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Hardness, tensile, and impact tests were conducted on a nickel alloy flux cored electrode to determine its suitability as a substitute for comparable covered electrodes
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308-S Effects of Fusion Zone Size on Failure Modes and Static Strength of Aluminum Resistance Spot Welds
Various aluminum spot welds were investigated to determine how size might affect failure mode
X. Sun et al.
The AWS Welding Show and FABTECH International Join Forces

Three industry-leading trade show organizers have combined forces to better serve the needs of their trade show exhibitors in the fields of welding and cutting, forming and fabricating, and pipe and tube. The new joint trade show will be branded FABTECH International and the AWS Welding Show.

The show alliance was formed by a triad that includes the American Welding Society (AWS) and the two organizers of FABTECH, the Society of Manufacturing Engineers (SME) and the Fabricators and Manufacturers Association (FMA).

The identity of the AWS Welding Show remains intact, but it will be held at the same time and place as FABTECH, creating a much larger audience for both shows and helping participants cut costs by making only one trip to exhibit or see the very latest in welding and fabricating technology. The Welding Show will maintain a consolidated location within the show hull.

The new joint show is expected to cover 350,000 net sq ft with 900 exhibiting companies, becoming a dominant trade show for all metalworking, forming, fabricating, welding, and cutting technologies. It is anticipated displays, as well as new product introductions, will expand beyond what was experienced at either the AWS Welding Show or FABTECH in the past. Traditional exhibitors at FABTECH display equipment for bending, stamping, punching, joining, tooling, coil processing, and material handling.

"AWS is proud to have an alliance with FABTECH International," said Ray Shook, executive director, American Welding Society. "This strategic initiative will enhance our long history of service to the welding and cutting industries. We're confident that this alliance will add significantly to exhibitor and attendee value."

Nancy Berg, SME executive director and general manager, added, "This alliance is a highly effective way to serve manufacturing companies even better than we have in the past. Our customers have asked for expanded access to metalworking and fabricating technologies, and we are pleased to have been able to respond."

Gerald M. Shankel, FMA president and CEO, noted, "This is a good move for the industry. The AWS Welding Show brings an in-depth level of welding and cutting technologies and, together with FABTECH's unmatched quality of fabricating machinery, will offer a first-rate venue."

The transition will not occur until the fall of 2005. FABTECH International held its regular 2004 show October 26-28 at the I-X Center in Cleveland, Ohio. Likewise, the American Welding Society will offer its traditional AWS Welding Show April 26-28, 2005, in Dallas, Tex., which will represent the final stand-alone show of its kind. Exhibitor interest has been very strong for the Dallas event, and visitor turnout is expected to be just as strong.

Subsequent Welding Shows will be held in conjunction with FABTECH International in the fall of each year. The professional programs, conferences, and educational programs of AWS and FABTECH will be conducted independently. The first combined event will be held November 13-16, 2005, at McCormick Place, in Chicago, Ill. Exhibit space sales for the combined event begins immediately. For more information on the three organizations, visit their web sites at www.aws.org, www.sme.org, and www.finanet.org.
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Keeping Fit Financially

The American Welding Society has gone through its financial audit for the fiscal year ending May 31, 2004, and I’m pleased to tell you that your Society is financially fit. This does not mean we are past needing to be diligent regarding our finances, instead it means we must continue making decisions that lead AWS on the path to a more secure fiscal solvency.

The AWS Executive Committee met this past August. At that time, I submitted a truly positive report, the highlights of which I will now share with you. I also encourage you to examine the Financial Statement that begins on page 26 of this issue of the Welding Journal. We ended this fiscal year with a surplus slightly more than $200,000 after Board-approved projects were deducted. We completed the year with the highest net operating surplus since 1998 and the second highest in 17 years.

Our unrestricted fund in the Foundation also had a substantial increase. The Foundation is striving to achieve economic independence and, with the strong, focused leadership of its chair, Ron Pierce, I believe it is heading successfully in that direction.

The American Welding Society, like all the rest of industry, is working to survive in an economy that has struggled since the terrorist attacks on September 11, 2001. We are finally seeing signs that the manufacturing sector is starting to turn around as production slowly increases and the unemployment rate gradually decreases. While the number of new jobs is still slow to respond to the increase in production, the unemployment rate is declining slightly and there is every reason to feel it will continue to do so. We all would be happier if the jobless rate would drop more quickly and that may happen once the nation’s leaders begin focusing on the gross national product.

As a professional society, the real good news for AWS is that it has survived all of these problems without sacrificing service to its membership or to its corporate supporters. The Society is still seeking opportunities to expand its much needed income sources. The leadership is aware that the Society needs more revenue streams to support its programs and activities. The American Welding Society cannot continue to depend solely on the present profit centers, but needs to add new, profitable endeavors as well as reduce losses in areas that are very necessary to its members but which will never be centers of profits.

The costs of operations can only be pared so far before we see erosion in our ability to service our constituency. We cannot allow that to happen and therefore must seek additional sources of income. The Board of Directors is dedicated to finding revenue-producing areas that will fit within our structure and will enhance AWS’s future without affecting its mission or the integrity of the Society.

I know I seem to praise our Board and our staff in every report I write and every editorial I write for the Welding Journal. That’s because both groups work so diligently to keep us on track. Working in tandem, they allow the Society the opportunity to grow and to remain a strong, viable organization with a tremendous influence on the worldwide welding arena.

I also want to take this opportunity to thank you, the members, for continuing to support this world-class society.

Earl C. Lipphardt
AWS Treasurer
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Welder Named Indiana Worker of the Year

Work clothing manufacturer Dickies, Fort Worth, Tex., recently selected Rick Scott, who has owned a welding business for 12 years, as Indiana's worker of the year. He was nominated by his father-in-law, John Shaw, who wrote in an essay that Scott deserved the award because he is a mentor and encourager to his employees. Scott didn't even know he was nominated for this position, but he enjoys teaching others how to weld and seeing their progress with his guidance. For this accomplishment, he will receive more than $500 in cash and prizes.

Dickies chooses 50 state winners and one national winner from almost 9000 entries each year.

Octavio Vazquez was selected as its winner for the national 2004 American Worker of the Year. Vazquez owns a small cattle hauling business in Tribune, Kans. His wife, Jill, nominated him and wrote an essay saying that he represented the spirit of the American worker because he came to the United States without a penny and built himself up to be a successful owner/operator truck driver. He won a 2005 Dodge Ram 1500 Quad-Cab pickup truck, and an all-expense-paid trip for two to Nashville for the American Worker of the Year Awards ceremony.

Linde Retail Store Sells Specialty Gas Products

Linde Gas LLC, Cleveland, Ohio, announced its retail store in Cambridge, Mass., will be the company's first to sell specialty gas products. It stocks a full inventory of laboratory equipment and supplies, including specialty gas regulators, gas manifolds and panels, gas cabinets, gas detection monitors, cryogenic hoses and fittings, lab dewars, flow meters, and safety equipment. Also, the store is selling the company's EcoCyl, which is a proprietary package for storing analytical gases.

"The store will bring a new level of convenience and service to research, biotechnology, pharmaceutical, and university customers, and to mechanical contractors in the Boston area," said Howard Hubert, regional manager.

India's First Laser Processing Development Center Opens

GSI Lumonics, Inc., Farmington Hills, Mich., recently announced that its distributor, Optilase, has opened India's first
ISPC Moves Customer Service Center to Houston

International Surface Preparation is moving to a larger customer service center in Houston, Tex. This new facility enables the company to expand its resources to handle increased call volume. ISPC has three other regional call centers in the United States and one in Ontario. The purpose of them is to provide customized service on a local basis. They are staffed by customer service representatives, and the customer support system is based on a “one call” approach that lets callers have all of their technical applications questions answered through a primary center. Also, each center has product experts who know today’s surface preparation applications and techniques, and they are available if callers have a special project or request.

United Defense Industries Gets Contract for Overhauling Armored Personnel Carriers

United Defense Industries, Inc., Anniston, Ala., recently received a contract modification from Anniston Army Depot worth...
up to $47.4 million for the overhaul of M113 armored personnel carriers. This indefinite quantity and delivery contract for M113 work allows Anniston Army Depot to call upon United Defense to perform services for up to 325 vehicles in 2005 and 2006. This modifies the original contract, awarded in July, bringing the total potential value up to $48.8 million.

