity. Mass density was taken to be 7600 kg·m⁻³. Thermal conductivity and specific heat were determined through handbook data for low-carbon steel (Ref. 16), with the values defined as shown in Table 1. Electrical resistivity as a function of temperature was measured through a modified form of ASTM B-193 (Ref. 17) (Table 1). While simulations were based on resistivity data collected on

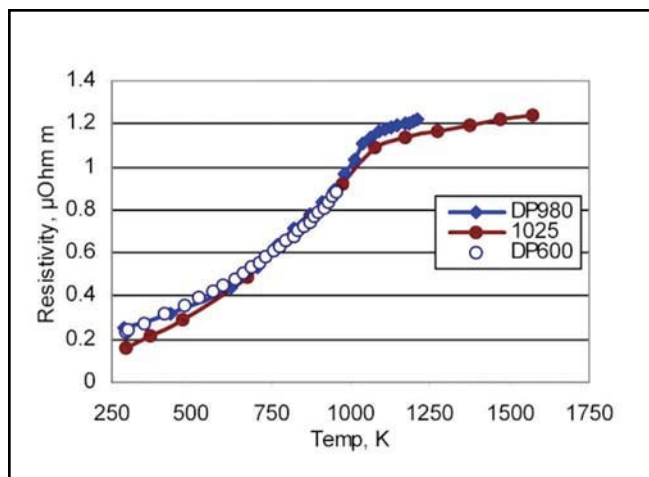


Fig. 8 — Resistivity vs. temperature profiles for DP600, DP980, and SAE 1025. Resistivity data for SAE 1025 taken from Ref. 16. Resistivity of DP steels determined through a modified form of ASTM B193-02 (Ref. 17).

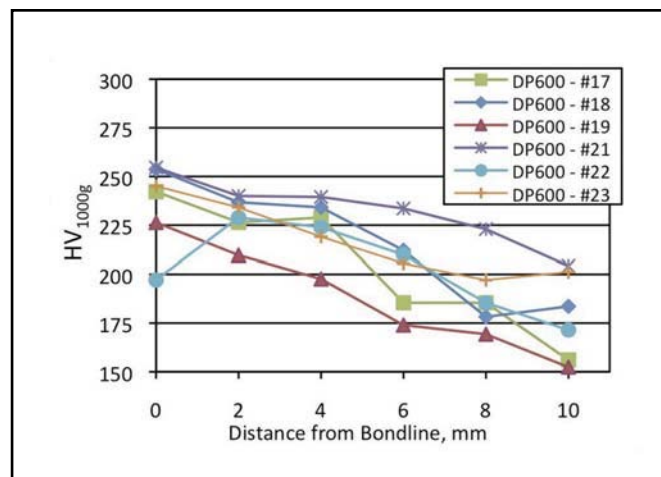


Fig. 9 — Hardness data on DP600 high-frequency welding simulation specimens.

DP980, additional resistivity testing of DP600 demonstrated the values to be nearly identical — Fig. 8. Magnetic loss was determined through the empirically based Steinmetz equation (Ref. 18):

$$\langle P_v(t) \rangle = C \cdot f^\alpha \cdot B^\gamma \quad (9)$$

where $\langle P_v(t) \rangle$ is the average power loss per volume; C , α , and γ are constants (set equal to 87500, 1, and 2, respectively); f is frequency; and B is the peak magnetic induction. Magnetic permeability was found through the following equation

$$\mu_r(H, T) = 1 + \sqrt{(T_c - T) \cdot k_1} \times \frac{k_2}{k_2 + H} \quad (10)$$

where μ_r is the relative magnetic permeability, k_1 and k_2 are constants (set equal to 10 and 100, respectively); and T_c is the Curie temperature. Magnetic induction (B-field) was subsequently determined by treating μ as the first derivative of the B-H curve and performing numerical integration (Ref. 15).

In the initial stages of material property definition, experimentally obtained heating profiles of DP steel at low powers (1 kW) were utilized to optimize the correlation between numerical and experimental simulation heating profiles. Assuming that hysteresis heating dominates the heating mechanism before the Curie temperature, hysteresis loss was treated as a correction factor and the constants of Equation 1 were iteratively adjusted until an optimal correlation was obtained with experimental heating curves. Following material property definition, high-power simulations were conducted (1000–1750 A_{rms} coil

current input, 250–400 kHz, and 4.5 s heating time). A complete list of material input properties for DP600 is provided in Table 1. Electromagnetic models were solved using the time-harmonic approximation (material nonlinearities were still considered) while the thermal mode was solved for the transient solution. A time step of 0.25 s was used in the electromagnetic model, while a 0.10 s time step was utilized in the thermal model.

Experimental Simulation Methodology

Dual-phase steel and SAE 1018 carbon steel specimens (1.5 mm thick) were water cut to 1.75 × 3.5 in. (44.45 × 88.9 mm), sand-blasted, and painted with high-temperature HiE-Coat™ 840-M paint (Ref. 19), designed to ensure consistent material emissivity and corresponding infrared radiation (IR) camera accuracy. Welds were made on both DP and carbons steel, with the primary operating parameters being 4-mm coil liftoff, 42 kW, 315 kHz, and a 1-mm root opening (Table 2). During heating, the transient thermal response was collected via two digital IR cameras, which provided (when operated together) an accurate measure of a range of temperatures between 298 and 1733 K. Data collected with these two cameras enabled temperature evolution at the weld interface and temperature distributions transverse to faying surfaces to be measured. Following welding, metallurgical analysis was performed using optical microscopy and Vickers microhardness indentation (1000-g load and 12-s dwell time). Selected specimens were cross sectioned transverse to the weld interface, mounted, prepared to a 1.0 μm final polish, and chemically etched using 2% Nital etch.

Results

Numerical Simulation

Temperature evolution profiles for the faying surface of DP600 specimens (FEA simulation at 1750 A_{rms} input current and 315 kHz) clearly indicated the distinct heating mechanisms occurring before and after the Curie temperature — Fig. 4A. Before the Curie temperature (~1033 K), heating rates are as high as 1000 K s⁻¹. After the Curie temperature, heating rates drop to approximately 225 K s⁻¹, a decrease of approximately 75% — Fig. 4B. Comparison with physical simulation results indicates that the numerical values fall within approximately 10% of the experimental data, emphasizing that the dramatic decrease in heating rate after the Curie temperature observed in our numerical simulations is indeed a real result.

While heating profiles at the faying surface correspond well between the numerical and physical simulations, temperature distribution comparisons (sampled at the peak temperature in static heating trials) reveal a growing divergence (with increasing distance from the weld interface) between the numerical and experimental temperature distributions — Fig. 5. Divergence between numerical and experimental simulations in the transverse heating profiles suggests that our material property values could be further refined. We consider Equations 9 and 10 to be the most likely source of this divergence, especially since Equation 10 deviates somewhat from formulations given in the literature (Refs. 13, 15). However, the accurate temperature evolution profiles indicate that our general methodology is sound, and we anticipate that future re-

Table 3 — Summary of Statistical Analysis

	Pre-Curie Temp Heating Rate Ks ⁻¹		Post-Curie Temp Heating Rate Ks ⁻¹		Max. Temp. K	
	DP 600	SAE 1018	DP 600	SAE 1018	DP 600	SAE 1018
Mean	904.9	786.0	227.6	225.6	1697.6	1692.5
St. Dev.	62.8	68.0	25.1	42.2	8.9	27.2
Observations	8	9	25.1	42.2	7	3
df	15		13		2	
Hypo. Dif.	60		0		0	
t Stat	1.856		0.122		0.317	
t Stat-Critical	1.753		1.77		2.920	
1 Tail P Value	0.04		0.45		0.390	
DP 600>SAE 1018 by with Confidence	7.6%		0%		0%	
	96%		—		—	

Table 4 — Composition Information

	C	Mn	P	S	Si	Cr	Mo	Al	N	Ti	Other
1.52 mm DP 600 GN (Ref. 23)	0.084	1.50	0.009	0.0073	0.010	0.032	0.315	0.054	0.017	<0.002	V = 0.003 Cu = 0.037
AISI 1018 (Ref. 24)	0.15–0.20	0.60–0.90	≤0.04	≤0.05	0.15–0.30	—	—	—	—	—	Cu ≥0.20

finement of model material properties (particularly magnetic loss and permeability) could improve results.

Physical Simulation

Both SAE 1018 and DP600 steel sheet specimens (1.6 × 44 × 89 mm) were welded at the parameters in Table 2, successful welds being produced in all cases — Fig. 6. During welding, IR thermal imaging of specimens was obtained, enabling the determination of temperature evolution of the weld interface and temperature distributions transverse to the weld interface (measured right before the weld plunge).

Curie Temperature Effect on Heating Rate

Analysis of the continuous heating profiles (Fig. 7) indicates a striking difference in heating rate before and after the Curie temperature (inflection point in the heating curve), similar to the results obtained through numerical simulations. This difference was the expected result due to the sudden change in heating mechanism upon reaching the Curie temperature. The magnitude of the heating rate differences was significant, with the post-Curie temperature heating rate being nearly 75% less than the pre-Curie temperature heating rates (~225 K s⁻¹ vs. ~900 K s⁻¹).

Heating Rate Comparisons between DP600 and SAE 1018

In addition to a difference in heating

rate before and after the Curie temperature, comparison of continuous heating profiles between DP600 and SAE 1018 welding specimens revealed a noticeable difference (also observed qualitatively during experiments) in induction heating response. Statistical analysis performed using a one-sided t-test (data assumed to be normally distributed and variances assumed to be unequal) indicated a statistically significant difference between the mean heating rates for DP600 and SAE 1018. For mean pre-Curie temperature heating rates, DP600 was shown to be 7.6% greater than SAE 1018 at a 96% confidence level (Table 3). However, post-Curie temperature heating rates and maximum temperatures were not shown to have any statistically significant differences.

The lack of a statistically significant difference in heating rate after the Curie temperature indicates that heating arising from resistive losses is essentially the same in the two materials, prompting the supposition that the difference in heating rate between DP600 and SAE 1018 must arise from a difference in the magnetic response of each material. Support for this conjecture is supported first by the similarity in resistivity vs. temperature profiles for dual-phase and carbon steel (Fig. 8) (Refs. 16, 17). Secondly, such an explanation is bolstered by the reported sensitivity of the magnetization response of materials to their composition and microstructural differences (Refs. 20–22). Considering that compositions (Table 4) (Refs. 23, 24) and microstructures

(by definition of a dual-phase vs. plain carbon steel) are different between DP600 and SAE 1018, the magnetization response ought to be different between the two materials, as was observed experimentally.

Metallography

Microstructure analysis of the DP600 specimens revealed grain coarsening at the weld interface, indicating that upset was not sufficient to expel the thermally affected base metal completely from the weld interface — Fig. 6. Microhardness profiles across the welding zone indicated a slight hardening at the weld interface — Fig. 9. However, in an extreme case of failure to upset the cast microstructure, hardness at the weld interface was double those values found in other specimens, underscoring the importance of sufficient upset to displace unwanted material from the faying surfaces.

Deformation Response

A maximum force of approximately 275 kN was measured at the faying surfaces, indicating that a maximum pressure of 20 MPa ensured faying surface coalescence and upset.

Conclusions

1) Fundamental induction heating mechanisms were revealed through a combined numerical and physical simulation effort. Specifically, in both DP600 and

SAE 1018 (ferromagnetic) materials, heating rates were found to be significantly different before and after the Curie temperature. Additionally, induction heating rates were found to be dependent on the ferromagnetic material type.

2) Satisfactory simulated welds can be produced in sheet steel specimens at 42 kW, 315 kHz, and heating for 4 s with 1-mm root opening (gap) between faying surfaces. This result demonstrates that high-frequency induction heating/pressure welding could serve as an excellent solid-state joining process for use in joining steel coil ends in continuous coil processing mills.

3) The usefulness of the coupled numerical and experimental simulation tech-

nique was clearly evidenced by the insights gained into the high-frequency induction heating process.

Additional study of this new process is certainly warranted and successful realization of a full-scale prototype of the joining process is optimistically anticipated.

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Appendix 1 — Data Table

Table 5 — Summary of Data Collected during April 10, 2008, Trial

Spec. Num	Mat.	Freq.	Power	Root Opening Size	Upset	Disp. Rate	Forge Delay	Set Trial Time	Liftoff	Time to Max. Temp.	Max. Temp.	Pre-Curie Temp. Heating Rate	Post-Curie Temp. Heating Rate
No.		kHz	kW	mm	mm	mm s ⁻¹	s	s	mm	s	K	K s ⁻¹	K s ⁻¹
1	1018	310	300 set			0		1.0	4	?	?	744	388
2	1018	317	42	0.5	0	0		2.0	4	2.4	?	929	265
3	1018	317	42	0.5	0	0		2.5	4	2.8	1505	840	310
4	1018	317	42	1	0	0		2.5	4	2.7	1434	696	301
5	1018	317	42	1.5	0	0		2.5	4	2.5	1401	794	273
6	1018	317	42	1	0	0		3.0	4	3.0	1539	837	286
7	1018	317	42	1	0	0		3.5	4	3.9	1628	724	232
8	1018	317	42	1	0	0		4.0	4	4.2	1661	787	205
9	1018	318	42	1	0	0		4.0	4	4.0	1706	807	212
10	1018	316	42	1	-1	10		4.0	4	4.7	1710	694	196
11	1018	316	42	1	-1	10	-0.25	4.8	4	3.8	1707	889	226
12	1018	317	42	1	-1	10	-0.25	4.8	4	4.4	1714	806	200
13	DP 600	315	42	1	-2	20	-0.25	4.75	4	4.0	1731	969	250
14	1018	316	42	1	-1	100	-0.25	4.5	4	4.7	1706	836	172
15	DP 600	315	42	1	-1	20	-0.25	4.5	4	?	1688	?	240
16	DP 600	313	42	1	-1	20	-0.25	4	4	3.9	1698	831	219
17	DP 600	309	42	1	-2	20	-0.25	4	4	?	1715	?	242
18	DP 600	308	42	1	-1	100	-0.25	4	4	4.2	1701	965	207
19	DP 600	315	42	1	-2	100	-0.25	4	4	4.2	1679	915	185
20	DP 600	319	42	1	-1	20	-0.25	4	4	3.7	1697	923	216
21	DP 600	319	42	1	-2	20	-0.25	4	4	3.6	1697	959	236
22	DP 600	318	42	1	-1	100	-0.25	4	4	3.3	1703	872	259
23	DP 600	318	42	1	-2	100	-0.25	4	4	3.7	1707	805	248
24	1018	403	42	1	-2	20	-0.25	4	4	4.6	1695	692	224
25	DP 600	398	42	1	-2	20	-0.25	4	4	3.6	1670	755	226

Frequency, root opening size, upset, displacement rate, forge delay, set trial time, and liftoff were input parameters. Time to maximum temperature, maximum temperature, pre-Curie temperature heating rate, and post-Curie temperature heating rate were determined via analysis of IR thermal imaging.

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

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Near Weld Interface Compositional Variations in Low-Alloy Steel Weldments

Both diffusion into the base metal and incomplete dilution into the weld metal pool create discontinuous composition gradients

BY D. B. KNORR AND J. J. MCGEE

ABSTRACT

The forged low-alloy steel and weld consumable used in this study have compositions that differ enough to create a significant concentration gradient adjacent to the weld interface following welding. The major compositional differences between base metal and weld, respectively, are 3.4 vs. 0.95 wt-% Ni, 1.75 vs. 0.1 wt-% Cr, and 0.25 vs. 1.4 wt-% Mn. This study measures the concentration gradients and models their development based on the mass transport processes during solidification and cooling of the weld, which occurs over a time period of only about 5 s. The composition of the base metal heat-affected zone is altered by diffusion adjacent to the weld interface. Nickel and chromium diffuse out, and manganese diffuses in, where the extent is predicted by a simple diffusion model. In the weld metal, local maxima in nickel and chromium are attributed to unmixed zones that detach from the base metal but are not fully dissolved into the weld pool. These compositional maxima occur within 75 μm of the weld interface and are intermittent. Both compositional and microstructural evidence exists for these localized regions. The composition in the weld adjacent to the weld interface influences the fracture behavior, where the unmixed regions are susceptible to intergranular fracture.

Introduction

ASTM A508-95 Grade 4N Class 2 low-alloy steel welds that are made with a S3NiMo1 weld consumable typically display significant gradients in microstructure and chemistry. This low-alloy steel is characterized by a microstructure consisting of bainite and autotempered martensite. The nominal composition is Fe-0.20C-3.4Ni-1.75Cr-0.55Mo-0.25Mn. The S3NiMo1 weldment is composed of a microstructure of acicular ferrite and has a typical composition of Fe-0.10C-1.4Mn-0.95Ni-0.5Mo-0.2Si-0.1Cr, i.e., lower in nickel and chromium and higher in manganese than the base metal. The differences in composition between the base metal and the weld metal lead to complex microchemical variations near the weld interface, where diffusion in the heat-affected zone (HAZ) is rapid and convective mixing in the rapidly solidifying weld metal becomes limited. This study evaluates the near weld interface region in two automatic submerged arc (ASA) welds, one manual shielded metal arc (SMA) weld, and one automatic gas tungsten arc (GTA) weld. Electron probe microanalysis compositional profiles and elemental distribution maps were obtained from each weld. The goals of this study of the region near the weld interface are to examine and understand the chemical and microstructural gradients, to compare the composition profiles in automatic submerged arc, manual shielded metal arc, and automatic gas

tungsten arc welds, and to examine the implications of these gradients on brittle fracture properties.

Materials and Experimental Procedures

Table 1 identifies the materials used in each weldment as well as key processing parameters. The automatic arc welds were made using a nominally neutral flux, Oerlikon OP 121TT. The heat input for the manual shielded metal arc weld could not be calculated but is estimated to be between the heat input of the automatic submerged arc welds and the automatic GTA weld. A comparison of the measured HAZ sizes supports this conclusion. Two heats of base metal material were procured as forged plate to ASTM 508-95 Grade 4N Class 2. The bulk chemical analyses of each heat are provided in Table 2. Each weldment received a post-weld heat treatment of 566°C for 50 h followed by a slow cool of 11.1°C/h. All welds were nominally 101.6 mm (4 in.) in thickness. The length and width of the weld assemblies were nominally 914 mm (36 in.) and 203 mm (8 in.), respectively. The weld assembly was spot welded to a strongback during weld deposition.