ASTM International Signs Memorandum of Understanding with SAC

ASTM International, W. Conshohocken, Pa., has signed a memorandum of understanding (MOU) with the Standardization Administration of the People’s Republic of China (SAC) to strengthen the relationship between the two standards organizations. This is the first time a standards development organization based in the United States has signed a MOU with the national standards body of China. The MOU will enhance the ability of ASTM and SAC to support the needs of Chinese people, and aid in the development of Chinese national standards for health, safety, and the environment. Part of the agreement involves ASTM to annually provide its full collection of standards to SAC, jointly sponsor standards and training programs, provide participating membership to representatives of SAC on its technical committees, and give internship programs for SAC experts to come to its headquarters for extended study of the standards development process. In return, SAC will promote the acceptance and use of ASTM standards in China, utilize the resources of ASTM to develop Chinese national standards and reference ASTM standards where applicable, and provide access to current ASTM standards, including a link to the ASTM Web site on the SAC home page. Also, SAC will facilitate connections between Chinese technical experts and ASTM technical committees to ensure the standards meet their needs.

Laboratory Testing, Celebrates 20th Anniversary

Pictured from left to right are Laboratory Testing owners Mike, Joan, and Tom.

Laboratory Testing, Inc., Hatfield, Pa., celebrates its 20th Anniversary this year. The company has grown from a small, non-

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- Free company publicity — give your company a global presence in the Welding Journal, on the AWS Website, and at the AWS WELDING SHOW

• Exclusive usage of the AWS Sustaining Company logo on your company’s letterhead and on promotional materials for a competitive edge
• An attractive AWS Sustaining Company wall plaque
• Free hyperlink from AWS’s 40,000-visitor-a-month website to your company’s website
• Complimentary VIP passes to the AWS WELDING SHOW
• An additional 5% discount off the already-reduced member price of any AWS conference or seminar registration
• Up to 62% off Yellow Freight shipping charges, outbound or inbound, short or long haul

AND MUCH MORE...
Also available AWS Supporting Company Membership, AWS Welding Distributor Membership and AWS Educational Institution Membership

For more information on AWS Corporate Membership, call (800) 443-9853, ext. 258 or 260. E-mail: service@aws.org for an application.

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destructive testing laboratory to a full-service materials testing, metrology, and machining business with 90 employees. It began doing business in 1976 as Carson NDT and provided commercial magnetic particle, liquid penetrant, X-ray, and ultrasonic inspection services. In 1984, founder Robert W. McVaugh, Sr., changed the company's name to Laboratory Testing, Inc., and since that time, its services have expanded to include hydrostatic pressure testing, chemical analysis, dimensional inspection, metallography, mechanical testing, metrology, specimen machining, failure analysis, and materials engineering. It is accredited by the American Association for Laboratory Accreditation (A2LA) and the National Aerospace and Defense Contractors Accreditation Program (NADCAP). Today the company is owned by McVaugh's three children, Mike, Joan, and Tom, and specializes in the inspection and analysis of metals and alloys found in fasteners, tubular products, bars, plates, and castings.

Willbros Group Selected for Business Units Projects

Willbros Group, Inc., Houston, Tex., recently announced that several of its business units in North America have been selected for projects. The Willbros USA, Inc. (WUSA), business unit entered into a Memorandum of Understanding with Multifuels LP, to participate in the expansion of a gas storage facility in Northwestern Alabama. The Freebird Gas Storage Project proposes to expand an existing storage facility in Lamar County, Ala., by adding an additional 7.4 to 9.0 billion cubic feet and providing a withdrawal capacity of approximately 250 million cubic feet per
Q: Our quality assurance department has noticed a shipment of stainless steel filler metals that seems to have two classifications on them — E308-16 and E308L-16. What is that all about? I ordered E308L-16. Is there something substandard about these electrodes?

A: Perhaps your quality assurance department didn’t notice this before. Perhaps you just changed suppliers, or perhaps your supplier is following the trend for dual classification of stainless steel filler metals.

First, I should note that dual classification according to coating type is not allowed per AWS A5.4, Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding. It is not allowed to classify a given electrode as both E308L-16 and E308L-17. The electrode can only be classified as one or the other coating type. But dual classification by composition is allowed if the electrode meets all of the classification requirements for two compositions. In practice, dual classification only works for carbon limits.

Actually, there are only benefits in dual classification, and there is no downside. Let me explain, by way of example with your E308L-16/E308-16. First we need to look at the relevant requirements in the AWS A5.4 specification for stainless steel covered electrodes. Table 1 shows the chemical composition requirements for the two classifications. Note that the only compositional difference between E308-16 and E308L-16 is the carbon range. The carbon content of the deposit from E308-16 can be anything from nil up to 0.08%, while the carbon content of the deposit from E308L-16 can range from nil up to 0.04%. Obviously, if a given electrode meets the carbon requirement for E308L-16, it also meets the carbon requirement for E308-16. If I only classify my electrode as E308-

<table>
<thead>
<tr>
<th>Table 1 — AWS A5.4 Composition Requirements (%)</th>
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<tr>
<td></td>
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<tr>
<td>E308-16</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>E308L-16</td>
</tr>
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</tbody>
</table>

Table 2 — AWS A5.4 Mechanical Property Requirements

<table>
<thead>
<tr>
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<th>Tensile Strength (min.)</th>
<th>Elongation (min.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>E308-16</td>
<td>80,000 lb/in.² 550 MPa</td>
<td>35%</td>
</tr>
<tr>
<td>E308L-16</td>
<td>75,000 lb/in.² 520 MPa</td>
<td>35%</td>
</tr>
</tbody>
</table>
you have no idea if the carbon is actually above or below 0.04%, but if I classify it as E308L-16, you are guaranteed that the deposit will be 0.04% or less.

Beside carbon content, the only other difference in requirements between E308-16 and E308L-16 is in the mechanical property requirements for the weld metals (Table 2). The tensile strength requirement is higher for E308-16 than for E308L-16. So, if I classify my electrodes as E308L-16, the user has no idea as to whether or not the weld metal will exceed 80,000 lb/in.² tensile strength. But if I classify it as E308-16, the user is guaranteed that the weld metal will exceed 80,000 lb/in.² tensile strength. So, by dual classifying the electrode as E308L-16 and E308-16, the user receives a guarantee that the electrodes meet both the low-carbon requirement of E308L-16 and the high-strength requirement of E308-16. This in turn allows the user to maintain a smaller inventory.

Dual classification is not unique to E308-16 and E308L-16 covered electrodes. In AWS A5.4 classifications this same situation arises also with alloy types 308Mo and 308MoL, 309 and 309L, 309Mo and 309MoL, 316 and 316L, and 317 and 317L.

Furthermore, this situation is not unique to covered stainless steel electrodes. The flux cored stainless steel electrodes classified according to AWS A5.22 also allow for this same dual classification based upon deposit chemical composition. The same strength differentials exist between the low-carbon alloy requirements and the nonlow-carbon alloy requirements, and higher-strength low-carbon compositions can be dual classified in exactly the same manner as the covered electrodes. In fact, flux cored stainless electrodes have a second possibility for dual classification. In addition to dual classification based upon chemical composition, flux cored stainless electrodes can be dual classified based upon shielding gas. Today, it is quite common for a flux cored stainless steel electrode to be suitable for both CO₂ shielding gas and for 75%Ar-25%CO₂ shielding gas. If the electrode is classified with CO₂ shielding gas, the classification is, for example, E308LTX-1, where the "X" is either a "0" for flat and horizontal position only, or a "1" for all positions. And if the electrode is classified with 75%Ar-25%CO₂, the classification is, for example, E308LTX-4. So, it is possible for a given flux cored stainless steel electrode to have four classifications: E308LTX-0, E308LTX-1, E308LTX-4, and E308LTX-4, as an example. Many manufacturers of flux cored stainless steel electrodes classify in this way.

The situation with bare solid wires and rods or metal cored wires classified according to AWS A5.9 is not quite so advantageous to the user. The reason for this is that the classifications of AWS A5.9 do not include a strength requirement, primarily because they are used for multiple welding processes (GMA, GTA, SA, and PA). The supplier cannot know how the user will use the product. Nevertheless, suppliers can and do use dual classification. In this case, dual classification only provides a guarantee of carbon content meeting both classifications, e.g., ER308Si and ER308LSi. And this is helpful to the user because the AWS D1.6, Structural Welding Code — Stainless Steel, prequalifies the nonlow-carbon stainless steel wires and rods for 5000 lb/in.² higher-strength applications than their low-carbon cousins.

So dual (or, in the case of flux cored stainless, multiple) classifications are a real benefit to the user because they provide a more specific definition of the product than any single classification does, and they permit a reduction in filler metal inventories. •

DAMIAN J. KOTECKI is Technical Director for Stainless and High-Alloy Product Development for The Lincoln Electric Co., Cleveland, Ohio. He is an AWS Vice President, and a member of the ASD Subcommittee on Stainless Steel Filler Metals; D1 Committee on Structural Welding, D1K Subcommittee on Stainless Steel Welding; and a member and past chair of the Welding Research Council Subcommittee on Welding Stainless Steels and Nickel-Base Alloys. Questions may be sent to Dr. Kotecki c/o Welding Journal, 550 NW LeJeune Rd., Miami, FL 33126; or send e-mail to Damian_Kotecki@lincolnelectric.com.
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day, Willbros Engineers, Inc. (WEI), Tulsa, Okla., has been awarded a contract by Alliance Energy, LLC (Alliance), to provide project management, engineering, procurement, and construction services for a new natural gas pipeline on the southern Kenai Peninsula, Alaska. WEI is proceeding with route selection, permitting, and design of the proposed pipeline. Also, Willbros RPI, Inc. (RPI), Houston, Tex., has been awarded with a looping project for a natural gas pipeline in Iowa by Kinder Morgan. This project scope includes new 30-, 20-, and 12-in.-diameter pipelines, provisions for a future compressor station hook-up, and 30-in. launchers and receivers. Completion is scheduled for the fourth quarter of 2004.

Industry Notes

• U.S. Army Tank-Automotive and Armaments Command awarded General Dynamics Land Systems, a business unit of General Dynamics, a $22.4 million contract to repair and modify 111 M1A2 Abrams Systems Enhancement Package (SEP) tanks. The work will be performed at the Joint Systems Manufacturing Center in Lima, Ohio, and should be completed by July 30, 2005.

• Hyundai Heavy Industries Co., a South Korean shipbuilder, won a $1.5 billion order from BP Shipping Ltd., a British company, to build eight liquefied-natural-gas carriers. BP placed the orders for delivery starting in June 2007, according to a recent article in the Wall Street Journal.
Friends and Colleagues:

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

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

Sincerely,

Alexander Lesnewich

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

(please type or print in black ink)

NAME OF CANDIDATE

AWS MEMBER NO.

YEARS OF AWS MEMBERSHIP

HOME ADDRESS

CITY

STATE

ZIP CODE

PHONE

PRESENT COMPANY/INSTITUTION AFFILIATION

TITLE/POSITION

BUSINESS ADDRESS

CITY

STATE

ZIP CODE

PHONE

ACADEMIC BACKGROUND, AS APPLICABLE:

INSTITUTION

MAJOR & MINOR

DEGREES OR CERTIFICATES/YEAR

LICENSED PROFESSIONAL ENGINEER: YES NO STATE

SIGNIFICANT WORK EXPERIENCE:

COMPANY/CITY/STATE

POSITION

YEARS

COMPANY/CITY/STATE

POSITION

YEARS

SUMMARIZE MAJOR CONTRIBUTIONS IN THESE POSITIONS:


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

SEE GUIDELINES ON REVERSE SIDE

SUBMITTED BY: PROPOSER

AWS Member No.

Print Name

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

NOMINATING MEMBER:

Print Name

AWS Member No.

NOMINATING MEMBER:

Print Name

AWS Member No.

NOMINATING MEMBER:

Print Name

AWS Member No.

NOMINATING MEMBER:

Print Name

AWS Member No.

SUBMISSION DEADLINE FEBRUARY 1, 2005
American Welding Society

Fellow Description

DEFINITION AND HISTORY
The American Welding Society, in 1990, established the honor of Fellow of the Society to recognize members for distinguished contributions to the field of welding science and technology, and for promoting and sustaining the professional stature of the field. Election as a Fellow of the Society is based on the outstanding accomplishments and technical impact of the individual. Such accomplishments will have advanced the science, technology and application of welding, as evidenced by:
* Sustained service and performance in the advancement of welding science and technology
* Publication of papers, articles and books which enhance knowledge of welding
* Innovative development of welding technology
* Society and chapter contributions
* Professional recognition

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

NUMBER OF FELLOWS
Maximum of 10 Fellows selected each year.

AWS Fellow Application Guidelines

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

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

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

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

Return completed Fellow nomination package to:

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

Telephone: 800-443-9353, extension 293

SUBMISSION DEADLINE: February 1, 2005
AWS Fellowships

To: Professors Engaged in Joining Research

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

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

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

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

THE AWARDS

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

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

DETAILS

The Proposal should include:

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

In addition, the proposal must include:

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

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

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

Yours sincerely,

Ray W. Shook
Executive Director
American Welding Society
Cut-Off Wheels Handle Stainless Steel Applications

Alpha-Green stainless steel cut-off wheels are designed to cut faster and smoother, as well as run cooler than conventional wheels. Available in Type 1 straight-sided and Type 27 depressed-center styles, they can cut stainless steel pipe, rod, and sheet metal. They are 0.040 in. thick, and feature a reinforced resinoid bonding system of 60-grit aluminum oxide abrasives. Sizes vary from 3 to 7 in. A 46-grit, 0.045-in.-thick version is also available.

Rex-Cut Products, Inc.
960 Airport Rd., D10, Box 2109, Fall River, MA 02722

Aluminum GMAW Wire Comes in Recyclable Box

SuperGlaze™ aluminum GMAW wire is now available in a 100% recyclable container. When users are finished with the product, all they do is remove the ring, cardboard core, and corner supports, collapse the box, and place everything into the recycle bin. The Accu-Pak box has an Accu-Trak precision wire delivery system, which provides accurate and twist-free wire placement in the arc, and is designed to stop wire flipping during feeding. This 200-lb box is available in 7/8 in. diameter for the 5356 aluminum alloy electrode type and has a lifting strap.

The Lincoln Electric Co.
22001 St. Clair Ave., Cleveland, OH 44117

Retrofit Torch Increases Productivity

The RT60 retrofit torch, designed for mechanized and manual Powermax and MAX systems, improves cutting performance and extends consumable life. The 60-A torch features Coaxial-assist™ jet tech-
Hydrotherm, Inc.  
Etna Rd., P.O. Box 5010, Hanover, NH 03755

Hardfacing Wire Provides Better Weldability

Stoody 101HD high-hardness, small-diameter hardfacing wire is the new hybrid alloy of the company’s 101HC. It was developed to better match the high-chemistry, hardfaced plate that is popular in aggregate, concrete, power plant, and mining applications. Compared to the company’s 965 and 101HC wire, the 101HD exhibits excellent weldability and performance. Currently, this product is available in only a ¼-in.-diameter wire, because of its high percentage of fill, and comes on a 33-lb wire basket.

Stoody Co.  
16052 Swagely Ridge Rd., Ste. 300  
Chesterfield, MO 63017

Cold Saw Handles Hard-to-Cut Materials

The Kalamazoo Machine Tool Model C370SA Cold Saw has an infinitely variable cut speed, which delivers cut speeds of 41 in./min on ¼-in. steel, and offers long-lasting consumable parts life. The patented blow-back contact-start torch technology assures consistent cut quality. The RT60 is based on the T60 torch design, is compatible with the company’s G3 system consumables, and comes with a one-year torch and lead warranty.

Hypertherm, Inc.
Elma Rd., P.O. Box 5010, Hanover, NH 03755
able blade speed control from 13 to 76 rpm, which provides the ability to fine-tune the settings for sawing various materials. Plugging and loading that can cause premature blade failure are eliminated by the blade-powered rotary blade-cleaning brush. This product is designed for semiautomatic operation with an air-over-hydraulic system to provide optimum sawing rates with minimum user effort. It can be operated in a conventional 90-deg cutoff mode, or swiveled to any angle up to a 45-deg left or 60-deg right for miter cutting. The saw features a full electronic control/information system, air vise to supply infinitely variable clamping pressure to prevent distortion of structural stock, vertical column construction for vibration-free sawing, full coolant system, heavy-duty 4-hp motor, and accepts blades from 12½ to 14½ in. in diameter.

**Wheels Offer Increased Cutting Speed and Minimal Burr**

The company's aluminum oxide Type 1 Slicer-Plus high-performance wheels provide increased speed and minimal burr when cutting heavier gauge metals. This product is a 0.045-in.-thick rigid cutting wheel that is coated with an aggressive fine grit for cutting materials such as rebar, large-diameter rods, and stainless steel. The wheels are available in 4½- and 6-in. versions, employ an improved abrasive/resin formulation to increase wheel life by up to 300%, and are formulated to leave no contaminants behind that could impact a weld.

**Wires Improve Travel Speed, Deposition Rates**

McKay® GOLDCOR® 308LSi and 316LSi metal cored gas shielded stainless wires are designed for chemical and food service fabrications that have poor-to-fair fitup. The wires offer high travel speeds and deposition rates. In the recommended spray transfer mode and welding in the flat and horizontal positions, the deposition rates range from 8.0 to 20.22 lb/h for the 0.045-in.-diameter wire and 7.5 to 27.0 lb/h for the ½-in. wire while operating at 185 to 450 Amps DCEP (22 to 34 V). They produce a moderately soft arc, concave bead profile, are well suited for downhill (30- to 60-deg incline) robotic welding, and are formulated to operate in the spray transfer mode with a shielding gas of 98%Ar/2%O2. While both products offer low spatter and reduced slag, the 308LSi is useful for joining 301, 302, 304, 304L, and 308 stainless steels, while the 316LSi is designed to join 316 and 316L stainless steel.