The weldments were sectioned to provide bulk chemistry samples and samples for metallography. Each bulk chemistry sample was taken from the middle of the weld, where dilution from the base metal was not a factor. Metallographic sections were cut to locate several beads that tie into the base metal, which included some bulk A508 Grade 4N, its HAZ, and the weld interface. The samples were mounted and polished to provide a very flat surface for electron microprobe analysis. Following the microprobe work, the same samples were etched in 2% Nital to examine the same regions by light optical microscopy.

Electron microprobe wavelength dispersive spectrometry (WDS) was utilized to obtain quantitative compositional

KEYWORDS

Unmixed Zone
Heat-Affected Zone
Shielded Metal Arc Welding
Submerged Arc Welding
Gas Tungsten Arc Welding
Low-Alloy Steel
Composition Profiles

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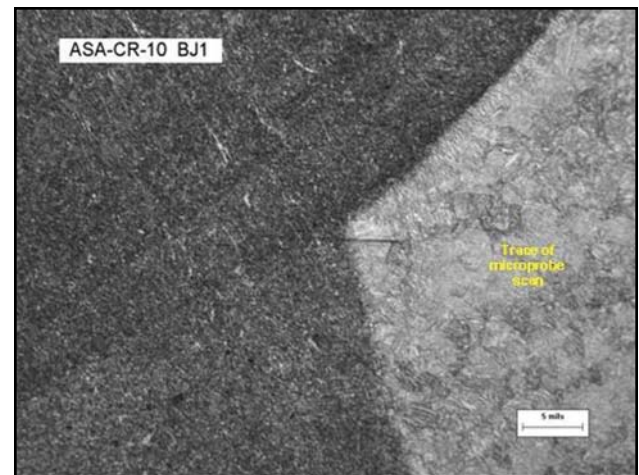
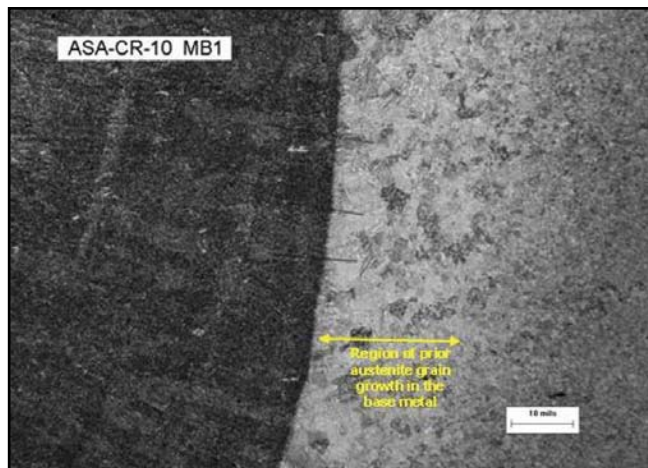


Fig. 1 — Metallography showing MB and BJ locations.

analyses of the base metal in the HAZ adjacent to the weld interface and the weld metal. The profiles started in the base metal ~75 μm from the weld interface and proceeded across the boundary, ~200 μm into the S3NiMo1 weld metal. These analytical profiles were measured using 5 μm step intervals, with a 5- μm -diameter an-

alytical spot, essentially providing a continuous compositional traverse across the base-metal/weld-metal interface. The quantitative analysis profiles were set up approximately normal to the interface. The measurements were made with a JEOL 8200 microprobe operated at 15-kV accelerating voltage and 40-nAmps probe current.

Table 1 — Materials and Processing Details for Weldment Fabrication

Weld Wire Heat	Weldment Designation	Welding Process ^(a)	Wire Dia. (mm)	Weld Layout No. Layers	No. Passes	Heat Input (kJ/mm)	Base Metal Heat
158526	ASA-CR-10	ASA	2.36	26	115	1.86	G1969
202504	ASA-CR-12	ASA	2.36	25	114	1.86	G1969
412W0131	SMA-CR-2	SMA	3.97	36	196	NA	27-3581
Lot 3004A							
158526	GTA-CR-8	AGTA	1.14	53	577	1.50	27-3581

(a) ASA = Submerged arc welding (automatic); SMA = shielded metal arc (manual); AGTA = gas tungsten arc welding (GTAW, automatic)

Table 2 — Chemistry of A508 Grade 4N Base Metals

Element	A508 Grade 4N Composition (wt-%)			
	Product 1	Product 2	Certification	Overcheck
	G1969		27-3581	
C	0.21	0.22	0.21	0.20
Ni	3.48	3.44	3.46	3.52
Cr	1.70	1.68	1.65	1.63
Mn	0.28	0.27	0.27	0.27
Mo	0.48	0.47	0.44	0.43
Si	0.08	0.08	0.05	0.06
V	0.018	0.01	0.010	0.009
P	0.006	0.007	0.009	0.007
S	0.001	0.003	0.010	0.008
Sn	0.002	NA	0.004	0.005
As	0.004	NA	<0.01	0.007
Sb	<0.001	NA	<0.001	0.0001
Cu	0.06	NA	0.05	0.05
N	0.0081	NA	0.0031	0.0039
O	0.0023	NA	0.0029	0.0030
Fe	bal	bal	bal	bal

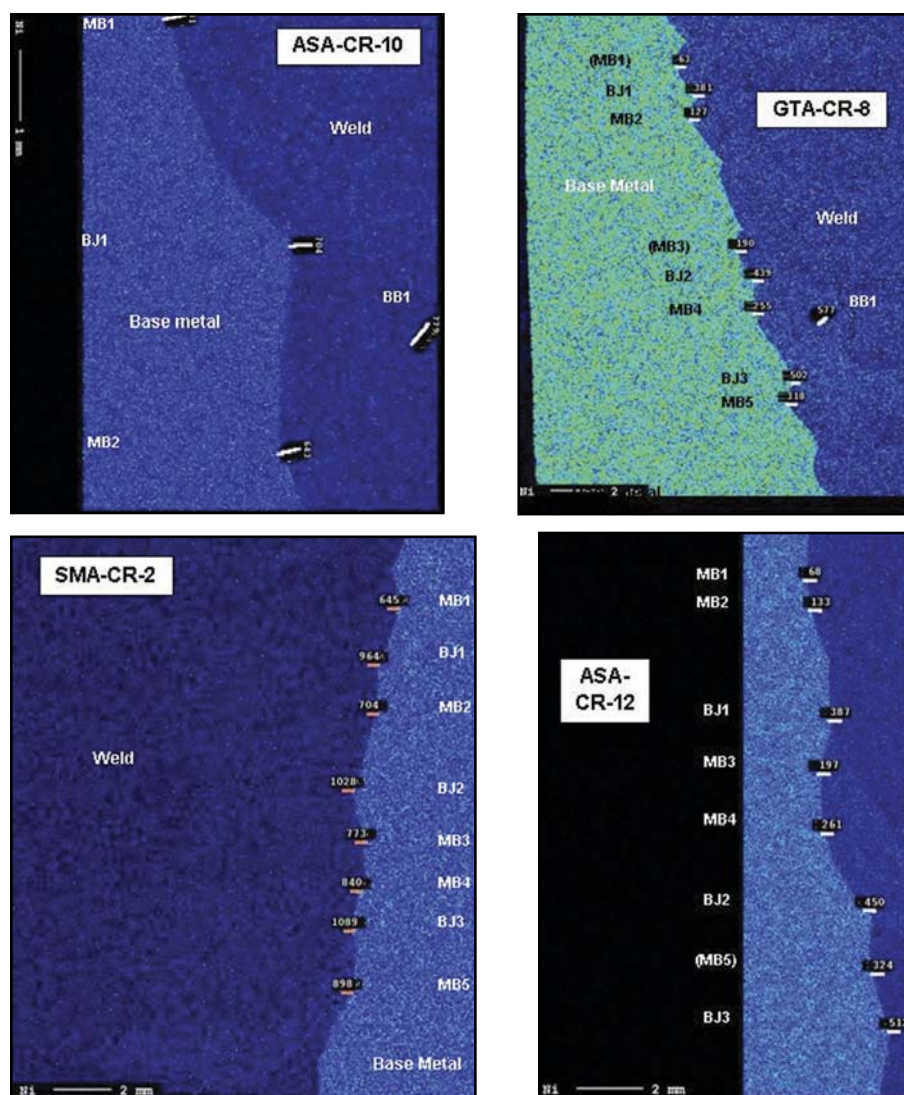


Fig. 2 — Electron microprobe nickel maps showing analysis locations (decreasing concentration from green > light blue > dark blue).