**Hire Job Seekers Who Stand Out**

AWS JobFind works better than other job sites because it specializes in the materials joining industry. Hire those hard-to-find Certified Welding Inspectors (CWIs), Welders, Engineers, Welding Managers, Consultants and more at www.awsjobfind.com. You'll find more than 2,000 résumés of top job seekers in the industry!

**The Tools to Do More**

AWS JobFind provides companies with the tools to post, edit and manage their job listings easily and effectively, any day or time, have immediate access to an entire résumé database of qualified candidates, look for candidates who match their employment needs: full-time, part-time or contract employees, receive and respond to résumés, cover letters, etc. via e-mail.
Multiprocess Power Source Designed for Heavy Duties

ESAB’s MultiPower 460 is a three-phase power source designed for heavy-duty industrial DC welding applications. It offers high-performance gas metal arc welding (GMAW), pulsed GMAW, gas tungsten arc welding, shielded metal arc welding (SMAW), and air carbon arc gouging capabilities. The SuperSwitch Technology design provides inverter-like performance in the welding arc and silicon-controlled-rectifier-like reliability. Fine tuning of the arc characteristics for short arc welding comes from the variable inductance feature. It offers built-in arc force control for SMAW. The synergistic/nonsynergistic pulse welding capability, with the intelligence built into the power source, allows GMAW-P to be done with almost any wire feeder. The power source offers energy savings and reduced power costs. The unit comes standard with an auto fan feature that saves energy by automatically turning the fan motor on or off and a 115-VAC auxiliary power receptacle. The welding range is 10 A/12 V to 500 A/40 V.

ESAB Welding & Cutting Products 107
411 S. Ebenezer Rd., P.O. Box 100545, Florence, SC 29501

Laser Regulator Maintains Beam-Mode Quality

CONCOA’s 601 Series incorporates new M² technology to minimize atmospheric contamination that reduces laser power output and distorts beam-mode quality. Stable emission and higher resonator efficiencies are achieved because of the low internal volume construction and smooth flow paths that eliminate dead space as potential entrapment sites for moisture or hydrocarbons. An optional integral purge assembly and an internal check valve to guarantee gas purity and lower maintenance costs are available. The delivery system’s low-diffusion design incorporates stainless steel diaphragms and a $1 \times 10^{-8}$ He cc/s leak rate, and a PTFE or Kel-F® seat. The operating temperature range is -40° to 140°F, and the basic regulator weighs 4.8 lb.

CONCOA 108
1501 Harpers Rd., Virginia Beach, VA 23454

Dust Collector Designed for High Volumes

The RP8-3 dust collector has 24 cartridge filters and more than 15,000 ft³/min of air cleaning volume. It collects welding smoke and fumes, metalworking dust, process dust, powders, and general plant air. The modular design allows multiple units to be bolted together to handle large air cleaning. The Roto-Pulse™ cartridge cleaning system automatically cleans the filter cartridges with up to a 99.9% efficiency, which facilitates lower maintenance costs and longer filter life. Gravity

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

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

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

Call TOLL-FREE 1-866-924-7427 for the Airgas location nearest you, or visit our eCatalog at: www.airgas.com.

Airgas

Circle No. 4 on Reader Info-Card
flow brings air in from the top, down through the filters, and out the bottom, where the motor is located.

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

Flap Discs Handle a Variety of Jobs

Weiler's line of abrasive flap discs provides cost-effective solutions for surface conditioning applications from deburring and cleaning to weld blending and finishing. The user can grind and finish in one step, resulting in fewer changeovers and increased productivity. The line includes Tiger® Discs for medium to high production environments, Vortec™ abrasive flap discs for low to medium production environments, BohCat® abrasive flap discs for use on right-angle air die grinders, and Big Cat® for grinding and finishing curved and irregular surfaces.

Weiler Corp.  
One Wildwood Dr., Cresco, PA 18326

Liner Loads from the Front End

The Tough Gun Quick Load Liner™ loads from the front of the gas metal arc welding gun, eliminating the need to climb around tooling and transfer systems. Users can change the liner without removing the gun from the feeder, so fewer steps allow them to change the liner faster. The liner is available for robotic applications using cables of up to 6 ft.

Tregaskiss Ltd.  
2750 N Talbot Rd., Windsor, ON, Canada N9R 1L0

Blast Cleaning System Features Large Work Table

The company's expanded workstation for its RXS-890 blast cleaning system provides additional space for component handling at the load/unload position. A wrap-around table allows staging of parts, inspection routines, or tray loading for more convenience. The midsize rotary indexing table has four ball bearing spindles equally spaced around the circumference of its 36-in.-diameter table. The inside of the cabinet is divided for separate chambers of isolation, blast treatment, and blow-off processed components, and the 50- by 64-in. footprint of the blast cabinet is not increased by the overhanging work table. Inside the blast chamber, the fixture can be rotated at adjustable speed as it surfaces are exposed to blast from up to eight suction-blast guns or four pressure-blast nozzles. A light curtain disables the machine's indexer when the user is not safely clear. It features a compact touch-screen panel.

Guyson Corporation of U.S.A.  
W. J. Grande Industrial Pk., 13 Grande Blvd.  
Saratoga Springs, NY 12866
INTRODUCING TOUGH GUN I.C.E.

Tregaskiss has combined the durability of an air-cooled platform with the chilling capabilities of the I.C.E (Integrated Cooling Enhancer) package. The result; a cooler running, more dependable robotic torch.

Longer Life
- Cooler front end parts = extended life

Maintenance Friendly
- Eliminates hassles common to conventional style water-cooled torches

Increased Safety
- Gooseneck no hotter than 122° F
- Nozzle cools to 122° F in 90 seconds

TOUGH GUN I.C.E...bringing new meaning to the term I.C.E. age.

Contact your Tregaskiss Sales Representative today!

Circle No. 49 on Reader Info-Card
The Society's 2003-2004 fiscal year reflected the economic trends our country experienced. There were promising indicators, but caution and prudence must remain the steering currents. There were some very encouraging signs though. The operating surplus was in excess of $200,000, which is the highest it has been in six years and the second highest in the past 17 years. A strong contributor to revenues continues to be the Society's certification programs. The Seminars and Conferences Department experienced an encouraging turnaround. From a net operating loss during the prior fiscal year, it contributed almost $100,000 during this fiscal reporting period. A truly noteworthy development was the combined net assets of the Society and the Foundation were almost $11-million, which is a historical high.

To provide guidance and direction to the Society's pursuits, the Board of Directors instructed the Executive Director and Staff to develop a strategic plan. The result was a plan extended over the next three years that pinpointed 13 initiatives, which included growth in membership and certification programs; a broadened scope for conferences and seminars; exploration of alliances and partnering opportunities; determination of the future direction of the Welding Show; promotion of welding education, training, and research; the development of new technical documents; increased marketing of products; and maintaining the excellence of the Welding Journal while investigating other periodical opportunities. Additionally, the Executive Director and Staff have developed an on-going business plan to guide the Society's future ventures.

In conjunction with the development of the strategic plan, the Board of Directors, recognizing the Society's plans must include the broad range of disciplines that fill the interests and professional pursuits of its members, made an adjustment to the Society's mission statement as follows: "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."

Other developments during the reporting period included entering into a contract with Open Text AG to develop a web-based environment for the development of AWS standards. The system went live on November 24, 2003, enabling the electronic circulation of committee documents, drafts and ballots, as well as conducting Web-based meetings and discussions. This system should speed up the standards development process while at the same time reduce postage and in-house copying expenses. It will also allow more volunteers to participate through virtual meetings and electronic discussion groups. The system is open for use by all AWS committee members from the Board of Directors down to subcommittee level.

The newest volume of the Welding Handbook, Welding Processes, Part 1, made its debut at the 2004 AWS Welding Show in Chicago. This publication contains new and updated information on welding, brazing, soldering, and thermal cutting processes, as well as power sources. Approximately 100 experts were involved in its review and production, making the final 720-page book a reflection of the strength of the Society's committee system.

The Gases and Welding Distributors Association (GAWDA) held its first Spring Management Conference in conjunction with the AWS Welding Show in Chicago last April, and it plans to do so again at the AWS Welding Show in Dallas next spring.

During the reporting period, a letter of intent was signed by the AWS and organizers of FABTECH International to pursue discussion of a mutually beneficial business alliance. The results of that pursuit are reported on page 4 in this issue of the Welding Journal.

The Society faced many challenges during this past fiscal year, but with firm and steady leadership, those challenges were met and new initiatives were launched. The Society finished the fiscal year in a very promising financial position.
Board of Directors
American Welding Society, Inc. and AWS Foundation

We have audited the accompanying combined statement of financial position of American Welding Society, Inc. and AWS Foundation (the Organizations) as of May 31, 2004 and the related combined statements of activities, changes in net assets and cash flows for the year then ended. These combined financial statements are the responsibility of the Organizations' management. Our responsibility is to express an opinion on these combined financial statements based on our audit. The financial statements of the prior period were audited by other auditors whose report dated August 1, 2003, expressed an unqualified opinion on those statements. Information for the year ended May 31, 2003 is presented for comparative purposes only and was extracted from the audited combined financial statements represented for that year.

We conducted our audit in accordance with auditing standards generally accepted in the United States. Those standards require that we plan and perform the audit to obtain reasonable assurance about whether the combined financial statements are free of material misstatement. An audit includes examining, on a test basis, evidence supporting the amounts and disclosures in the combined financial statements. An audit also includes assessing the accounting principles used and significant estimates made by management, as well as evaluating the overall financial statement presentation. We believe that our audit provides a reasonable basis for our opinion.

In our opinion, the combined financial statements referred to above present fairly, in all material respects, the financial position of American Welding Society, Inc. and AWS Foundation as of May 31, 2004, and the changes in their net assets and their cash flows for the year then ended in conformity with accounting principles generally accepted in the United States.

Rachlin Cohen & Holtz LLP
Certified Public Accountants
Miami, Florida
July 23, 2004
### AMERICAN WELDING SOCIETY, INC. AND AWS FOUNDATION
### COMBINED STATEMENT OF FINANCIAL POSITION

**MAY 31, 2004 (WITH COMPARATIVE TOTALS FOR MAY 31, 2003)**

#### OPERATING RESERVE FUND

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Cash and cash equivalents</td>
<td>$826,756</td>
<td>$42,637</td>
<td>$475,251</td>
<td>$1,344,644</td>
<td>$1,210,176</td>
</tr>
<tr>
<td>Grants and contracts receivable</td>
<td>13,000</td>
<td></td>
<td>60,000</td>
<td>63,000</td>
<td>60,655</td>
</tr>
<tr>
<td>Accounts receivable, less allowance for possible losses of approximately $79,000 and $95,000, respectively</td>
<td>1,252,262</td>
<td></td>
<td>22,302</td>
<td>1,294,564</td>
<td>1,315,361</td>
</tr>
<tr>
<td>Pledges receivable</td>
<td>-</td>
<td></td>
<td>73,291</td>
<td>73,291</td>
<td>188,425</td>
</tr>
<tr>
<td>Inventory</td>
<td>205,093</td>
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<td>-</td>
<td>205,093</td>
<td>360,384</td>
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<tr>
<td>Prepaid and other assets</td>
<td>590,121</td>
<td></td>
<td>-</td>
<td>593,366</td>
<td>832,571</td>
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<tr>
<td>Deposits and other receivables</td>
<td>11,967</td>
<td></td>
<td>-</td>
<td>76,434</td>
<td>88,401</td>
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<tr>
<td>Investments</td>
<td>-</td>
<td>4,446,441</td>
<td>3,418,775</td>
<td>7,865,216</td>
<td>6,761,368</td>
</tr>
<tr>
<td>Property and equipment, less accumulated depreciation</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2,595,835</td>
<td>2,660,938</td>
</tr>
<tr>
<td><strong>Total assets</strong></td>
<td>$5,495,034</td>
<td>$4,489,078</td>
<td>$4,239,298</td>
<td>$14,223,410</td>
<td>$13,566,348</td>
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#### LIABILITIES AND NET ASSETS

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</tr>
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<tbody>
<tr>
<td>Accounts payable and accrued expenses</td>
<td>$1,303,777</td>
<td></td>
<td>$27,905</td>
<td>$1,331,682</td>
<td>$1,238,863</td>
</tr>
<tr>
<td>Deferred membership, subscription and convention income</td>
<td>1,922,051</td>
<td></td>
<td>-</td>
<td>1,922,051</td>
<td>1,927,421</td>
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<tr>
<td>Capital leases</td>
<td>-</td>
<td></td>
<td>-</td>
<td>128,084</td>
<td>128,084</td>
</tr>
<tr>
<td><strong>Total liabilities</strong></td>
<td>3,225,828</td>
<td></td>
<td>27,905</td>
<td>3,253,733</td>
<td>3,264,908</td>
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<tr>
<td>Commitments and Contingencies</td>
<td>-</td>
<td></td>
<td>-</td>
<td>-</td>
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</tr>
</thead>
<tbody>
<tr>
<td>Unrestricted</td>
<td>2,180,819</td>
<td>4,489,078</td>
<td>53,590</td>
<td>5,723,487</td>
<td>6,279,131</td>
</tr>
<tr>
<td>Temporarily restricted</td>
<td>89,987</td>
<td></td>
<td>1,668,829</td>
<td>1,777,216</td>
<td>1,856,501</td>
</tr>
<tr>
<td>Permanently restricted</td>
<td>-</td>
<td></td>
<td>2,489,974</td>
<td>2,489,974</td>
<td>2,166,348</td>
</tr>
<tr>
<td><strong>Total net assets</strong></td>
<td>2,299,206</td>
<td>4,489,078</td>
<td>4,211,393</td>
<td>10,969,677</td>
<td>10,301,380</td>
</tr>
<tr>
<td><strong>Total liabilities and net assets</strong></td>
<td>$5,495,034</td>
<td>$4,489,078</td>
<td>$4,239,298</td>
<td>$14,223,410</td>
<td>$13,566,348</td>
</tr>
</tbody>
</table>

See notes to combined financial statements.
## AMERICAN WELDING SOCIETY, INC. AND AWS FOUNDATION
### COMBINED STATEMENT OF ACTIVITIES AND CHANGES IN NET ASSETS

**YEAR ENDED MAY 31, 2004 (WITH COMPARATIVE TOTALS FOR THE YEAR ENDED MAY 31, 2003)**

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>Revenues</strong></td>
<td><strong>Expenses</strong></td>
<td><strong>Net</strong></td>
<td><strong>Net Assets</strong></td>
<td><strong>Net Assets</strong></td>
</tr>
<tr>
<td>Convention</td>
<td>$2,190,737</td>
<td>$1,461,469</td>
<td>$759,268</td>
<td>$1,103,942</td>
</tr>
<tr>
<td>Education</td>
<td>337,217</td>
<td>418,307</td>
<td>(81,090)</td>
<td>(143,217)</td>
</tr>
<tr>
<td>Seminar and conference</td>
<td>1,630,779</td>
<td>1,531,175</td>
<td>99,604</td>
<td>719,974</td>
</tr>
<tr>
<td>Marketing and corporate communications and governmental affairs</td>
<td>-</td>
<td>147,848</td>
<td>(147,848)</td>
<td>(147,848)</td>
</tr>
<tr>
<td>AWS Foundation</td>
<td>79,940</td>
<td>179,123</td>
<td>(99,183)</td>
<td>(120,311)</td>
</tr>
<tr>
<td>Membership</td>
<td>2,146,888</td>
<td>1,436,966</td>
<td>709,922</td>
<td>719,974</td>
</tr>
<tr>
<td>Certification</td>
<td>644,746</td>
<td>4,078,694</td>
<td>(4,043,541)</td>
<td>(3,785,892)</td>
</tr>
<tr>
<td>Technical</td>
<td>1,880,580</td>
<td>1,528,891</td>
<td>351,689</td>
<td>207,242</td>
</tr>
<tr>
<td>Publications</td>
<td>15,153</td>
<td>4,078,694</td>
<td>(4,043,541)</td>
<td>(3,785,892)</td>
</tr>
<tr>
<td>Administration</td>
<td>52,217</td>
<td>52,217</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Interest income</td>
<td>1,427</td>
<td>1,427</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>International Accreditation Registry</td>
<td>125,048</td>
<td>145,492</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Board approved programs</td>
<td>15,105</td>
<td>15,105</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Total operating fund</strong></td>
<td>15,588,027</td>
<td>13,877,649</td>
<td>2,000,378</td>
<td>581,061</td>
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**Reserve:**

<table>
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<tr>
<th>Reserves</th>
<th><strong>Net Assets</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Gain on investments</td>
<td>101,992</td>
</tr>
<tr>
<td>TFPS, Inc.</td>
<td>435</td>
</tr>
<tr>
<td>Interest and dividends</td>
<td>87,060</td>
</tr>
<tr>
<td><strong>Total reserve fund</strong></td>
<td>190,357</td>
</tr>
</tbody>
</table>