The resulting analyses had element detection limits on the order of 300 ppm (0.03 wt-%) and analytical uncertainty of ~2% relative for major elements (those present at >10 wt-%), ~5% relative for minor elements (1–10 wt-%), and 10–20% relative for elements present at concentrations below 1 wt-%. Pure metal standards were used for element calibrations. Element distribution maps were also acquired to qualitatively show compositional distributions of elements over larger areas of the sample. Note that the carbon analyses are higher than bulk levels and are considered unreliable due to surface contamination buildup on the metallographic mount as the beam impinges on the sample.

Multiple locations were selected for electron microprobe evaluation. The compositional profiles from the A508 Grade 4N across the weld interface into the weld bead were located at either mid-bead

(MB) or the bead joint (BJ). The MB locations cross the weld interface in the middle section of the weld bead. The BJ locations cross the weld interface where two stacked beads meet. These locations are illustrated in the metallographic images of Fig. 1 and the nickel distribution maps in Fig. 2. In ASA-CR-10, an analytical profile was measured near the center of the weld to obtain quantitative microprobe data in a region removed from, and not influenced by, the dilution from the base metal to facilitate a direct comparison between the quantitative microprobe data and the wet chemistry data. Finally, two line traces were done within weld beads crossing the weld interface between beads as bead-to-bead (BB) locations; the beads were adjacent to the weld interface. These traces served to characterize the local variability in composition due to weld bead solidification without having to deal with the gra-

dient in composition near the weld interface.

Compositional profiles were obtained from the following locations in the weld:

- ASA-CR-10: three MB locations, one BJ location, one BB location, one location in the weld away from the weld interface (reference to bulk metal composition measured by wet chemistry);
- ASA-CR-12: four MB locations, three BJ locations;
- SMA-CR-2: five MB locations, three BJ locations;
- GTA-CR-8: three MB locations, three BJ locations, one BB location.

Many of these locations are identified on Fig. 2. Subsequent results and discussion will excerpt representative data to illustrate specific points. Metallographic examination was done to relate the composition profiles to the microstructure, including the specific locations for composition analysis, which exhibited a metallographic etching response.

Results and Discussion

Nickel distribution maps indicating the locations for microprobe analytical profiles are shown in Fig. 2. The color scale assigns lower nickel to darker colors, i.e., the darkest blue is always the weld. The metallographic images, as exemplified by Fig. 1, are reversed compared to the microprobe elemental map due to the reversed optics of the metallograph.

The microprobe quantitative compositions have uncertainties of 5–10% relative for the minor elements, as noted above. The bulk chemical analyses for all welds are listed in Table 3. A comparison of wet chemistry results and microprobe results is given in Table 4 for the ASA-CR-10 weld metal. The microprobe compositions for Mn, Ni, and Cr tend to be slightly higher than the wet chemistry results, but the agreement for Mo and Si is good. The Cr composition is ~0.2 wt-% higher for the microprobe results, a bias that is also reflected in the base metal Cr levels. As noted above, carbon values determined by microprobe are considered unreliable due to sample surface contamination, so they are neither reported nor considered in the subsequent discussion.

Etching the weldments in 2% Nital following the microprobe data acquisition revealed both the microstructure of the weld/HAZ and the locations of the microprobe analyses. The electron microprobe beam generates a (carbon) contamination spot, which has an etching response at the individual analysis locations that is different from the surrounding material. Figure 1 shows examples of the locations of line scan profiles. Figure 3 demonstrates that individual analysis points can be resolved optically at higher magnification. The mi-

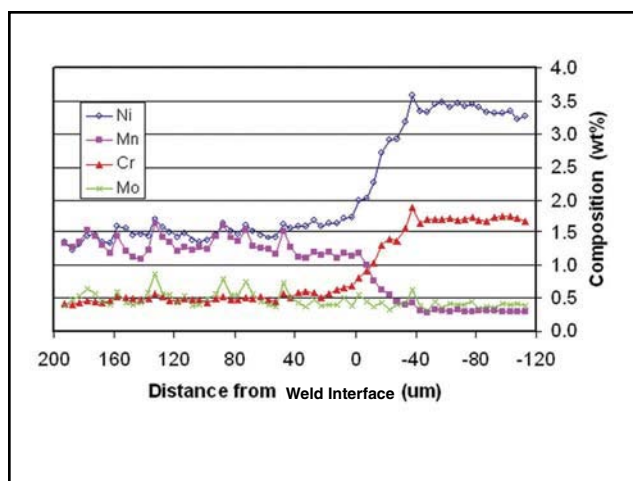


Fig. 3 — Composition and microstructure of ASA-CR-10, MB2.

croprobe analysis locations are easiest to resolve in the HAZ but more difficult in the weld due to the refined acicular ferrite. This detail of information enables specific locations to be matched with the chemistry. The automatic submerged arc HAZ/weld is discussed initially. The manual shielded metal arc and automatic GTA HAZ/weld demonstrate a more refined microstructure, so they are considered in the context of the automatic ASA results.

Heat-Affected Zone Behavior

A key reference point is the location of the weld interface. Often, the weld interface is quite distinct in metallographic images, such as Fig. 3. The composition at the weld interface is located on the microprobe profile by matching points to individual compositional analyses. The distance from the weld interface for the microprobe profile in Fig. 3 reflects this locating process and reveals that the weld interface is positioned at a composition more representative of the weld metal than the base metal. Thus, the rapid change in nickel, manganese, and chromium compositions occurs in the base metal HAZ rather than in the weld metal. This behavior is observed for all types of welds (automatic SAW, manual SMAW, and automatic GTAW) and regardless of the complexity of the composition profile in the weld metal. Since melting in the HAZ is not involved, a solid-state diffusion mechanism is considered to be operating to produce these compositional gradients.

The composition profiles demonstrate that there is mass transport of nickel and chromium from the A508 Grade 4N into the weld and mass transport of manganese from the weld into the base metal. Little diffusion of molybdenum is involved, since

the concentrations are comparable in both the base metal and the weld. Diffusion calculations for nickel transport were done using literature data (Ref. 1). The diffusion coefficients are as follows:

$$D_{\text{Ni in Fe}} = D_0 \exp(-Q/RT) \text{ cm}^2/\text{s} \text{ where } Q \text{ is the activation energy and } T \text{ is temperature in K}$$

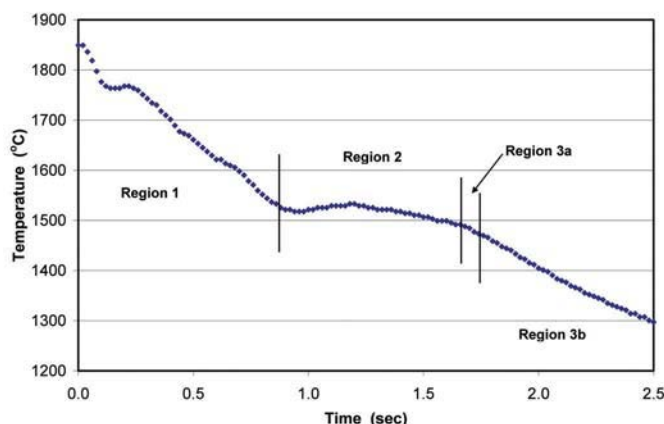
Delta phase: $D_0 = 9.7 \text{ cm}^2/\text{s}$, $Q = 267.5 \text{ kJ/mol}$

Table 3 — Wet Chemical Analysis of Weld Deposits

Element	Composition (wt-%)			
	ASA-CR-10	ASA-CR-12	SMA-CR-2	GTA-CR-8
C	0.11	0.11	0.07	0.12
Ni	0.94	1.16	0.97	0.94
Cr	0.11	0.13	0.05	0.10
Mn	1.38	1.44	1.42	1.59
Mo	0.53	0.57	0.41	0.52
Si	0.15	0.20	0.36	0.16
V	0.005	0.007	0.006	0.005
P	0.012	0.005	0.006	0.009
S	0.003	0.003	0.006	0.004
Sn	0.002	0.004	0.004	0.003
As	0.0050	0.0087	0.0087	0.0056
Sb	0.0001	<0.0001	0.0003	0.0001
Cu	0.07	0.32	0.04	0.01
Al	0.014	0.016	0.004	0.023
Ti	0.004	0.006	0.012	0.003
N	0.005	0.003	0.008	0.004
O	0.022	0.020	0.027	0.001
Fe	bal	bal	bal	bal

Table 4 — Comparison of Wet Chemistry and Microprobe Results for ASA-CR-10

Element	Composition (wt-%)	
	Wet Chemistry (Table 3)	Microprobe (25 point average)
Ni	0.94	1.05 ± 0.11
Cr	0.11	0.22 ± 0.02
Mn	1.38	1.53 ± 0.14
Mo	0.53	0.50 ± 0.06
Si	0.15	0.15 ± 0.013



Region	Weld Process	HAZ Process
1	Superheated weld metal contacts base metal	Dissipate superheat; weld arc heating melts base metal material into the weld
2	Weld solidification	HAZ held at high temperature: diffusion and prior austenite grain growth
3	Solid-state cooling and transformation	a: cool through δ -ferrite range b: cool through γ -ferrite range (extends to lower temperature than shown in figure)

Fig. 4 — Temperature profile for the solidification of an automatic SAW bead.