**AWS Foundation:**

<table>
<thead>
<tr>
<th>AWS Foundation</th>
<th><strong>Net Assets</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Donations</td>
<td>235,394</td>
</tr>
<tr>
<td>Interest</td>
<td>34,237</td>
</tr>
<tr>
<td>Gain on investments</td>
<td>210,308</td>
</tr>
<tr>
<td>Net assets released from restrictions by satisfaction of purpose restrictions</td>
<td>72,560</td>
</tr>
<tr>
<td>Operating expenses</td>
<td>166,296</td>
</tr>
<tr>
<td>Scholarships</td>
<td>157,100</td>
</tr>
<tr>
<td>Fellowships</td>
<td>116,666</td>
</tr>
<tr>
<td>Fundraising and other</td>
<td>58,816</td>
</tr>
<tr>
<td><strong>Total AWS Foundation</strong></td>
<td>552,499</td>
</tr>
</tbody>
</table>

**Change in Net Assets**

<table>
<thead>
<tr>
<th>Net Assets, Beginning</th>
<th>$6,228,457</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transfer In/Out</td>
<td>(218,218)</td>
</tr>
<tr>
<td>Net Assets, End</td>
<td>$6,010,239</td>
</tr>
</tbody>
</table>

See notes to combined financial statements.
# AMERICAN WELDING SOCIETY, INC. AND AWS FOUNDATION
## COMBINED STATEMENT OF CASH FLOWS

### YEAR ENDED MAY 31, 2004 (WITH COMPARATIVE TOTALS FOR THE YEAR ENDED MAY 31, 2003)

<table>
<thead>
<tr>
<th>Cash Flows from Operating Activities:</th>
<th>Operating Reserve AWS Total</th>
<th>2004</th>
<th>2003</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change in net assets</td>
<td>$ 200,378</td>
<td>$ 100,387</td>
<td>$ 278,302</td>
</tr>
<tr>
<td>Adjustments to reconcile change in net assets to net cash provided by operating activities:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gains on investments</td>
<td>-</td>
<td>(101,992)</td>
<td>(210,306)</td>
</tr>
<tr>
<td>Depreciation</td>
<td>284,010</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Provision for losses on accounts receivable</td>
<td>20,000</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(Increase) decrease in accounts receivable</td>
<td>(4,696)</td>
<td>-</td>
<td>5,486</td>
</tr>
<tr>
<td>Decrease in pledges receivable</td>
<td>-</td>
<td>115,134</td>
<td>115,134</td>
</tr>
<tr>
<td>Decrease in grants and contract receivable</td>
<td>6,855</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Decrease in inventory</td>
<td>164,299</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Decrease in prepaids and other assets</td>
<td>134,444</td>
<td>-</td>
<td>4,761</td>
</tr>
<tr>
<td>(Increase) decrease in deposits and other receivables</td>
<td>64,811</td>
<td>-</td>
<td>(3,730)</td>
</tr>
<tr>
<td>Increase (decrease) in accounts payable and accrued expenses</td>
<td>50,425</td>
<td>-</td>
<td>13,386</td>
</tr>
<tr>
<td>Decrease in deferred membership, subscription and convention income</td>
<td>(5,571)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Net cash provided by operating activities</td>
<td>$ 923,055</td>
<td>88,305</td>
<td>201,572</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cash Flows from Investing Activities:</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchases of property and equipment, net</td>
<td>(241,507)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Loss on disposal of property and equipment</td>
<td>22,905</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Proceeds from sales and maturities of investment securities</td>
<td>-</td>
<td>-</td>
<td>(287,960)</td>
</tr>
<tr>
<td>Purchases of investment securities</td>
<td>-</td>
<td>(503,585)</td>
<td>(791,555)</td>
</tr>
<tr>
<td>Net cash used in investing activities</td>
<td>(218,012)</td>
<td>(287,960)</td>
<td>(503,585)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cash Flows from Financing Activities:</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Interfund transfers</td>
<td>(111,619)</td>
<td>200,000</td>
<td>(38,387)</td>
</tr>
<tr>
<td>Payments on capital leases</td>
<td>(78,088)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Net cash used in (provided by) financing activities</td>
<td>(189,701)</td>
<td>200,000</td>
<td>(38,387)</td>
</tr>
</tbody>
</table>

| Net Increase (Decrease) in Cash and Cash Equivalents | $ 515,542 | $ 495 | (390,310) | $ 125,467 | $ 394,374 |
| Cash and Cash Equivalents, Beginning of Year | 311,413 | 42,202 | 865,561 | 1,219,176 | 824,802 |
| Cash and Cash Equivalents, End of Year | $ 825,755 | $ 42,887 | $ 475,251 | $ 1,344,643 | $ 1,219,176 |

See notes to combined financial statements.
NOTE 1. NATURE OF ORGANIZATION AND SIGNIFICANT ACCOUNTING POLICIES

Organization and Purpose

The accompanying combined financial statements include the accounts of American Welding Society, Inc., its wholly-owned subsidiary TFPS, Inc. and its affiliate, AWS Foundation (collectively, the "Organizations").

All material inter-organization accounts and transactions have been eliminated in combination. American Welding Society, Inc. and AWS Foundation are not-for-profit entities, exempt from income tax under Section 501 (c)(3) of the Internal Revenue Code and are primarily engaged in welding technology, education and research activities. For income tax purposes, publication advertising revenue and rental income are considered unrelated business income and subject to income tax. TFPS, Inc., a taxable subsidiary of the Organizations, engages in profit-oriented activities.

Basis of Accounting

The financial statements of the Organizations are prepared on the accrual basis of accounting. The accounts of the Organizations are maintained for internal reporting purposes in accordance with the guidelines of the Financial Accounting Standards Board Statement of Financial Accounting Standards No. 117, Financial Accounting Standards Board Statement No. 117. The Organizations conduct an annual convention near the Organizations' fiscal year-end. The Organizations recognize convention revenue in the fiscal year the convention is held, or normally held, thereby recognizing one event during any fiscal year.

Membership Fees and Services

Membership and subscription revenues are deferred when received and recognized as revenue over the life of the membership and subscription.

Contributions

The Organizations account for contributions in accordance with the provisions of Financial Accounting Standards Board Statement of Financial Accounting Standards No. 116, Accounting for Contributions Received and Contributions Made Except for the Accounting for Unconditional Promises to Give. In accordance with SFAS No. 116, contributed goods and services are recorded as contributions at their estimated fair value at date of receipt.

Contributed goods and services are recognized as contributions at their estimated fair value, if the services (a) create or enhance non-financial assets or (b) require specialized skills, are performed by people with those skills, and would otherwise be purchased by the Organizations. Volunteers also provided services throughout the year that are not recognized as contributions in the financial statements since these are not susceptible to objective measurement or valuation.

Promises to Give

Contributions are recognized when the donor makes a promise to give to the Organizations that is, in substance, unconditional. All other donor-restricted contributions are reported as increases in temporarily or permanently restricted net assets depending on the nature of the restrictions. When a restriction expires, temporarily restricted net assets are transferred to unrestricted net assets. The Organizations had no conditional promises to give as of May 31, 2004.

The Organizations uses the allowance method to determine the estimated unconditional promises to give that are doubtful of collection. The allowance is based on prior years' experience and management's analysis of specific promises made.

Cash Equivalents

The Organizations consider all highly liquid investments with an initial maturity of three months or less to be cash equivalents.

Investments

The Organizations carry investments in marketable securities with readily determinable market values at their fair value in
NOTE 1. NATURE OF ORGANIZATION AND SIGNIFICANT ACCOUNTING POLICIES (CONTINUED)

Investments (continued)

the statement of financial position. Investment income, including realized and unrealized gains and losses are reported as either unrestricted, temporarily restricted or permanently restricted, depending on the existence of donor-imposed restrictions on the income from the investments in the statement of activities and changes in net assets.

Property and Equipment

Property and equipment are defined by the Organizations as assets with an initial, individual cost of more than $1,000 and an estimated useful life in excess of one year. Property and equipment is stated at cost and is depreciated using the straight-line method over the following estimated useful lives of the respective assets:

<table>
<thead>
<tr>
<th>Estimated Useful Lives (Years)</th>
<th>Building and improvements</th>
<th>14-29</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Furniture and equipment</td>
<td>5-7</td>
</tr>
</tbody>
</table>

Inventory

Inventory consists primarily of work-in-process relating to various publications and is valued at cost. Cost is determined by the actual expenditures incurred in the production process.

Concentration of Credit Risk

Financial instruments that potentially subject the Organizations to a concentration of credit risk are cash. The Organizations maintain their cash in several commercial banks. Accounts at each bank are insured by the Federal Deposit Insurance Corporation up to $100,000 per bank. As of May 31, 2004 the Organization maintained cash balances totaling approximately $750,000 at institutions in excess of this federally insured limit; of this amount, approximately $654,000 was invested in overnight repurchase agreements to obtain optimum investment income. The Organizations maintain their deposits in high quality financial institutions which the Organizations believe limit this risk. The Organizations' investments are subject to the normal "market risks" of these types of investments, which are traded on equity markets.

Donated Services

The Organization receives donated services from a variety of unpaid volunteers who assist in fund raising. No amounts have been recognized in the accompanying statement of activities because the criteria for recognition of such volunteer effort under SFAS No. 116 has not been satisfied.

Donated Assets

Donated marketable securities and other noncash donations are recorded as contributions at their estimated fair values as of the date of donation. Donated property and equipment is recorded at estimated fair value at the date of donation. There was no donated property or equipment during 2004.

Allocation Expenses

The costs of performing the Organizations' various activities have been summarized on a functional basis in the accompanying combined statement of activities. Certain occupancy costs have been allocated among the activities benefited.

Prepays and Other Assets

Prepays and other assets consist primarily of work-in-process costs relating to various publications that have not yet been released for distribution. Once the publication is complete and ready for its intended use, the costs are amortized over the life of the publications, usually between two to three years. Additionally, expenditures which relate to programs for the next fiscal year are reported as a prepaid asset and are expensed during the next year as the related program function takes place.

Use of Estimates

The preparation of financial statements in conformity with accounting principles generally accepted in the United States requires management to make estimates and assumptions that affect the reported amounts of assets and liabilities and disclosure of contingent assets and liabilities at the date of the financial statements and the reported amounts of revenues and expenses during the reporting period. Actual results could differ from those estimates.

Income Taxes

American Welding Society, Inc. and AWS Foundation are not-for-profit corporations are exempt from federal income taxes under Section 501(c)(3) of the Internal Revenue Code. The Organizations are taxed on unrelated business income. There was no unrelated business income during the year ended May 31, 2004.

Reclassifications

Certain items included in the 2003 combined financial statements have been reclassified to conform with the presentation in the 2004 combined financial statements.

NOTE 2. PLEDGES RECEIVABLE

Unconditional promises are expected to be realized as follows:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>In one year or less</td>
<td>$34,000</td>
</tr>
<tr>
<td>Between one and five years</td>
<td>$34,791</td>
</tr>
<tr>
<td>More than five years</td>
<td>$4,500</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$73,291</strong></td>
</tr>
</tbody>
</table>

Pledges receivable in the amount of $44,437 as of May 31, 2004 are restricted for awards and scholarships. Management believes that all pledges are fully collectible and, therefore, has not recorded an allowance for collection losses.
NOTE 3. INVESTMENTS

Investments, which are comprised entirely of mutual funds, are presented in the combined financial statements at their fair market values and consist of the following at May 31, 2004:

<table>
<thead>
<tr>
<th>Vanguard Investments</th>
<th>Reserve Fund Investments</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-Yield Corporate Fund</td>
<td>236,656</td>
</tr>
<tr>
<td>Intermediate-Term Corporate Fund</td>
<td>528,935</td>
</tr>
<tr>
<td>Long-Term Bond Index Fund</td>
<td>235,060</td>
</tr>
<tr>
<td>Short-Term Bond Index Fund</td>
<td>335,179</td>
</tr>
<tr>
<td>Short-Term Corporate Fund</td>
<td>444,858</td>
</tr>
<tr>
<td>Explorer Fund</td>
<td>155,950</td>
</tr>
<tr>
<td>Total Stock Market Index Fund</td>
<td>1,067,051</td>
</tr>
<tr>
<td>Strategic Equity Fund</td>
<td>155,896</td>
</tr>
<tr>
<td>Total International Stock Index Fund</td>
<td>531,387</td>
</tr>
<tr>
<td>U.S. Growth Fund</td>
<td>377,851</td>
</tr>
<tr>
<td>Windsor II Fund</td>
<td>377,619</td>
</tr>
<tr>
<td>AWS Foundation Investments</td>
<td>3,418,775</td>
</tr>
</tbody>
</table>

Investment income consisted of the following for the year ended May 31, 2004:

<table>
<thead>
<tr>
<th>Reserve Fund</th>
<th>AWS Foundation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interest and dividends</td>
<td>87,060</td>
</tr>
<tr>
<td>Net realized and unrealized gains on investments</td>
<td>101,992</td>
</tr>
<tr>
<td>Total</td>
<td>189,052</td>
</tr>
</tbody>
</table>

NOTE 4. PROPERTY AND EQUIPMENT

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Land</td>
<td>816,726</td>
</tr>
<tr>
<td>Building and Improvements</td>
<td>4,369,999</td>
</tr>
<tr>
<td>Furniture and equipment</td>
<td>3,938,784</td>
</tr>
<tr>
<td>Less accumulated depreciation</td>
<td>6,529,674</td>
</tr>
<tr>
<td>Total</td>
<td>2,505,895</td>
</tr>
</tbody>
</table>

NOTE 5. TEMPORARILY RESTRICTED NET ASSETS

Net assets of the AWS Foundation in the amount of $1,688,829 as of May 31, 2004, are restricted for awards and scholarships. Net assets of $72,560 were released from donor restrictions by granting awards and scholarships.

NOTE 6. PERMANENTLY RESTRICTED NET ASSETS

Net assets in the amount of $2,468,974 as of May 31, 2004, are permanently restricted endowments which are to provide a source of funds predominantly for educational, research, and other charitable purposes.

NOTE 7. BOARD APPROVED PROGRAMS

American Welding Society, Inc.'s Board of Directors periodically approves expenditures for special programs designed, among other things, to further the development and public awareness of welding technology, education, and standards. For the year ended May 31, 2004, such special program expenses amounted to $15,000.

NOTE 8. COMMITMENTS AND CONTINGENCIES

Deferred Compensation Plan

American Welding Society, Inc.'s former Executive Director was employed under the terms of an employment contract. The contract provides for base compensation and bonuses at the discretion of the Board of Directors as well as severance compensation under certain circumstances. Additionally, the contract addresses post-separation benefits.

In 2002, the Organizations elected not to renew the contract, and therefore the former Executive Director's employment with the Organizations ended. Pursuant to the former Executive Director's employment contract, he is claiming certain deferred compensation and employment benefits. On August 21, 2003, the former Executive Director filed a demand for arbitration.

The Organizations have engaged legal counsel and are vigorously defending this claim and believe that such is without merit. The Organizations have accrued approximately $468,000 as their best estimate of the contingent liability associated with the former Executive Director's claim. Currently, the outcome of the case cannot be determined.

Litigation

The Organizations are exposed to various asserted and unasserted potential claims encountered in the normal course of business. In the opinion of management, the resolution of these matters will not have a material adverse effect on the Organizations' financial position or results of operations.
NOTE 8. COMMITMENTS AND CONTINGENCIES (Continued)

Litigation (Continued)

During the year ended May 31, 2002, the Organizations filed a lawsuit against parties who contracted to provide services including the installation of a computer system. Management had determined that the computer system was not capable of handling the business requirements of the Organizations. As a result, the Organizations filed a lawsuit. On June 27, 2003, this case was settled favorably by the Organizations. The net income effect of approximately $406,000 is included under the caption Administration on the 2003 financial statements.

Various claims and lawsuits incidental to the Organizations' operations are pending against the Organizations. Although the outcome of these claims and lawsuits are not presently determinable in the opinion of the Organizations' counsel and management, any claims or lawsuits not covered by insurance would not have a material adverse effect on the financial condition of the Organizations.

Royalty Agreement

During 2001, American Welding Society, Inc. (the "Organization") entered into a Copyright License Agreement with Information Handling Services ("IHS"), whereby IHS has been given rights to duplicate, package, facsimile transmit, promote, distribute, sell or lease the Organization's standards and technical publications. The term of the agreement is for sixty months and commenced on January 1, 2001. IHS guarantees the Organization that the total royalty payments to the Organization will equal or exceed minimum amounts of $1,300,000 for each of the upcoming years. The guarantee is contingent upon the Organization not entering into any other agreements with third parties that will adversely affect the economics of the agreement. The Organization will continue to produce new and revised publications and will continue to release these publications periodically as indicated, and the list price will be no less than the prices as indicated in the Organization's catalog. Under the terms of this agreement, the Organization earned approximately $1,600,000 during the year ended May 31, 2004.

NOTE 9. RELATED PARTY TRANSACTIONS

AWS Foundation administers investments on behalf of certain affiliated sections. The investments aggregated $1,173,463 at May 31, 2004 and are not included in the combined financial statements.