Gamma phase: $D_0 = 3.0 \text{ cm}^2/\text{s}$, $Q = 314.0 \text{ kJ/mol}$
Alpha phase: $D_0 = 9.9 \text{ cm}^2/\text{s}$, $Q = 257.2 \text{ kJ/mol}$

Figure 4 shows the temperature history for solidification of a S3NiMo1 ASA weld bead near the melting point. These data were obtained by plunging an alumina sheathed thermocouple with a bare junction into a molten weld bead and following the cooling/solidification process. The compositional evolution in the adjoining HAZ occurs in response to this high-temperature excursion in the weld. The processes are described in Fig. 4. The calculations demonstrate that most diffusion occurs when the base metal HAZ is in the δ -phase near its melting temperature, i.e., when the weld is solidifying and immediately following solidification. Thus, most diffusion occurs over a very short time span, which is estimated to be less than 5 s (time in Regions 2, 3a, and 3b extended over the γ -phase of Fig. 4). A schematic representation showing the progressive development of the composition profile is presented in Fig. 5.

A model for the composition profile in the A508 Grade 4N across the weld interface into the S3NiMo1 weldment was developed based on an error function (erf) solution to Fick's second law of diffusion (Ref. 2). This semi-infinite solution is justified because the size of both the base metal and weld are large compared with the extent of the diffusion zone. However, the model is an approximation, since the solid/liquid interface is moving in Region 1 of Fig. 4 and the concentration at the base metal/weld interface is changing with time due to solidification of the weld. The form of the solution describing the nickel composition profile is

$$C = C_w + (C_{bm} - C_w)/2 * [1 + \text{erf}(-x/2\sqrt{(Dt)_{\text{sum}}})] \quad (1)$$

C_{bm} = concentration of Ni in the base metal, assumed to be 3.6 wt-%;
 C_w = concentration of Ni in the S3NiMo1 weld bead adjacent to the weld interface, assumed to be 1.5 wt-% (higher than bulk due to dilution from the base metal);
 x = distance from the location where the nickel content is the mean of

C_{bm} and C_w (2.55 wt-%);
 $(Dt)_{\text{sum}}$ = a measure of the diffusion distance calculated by summing the incremental Dt contributions over Regions 2 and 3 in Fig. 4.

The fit between the simulation and the microprobe data is quite good for Ni, as shown in Fig. 6. Application of the model to Cr and Mn profiles produced model fits in agreement with the electron microprobe data. The simulation results are translated along the X-axis to align with the experimental microprobe data. The simulations accurately reproduce the experimental results, which corroborates the proposed diffusion mechanism. The data and model results are not symmetric about the weld interface, which would be expected in a completely solid-state diffusion process. More than half of the diffusion penetration is predicted to occur during weld bead solidification; no composition gradient is expected in the weld metal when it has a substantial liquid fraction, as shown schematically in Fig. 5.

The width of the compositional transition region in the HAZ will depend on the welding thermal history. The automatic GTA regions are narrower than those of the automatic SAW or manual SMAW. The lower heat input and resulting shorter time near the melting temperature reduce the extent of diffusion. If a location is reheated during subsequent weld pass(es), the transition is expected to be broader. This trend is confirmed by the BJ composition profiles for all three types of welds, where the bead joint region experiences more than one heating cycle.

Near Weld Interface Weld Composition in Automatic SAW

This section describes the composition profiles on the weld metal side of the weld interface. The discussion will concentrate on automatic SAW, which lays the groundwork for discussion of manual SMAW and automatic GTAW compositions in the next section. The behavior of the near weld interface region in the weld during weld solidification is deduced based on correlation of the composition profiles with the microstructure.

Five weld composition archetypes have been identified, two of which have already been introduced. Figure 3 shows a relatively flat composition profile in the weld metal, which indicates no anomalous melting of base metal. In contrast, a commonly observed near weld interface weld metal composition profile has a local maximum for nickel and chromium in the weld metal less than 50 μm from the weld interface, as shown in Fig. 7. The following five composition profiles demonstrate the variants of the near weld interface composition. The nickel concentration is plotted,

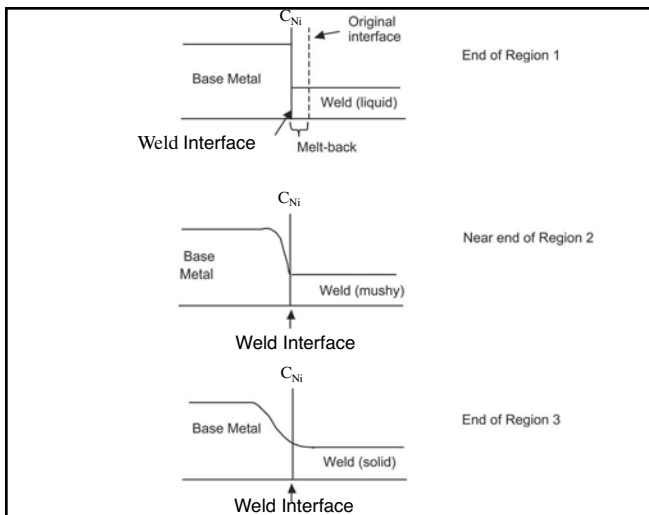


Fig. 5 — Schematic of composition profile development near the weld interface.

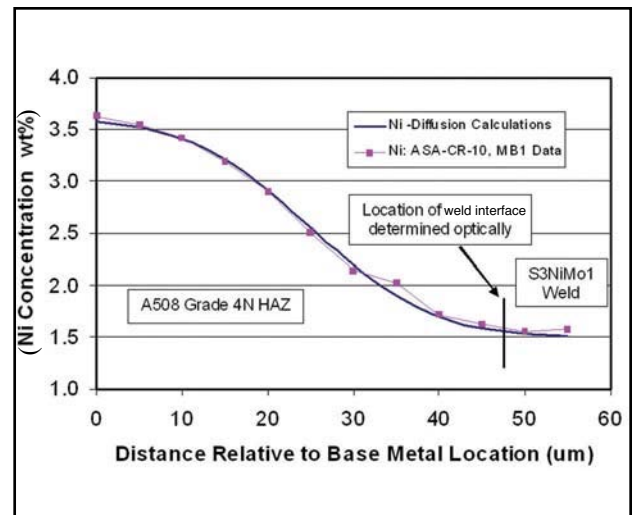


Fig. 6 — Comparison of microprobe data and diffusion model.

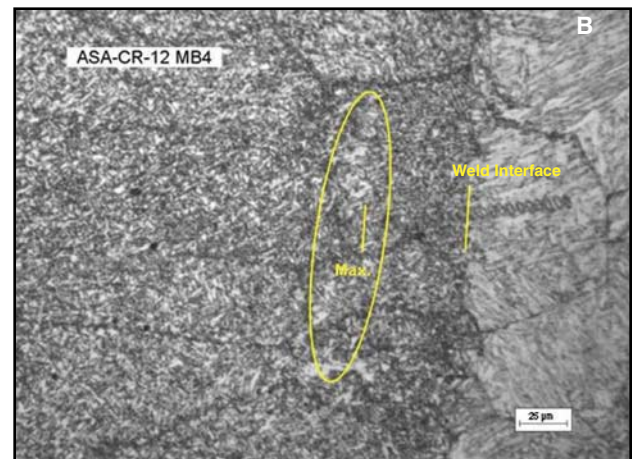
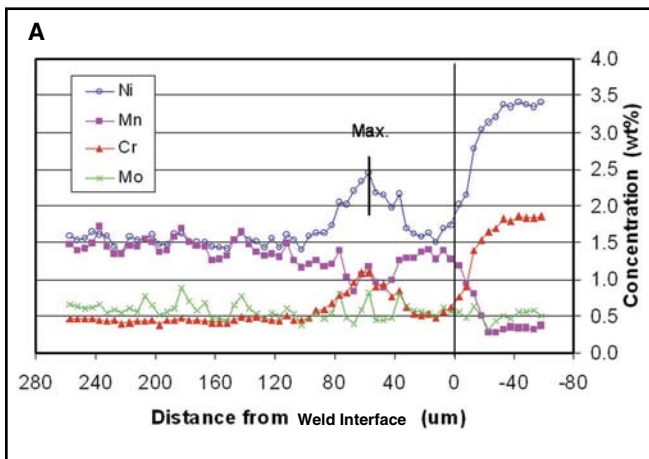


Fig. 7 — Local maximum of Ni and Cr in an automatic SA weld. A — Composition; B — microstructure.

since it best illustrates the trends. Figure 8 compares the nickel profiles that have increasing amounts of local enrichment:

- A) Flat composition profile: extracted from Fig. 3;
- B) Narrow plateau: ASA-CR-10 BJ1;
- C) Small composition peak: ASA-CR-12 MB2;
- D) Large composition peak: extracted from Fig. 7;
- E) Multiple peaks: SMA-CR-2 BJ1 and BJ2.

The origin of the local maxima in composition (e.g., Fig. 8, profiles C, D, and E) is the A508 Grade 4N base metal, which melted into the weld pool but is not fully mixed into the weld metal. The complementary Ni and Cr profiles are proof that the base metal is the origin, because elevated Cr in the weld metal can only originate in the A508 Grade 4N. The compositional peak is attributed to melted, but

only partially mixed, base metal that was not washed away from near the weld interface by convective currents in the weld pool (Ref. 3). Microstructural evidence of unmixed material is often correlated with the composition peaks of Ni and Cr. The region in Fig. 7 delineated by the oval contains the secondary compositional peak and has a coarser microstructure than the surrounding weld metal. An example of an extended unmixed band is shown in Fig. 9. The coarser microstructure in the band correlates with the difference in chemistry compared with the surrounding weld metal. The bead joint (BJ) regions are somewhat more prone to unmixed zones compared with the mid-bead (MB) regions, which might be related to the reheat history from the subsequent weld bead. However, the absence of secondary peaks can be observed in BJ regions and peaks in MB locations (Fig. 7).

The unmixed regions can complicate the identification of the weld interface location. In the previous examples, the weld interface is distinctly evident in the microstructure as the transition between the coarse lath martensite in the A508 Grade 4N HAZ and the acicular ferrite in the weld. The weld interface noted in Fig. 3 is very distinct in this region where no unmixed zone is present. Examples of highly banded weld interface regions are shown in Fig. 10. These regions present alternating narrow bands of microstructure resembling S3NiMo1 weld and A508 Grade 4N, which might qualify them as partially melted zones. All bands and compositional discontinuities examined by microprobe were found to be partially mixed. Two bands, which have separated from the base metal into the weld metal, are shown in Fig. 11. No microprobe data are available for these specific regions, but sub-

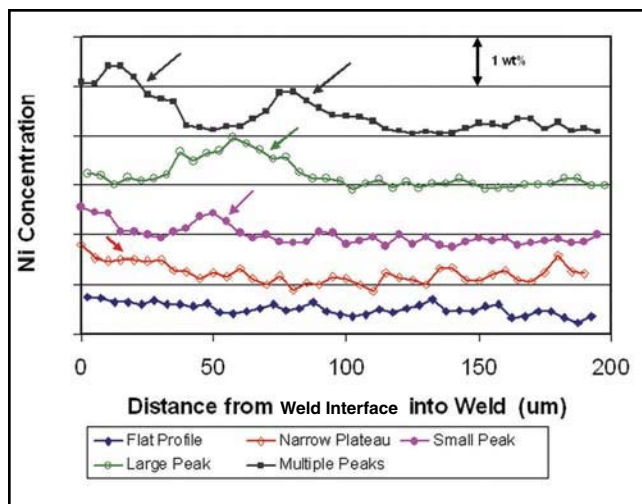


Fig. 8 — Nickel composition profiles in weld metal. Arrows note the location of local composition anomalies attributed to unmixed regions.

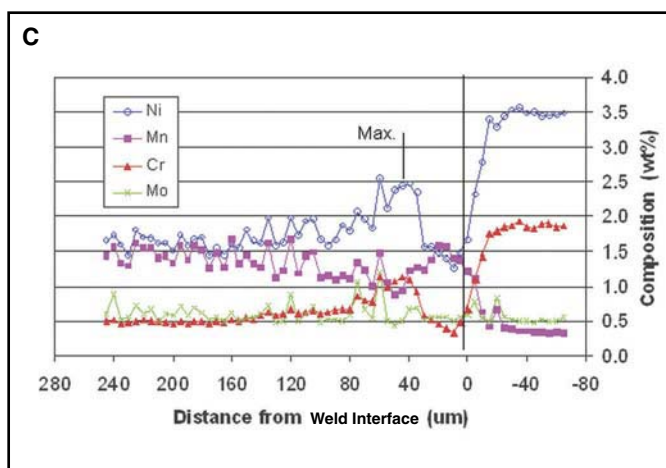
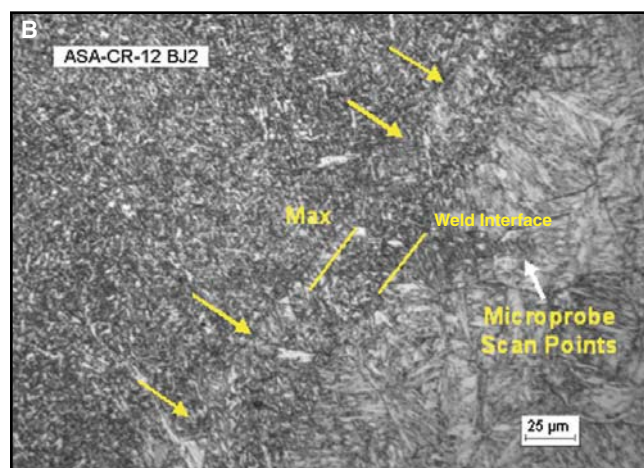
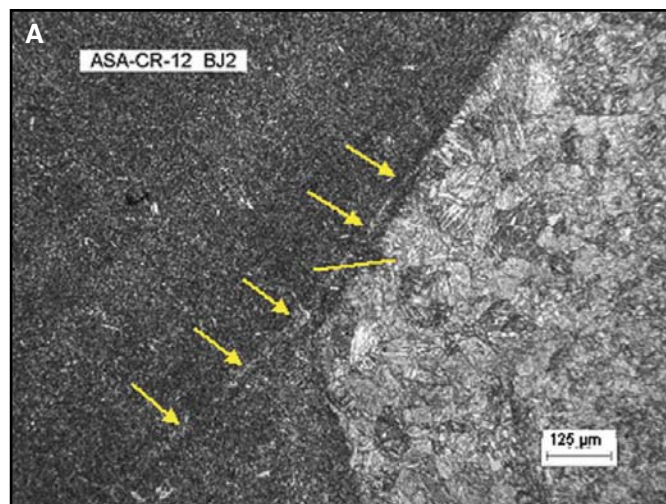


Fig. 9 — Examples of extended unmixed regions. A — Arrows show unmixed band. (Note that the band is continuous and does not extend the length of the bead. The location of the microprobe trace is delineated by the line that crosses the weld interface.) B — Higher magnification view of region scanned by microprobe. The arrows denote a segment of the band noted in A. The weld interface and maximum concentration (Max.) correspond to the locations and compositions shown below. The peak concentration of Ni and Cr in the weld metal is approximately 50 um from the weld interface. C — Microprobe profile across an unmixed band. Note the strong correlation between the nickel and chromium concentration profiles.

stantial variation in composition across these features is expected. No evidence for unmixed bands was found.

The macrosegregation shown in these welds was discussed recently by Kou and Yang (Ref. 4), who proposed solidification processes that can explain the features shown in this study. The terms “unmixed” and “partially mixed” zones were first observed and reported by Savage et al. (Refs. 5 and 6), while working on welded HY-80, which is similar in composition to the A508 Grade 4N studied here. Examples of the features observed in Figs. 7, 9–11 are seen in other studies of dissimilar ferritic welds (Refs. 6–9).

Welding Effects on Weldment Composition Profiles

The previous section presented the technical evidence for unmixed zones being responsible for compositional fluctuations (secondary peaks) in automatic submerged arc welds. The same processes are operative in manual shielded metal arc and automatic gas tungsten arc welds, but the composition profiles develop somewhat differently because of differences in welding process history. The automatic SA welds have the highest heat input, which is calculated to be 1.86 kJ/mm. The automatic GTA weld has the lowest heat input of 1.50 kJ/mm. Including arc efficiency will further separate the heat inputs for the automatic SA and GTA welds because the arc efficiency is greater for automatic SA welds. The effect of heat input is most evident in the HAZ microstructure. The automatic SA welds show sub-

stantial prior austenite grain growth in the base metal adjacent to the weld interface, as noted in Fig. 1 and also seen in Figs. 7, 9–11. The HAZs adjacent to the weld interface in the manual SMA and automatic GTA welds have not experienced grain growth to the same extent, as shown in Figs. 12 and 13, respectively. The HAZ grain size is smallest in the automatic GTA weld and somewhat larger in the manual SMA weld, but not as large as in the automatic SA welds. Consequently, the heat input for the manual SMA weld is probably between the levels for the automatic SA and GTA welds. The refined HAZ grain size in manual SMA and automatic GTA welds complicates the identification of the weld interface location because the refined microstructure resembles the fine acicular ferrite in the weld.

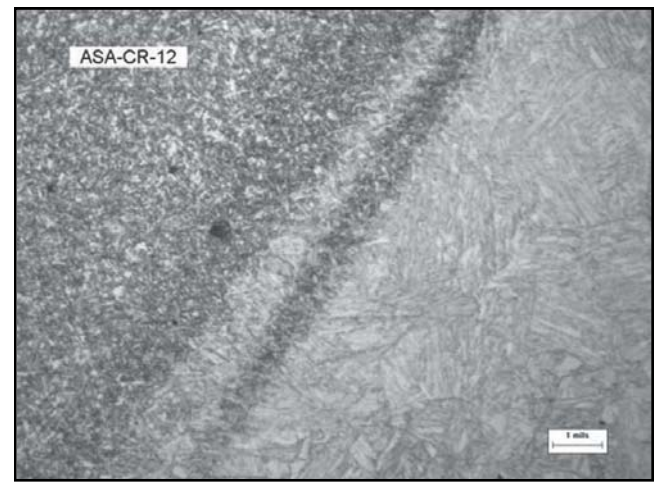
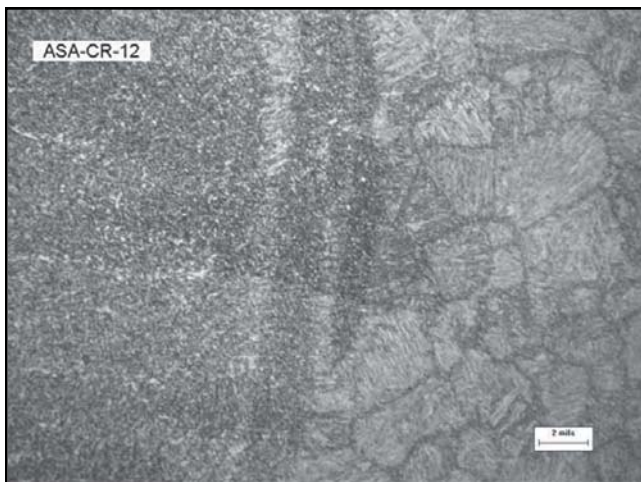


Fig. 10 — Two examples of multiple bands in the vicinity of the weld interface.

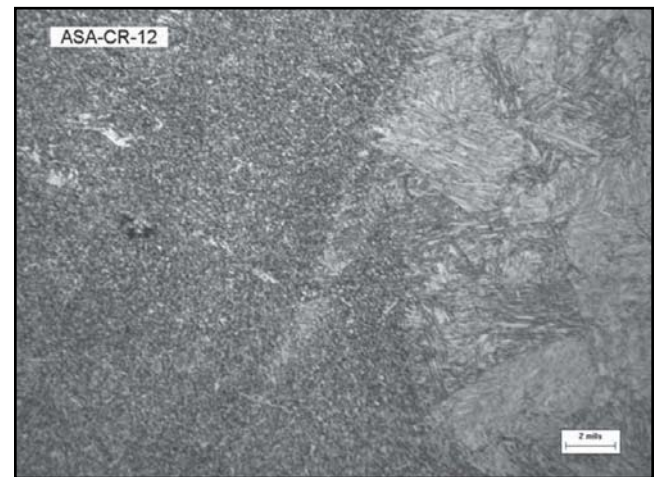
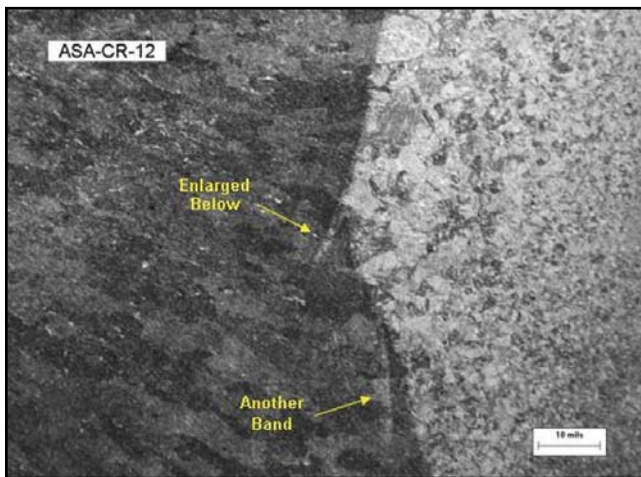


Fig. 11 — Unmixed regions in the vicinity of a bead joint.

The manual SMA weld often demonstrates compositional fluctuations in the weld. The bead joint locations show significant fluctuations, which exceed the fluctuations measured in the automatic SA welds. Figure 12 shows the only significant mid-bead fluctuation in five locations that were sampled. The nature of manual welding is expected to lead to more complicated behavior near the weld interface. The welder's need to ensure good tie-in with the base metal leads to torch motion, local dwells, and reheats, which could be manifested as an increased prevalence of unmixed base metal and diffusion into the HAZ.

The automatic GTA weld showed little unmixed material, as seen in Fig. 13. The largest composition peak in the weld, even in the bead joint regions, was very modest in extent. The most significant feature in the bead joint regions was an extended dif-

fusion profile into the A508 Grade 4N HAZ, which is attributed to reheats by subsequent beads that are quite close together due to the small bead size in automatic GTA welds.

Effects of the Near Weld Interface Composition Variations

The unmixed zones are believed to influence the fracture properties of the material near the weld interface. Charpy V-notch specimens were configured to test the HAZ in automatic SA welds, but the fracture path was found to jump from the HAZ to near the weld interface, as seen in Fig. 14. This behavior was prevalent in material that was intentionally temper embrittled by exposure at 427°C for 6–12 months, which is known to increase the ductile to brittle transition temperature in A508 Grade 4N (Ref. 10). This behavior is characteristic when

brittle fracture modes were operative, i.e., for testing done on the lower shelf and in the lower portion of the transition region of the Charpy transition curve.

A low-magnification scanning electron microscope view of the fracture surface is shown in Fig. 15. The fracture surface is composed of alternating bands of intergranular and transgranular failure along the direction of crack propagation. Intergranular fracture along prior austenite grain boundaries has previously been identified as prevalent in temper embrittled A508 Grade 4N (Ref. 10). Cosegregation of nickel (not an embrittler) and phosphorus (a strong grain boundary embrittler) creates a localized prior austenite grain boundary chemistry with increased temper embrittlement susceptibility. Manganese, a weak embrittler, is also believed to cosegregate with the nickel and phosphorus.

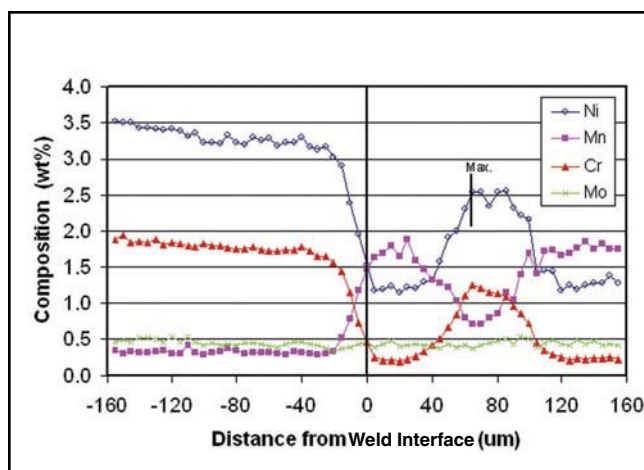


Fig. 12 — Composition and microstructure of SMA-CR-2, MB1.

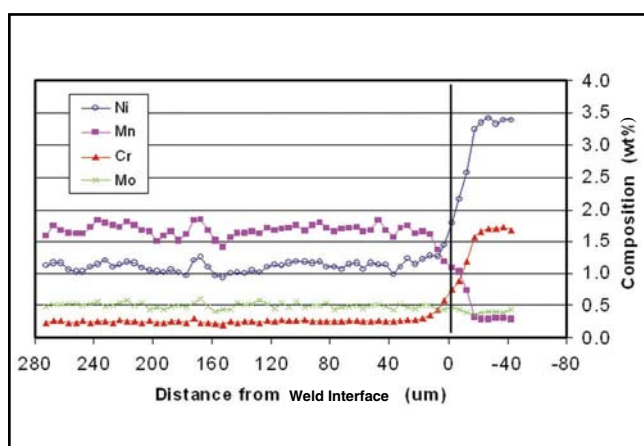
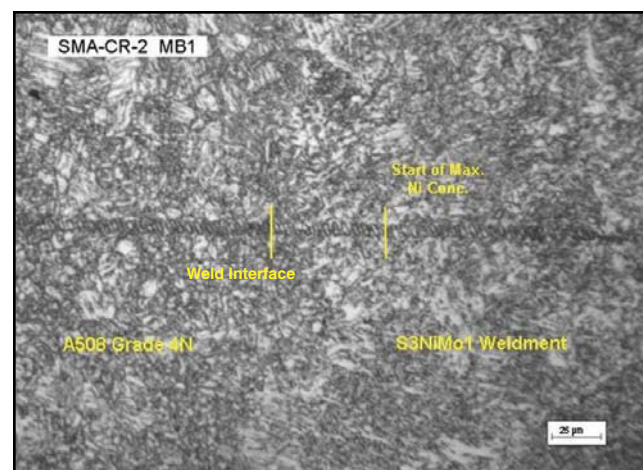
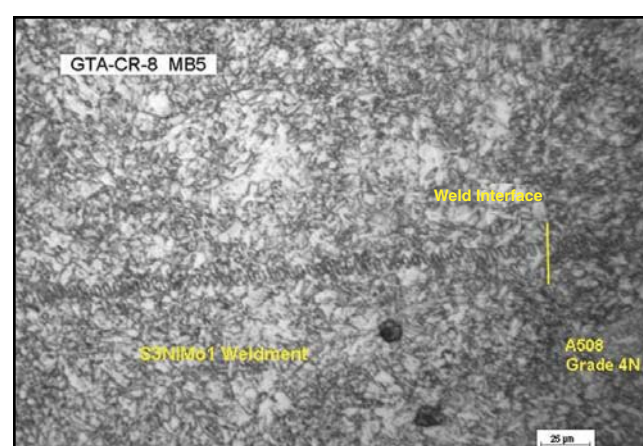


Fig. 13 — Composition and microstructure of GTA-CR-8, MB5.



The unmixed zones have locally elevated nickel content, as observed in Figs. 7–9, and 12. Local bands with elevated nickel content are believed to correspond to the intergranular bands seen in Fig. 15. The nickel content is locally increased, which, in the presence of manganese and impurity phosphorus in the weld metal, enhances the susceptibility to temper embrittlement in this local region. The data indicate that a local nickel level of ~1.5 wt-% is necessary. When no unmixed zones are present (e.g., Fig. 3), the local chemistry leads to significantly less temper embrittlement, so transgranular quasi-cleavage occurs, as exemplified by the right side of Fig. 15. The alternate banding of intergranular and transgranular cracking observed in thermally exposed welds is a manifestation of alternating mixed and unmixed regions. Effectively, the base metal has transferred temper embrittlement susceptibility to the weld metal through the presence of the un-

mixed zones. The evaluation of the microstructure and microchemistry shows that only local regions develop unmixed zones. Metallography and fractography demonstrate that the intergranular fracture is confined to the weld side of the weld interface. The metallography shows that the fracture path through the weld is displaced 50–75 μm from the weld interface, which corresponds with the local maximum in nickel content. The implication of this observation is that the steep concentration gradient in the HAZ is not associated with the fracture process.

Conclusions

The following conclusions are reached as a result of this study:

- 1) The steep gradient in Ni, Cr, and Mn compositions between the A508 Grade 4N base metal and the S3NiMo1 weld occurs in the base metal HAZ as a consequence of solid-state diffusion, primarily as the

weld bead solidifies and shortly thereafter when the HAZ region adjacent to the weld interface is δ -ferrite.

- 2) Local enrichment of nickel and chromium and depletion of manganese in the weld metal are manifested as plateaus, peaks, and valleys within approximately 75 μm of the weld interface. The source of the nickel and chromium is the A508 Grade 4N base metal, where unmixed zones develop during weld solidification. Intermittent enrichment is observed to be favored in regions where two stacked beads meet the base metal.

- 3) Automatic and manual shielded metal arc welds are prone to unmixed behavior, but automatic gas tungsten arc welds are much less susceptible due to the lower heat input during welding and, therefore, shorter time near the melting temperature.

- 4) The local unmixed zones in the weld metal result in increased susceptibility to temper embrittlement due to the local

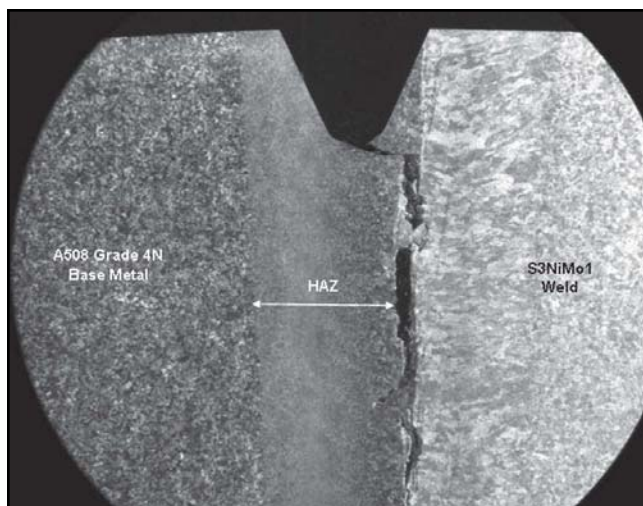


Fig. 14 — Metallographic section showing the fracture path through a Charpy specimen. (Charpy V-notch test was done at -115°C , and the specimen absorbed 11 J. The notch depth is nominally 2 mm.)

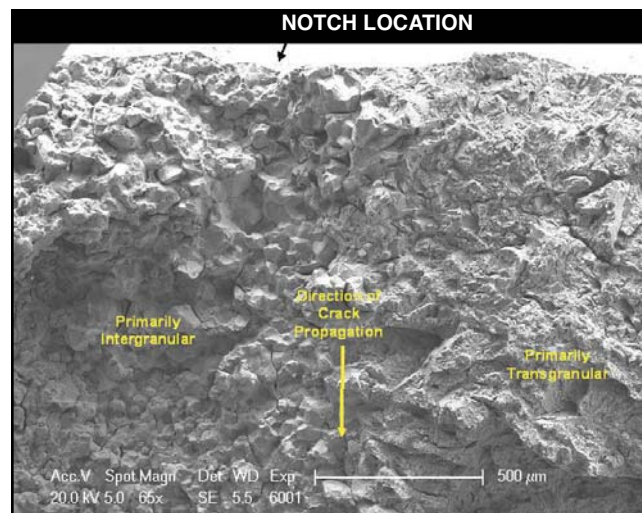


Fig. 15 — Macroscopic fracture surface from broken HAZ Charpy specimen. (Charpy V-notch test was performed at -84.4°C , and the specimen absorbed 11 J.)

chemistry. Local bands of intergranular and transgranular crack propagation on the weld side of the weld interface correlate with the local chemistry variations associated with the unmixed zones.

Acknowledgments

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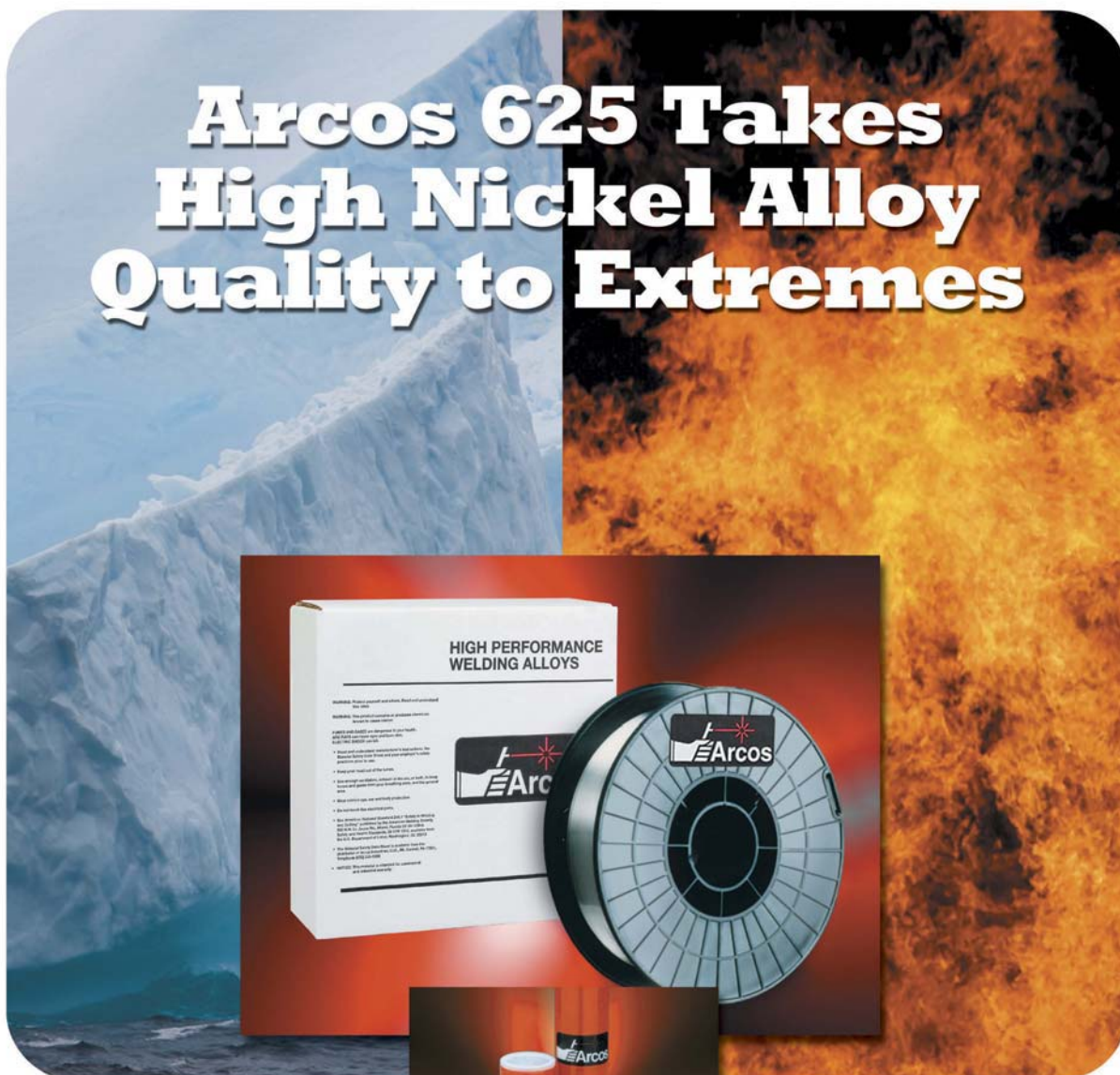
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