The American Welding Society has loaned monies to a number of employees at the Society. Generally, the loans bear interest at 8% per annum and are paid via monthly payroll deductions. The repayment terms range from less than a year to five years. The loans are not collateralized. The balance outstanding at May 31, 2004 was approximately $7,000 and is reported with the financial statement caption “Deposits and Other Receivables”.

NOTE 10. EMPLOYEE BENEFIT PLAN

The Organizations have a simplified employee pension plan for all full-time employees. Full-time employees are eligible for participation in the plan the first day of the month after they are employed. The Organizations will contribute a maximum of 4% of the employees' base salary. 2% of the employees' contribution is a 50% match of the employees' contribution. The Organization made contributions totaling approximately $161,000 during the year ended May 31, 2004.
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Circle No. 48 on Reader Info-Card
Since the tragic events of September 11, 2001, there has been a significant amount of debate and planning regarding the replacements for the two World Trade Center towers on the Manhattan skyline. However, many citizens outside of Manhattan are not aware that the twin towers were part of a much larger complex, including what was known as Seven World Trade Center. This building stood beside the towers until it was structurally weakened by the destruction of the nearby towers and subsequently also collapsed.

While dwarfed by the twin towers, the glass and red granite Seven World Trade Center was not a small building. It stood 570 ft (174 m) tall and contained 47 floors. Along with many tenant floors, the building also housed the Con Edison power substation serving much of Manhattan.

Renewal

New construction has begun on that site, and the erection of a new Seven World Trade Center building (Fig. 1) is quite significant since it is the first rebuild at the Ground Zero site. Marking the importance of this project for New York City, Mayor Michael Bloomberg was on site at the beginning of construction. Members of the mayor’s staff are following the progress of the building’s erection.

The new Seven World Trade Center has a parallelogram shape and will be 750 ft high (229 m) — almost 200 ft taller than its predecessor. It will feature 42 tenant floors above a 10-story base incorporating the Con Edison substation. The rentable area will measure more than 1.7 million ft². The north and south exposures of the building, along Barclay and Vesey St., respectively, will front the Con Edison substation. Floors 11 through 52 will be tenant office floors, typically with 10-ft-high floor-to-ceiling windows, 9-ft clear ceiling heights, and 45-ft lease spans that will be virtually column free.

David M. Childs, FAIA of Skidmore, Owings, & Merrill L.L.P., working with
glass artist and designer James Carpenter, expect natural light will create a shimmering façade whose appearance will subtly transform with the changing patterns of sunlight and weather.

The base is conceived as a block of stainless steel that is carved or sculpted from within to create the 45-ft-high lobby and front door of the tower. The building will feature a slender glass pylon to mark both the entrance to the World Trade Center and the Gateway to the future downtown district of New York.

Structural Construction — On and Off Site

Helmark Steel, Inc., one of the nation’s leading fabricators and erectors of structural steel, was chosen to complete the steelwork for the project. Helmark performs the fabrication work in the shop, while its sister company, Falcon Steel, erects the on-site assembly.

For both in-house and job-site welding, Helmark and Falcon rely on welding equipment manufactured by The Lincoln Electric Co. They both selected the Multi-Weld® 350, which is a system that can be set up for simultaneous welding by several operators working at the job site, and is powered by a single welding power source.

World Trade Center Seven Engineering

World Trade Center Seven is being constructed using a method called concrete core construction, in which the steel frame is set first and concrete is poured around the steel framework. Using concrete core construction means that the lateral resisting system is a concrete shear wall construction vs. typical steel brace frames.

Although this concept is not new, according to Dominick D’Antonio, senior project engineer with Helmark Steel, what makes this building unique is that the steel construction is up to 12 floors ahead of the concrete shear wall construction, necessitating additional temporary bracing in the building.

In a more typical application, the shear wall proceeds ahead of the steel. However, with the concrete core method used here, field erection welding is virtually eliminated.

Shop Welding

In fabricating the framework for this 52-story building, Helmark purchases bulk steel from various warehouses and then conducts its own tests for quality upon arrival at the shop. Next, in a mostly computer-operated process, pieces are cut, drilled, and punched to specifications and later laid out and inspected.

The sections are welded with a semiautomatic self-shielded flux-cored process. Depending on the weldment configuration on the shop floor at any given time, between 160,000 to 220,000 lb of framework are fabricated each day by Helmark’s 25 in-shop weld operators — Fig. 2. Welding on the Grade 50 steel includes both partial and complete joint penetration fillet welds at high deposition rates. The E70T-6 consumable (Innershield® NR-305) used on the job meets Charpy V-notch requirements for fracture-critical work.

Not Enough Power

A few years ago, with so many welding operators working simultaneously each day, Helmark found itself facing a problem at its Wilmington, Del., fabrication facility. It had an in-shop power grid shortage so severe it could not add another welding station. At the time, company representatives were testing Multi-Weld 350 units for possible fieldwork, but realized the system could be utilized indoors as well. The welding units are capable of reducing the overall current draw, since multiple arcs can be struck simultaneously with the use of a single power source.

Lee Roth, manager, quality assurance, safety, and personnel for Helmark, reported this system allows five or six arcs to run off of one, 100-A, 480-V outlet as opposed to needing one outlet for each welding machine. He noted arc performance remained steady, and no drops in current or voltage were experienced, nor any changes in the welding procedures.

Conclusion

For Helmark and Falcon Steel, being awarded the first contract to rebuild on the World Trade Center site is an honor. At a site that will forever be synonymous with the terrible events of September 11, 2001, these fabrication and erection companies are proud to be associated with the rebirth of this important financial district for the U.S. and the world.
Get some career exposure.
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We're proud to announce the AWS Radiographic Interpreter certification program. Designed for NDE professionals and current AWS Certified Welding Inspectors, this training and certification program assures employers and practitioners alike that the principles of radiographic interpretation are reliably applied to the examination of welds.

If your job responsibilities include reading and interpretation of weld radiographs, this program is for you. You'll learn proper film exposure, correct selection of penetrameters, characterization of indications and use of acceptance criteria as expressed in the AWS, API and ASME codes.

For more information on the course, qualification requirements, certification exams and test locations, please visit our website at www.aws.org/certification/RI or call 1-800-443-9353 ext 273.
Double Electrodes Improve GMAW Heat Input Control

Experimental method increases melting rate while holding base metal heat input at a desirable level

BY Y. M. ZHANG, M. JIANG, AND W. LU

In conventional gas metal arc welding (GMAW), the melting rate is increased by increasing the welding current. The heat imposed on the base metal increases accordingly. This increase in the base metal heat input may generate undesirable side effects. To increase the melting rate while controlling the base metal heat input at a suitable level, a double-electrode gas metal arc welding process is proposed which bypasses some of the current away from the base metal to a second electrode so that the base metal current becomes less than the current required to melt the welding wire. The heat imposed on the base metal is thus reduced from conventional gas metal arc welding (GMAW). Experiments have verified that sufficient fusion can be achieved when the base metal current is less than the current melting the welding wire.

Conventional Processes

In all conventional arc welding processes, the arc is established between the base metal and the torch electrode, either consumable as in GMAW, or non-consumable as in gas tungsten arc welding (GTAW) — Ref. 1. The base metal must be either the anode or cathode. This fundamental characteristic of conventional arc welding may sometimes impose unwanted side effects.

For GMAW, the consumable welding wire electrode is in a dynamic balance between melting and transferring. Because the transfer is not continuous but discrete, the dynamic balance is actually achieved in the sense of averaging over a period of time. The arc length and arcing conditions are subject to continuous fluctuations and variations. Metal transfer control (Refs. 2–4) tries to minimize the influence of the fluctuations and variations in the arc length and arcing conditions on arc stability. However, the fundamental characteristic of the arcing principle aforementioned is not modified or changed by metal transfer control and the arc stability in GMAW fundamentally differs from that in GTAW, where the electrode is not consumed.

Current Considerations

It is also known that in GMAW the base metal is typically the cathode and the part of arc heat determined by $IV_{\text{cathode}}$ (where $I$ is the welding current and $V_{\text{cathode}}$ is the cathode voltage drop) is directly absorbed by the base metal. Because this part of the heat directly melts the base metal and contributes to enlarging the weld pool and distortion, increasing the deposition rate via increasing the current can be limited unless backing is used to support the large weld pool. Arc pressure is given as

$$P_{\text{arc}} = \mu_0 I^2$$

(Refs. 5, 6), where $\mu_0$ is permeability in vacuum space, $I$ is the welding current.
Double-Electrode GMAW

A fundamental characteristic of conventional arc welding is that the base metal current (current flowing through the base metal) equals the gun current (current flowing through the electrode in the gun) that is the current that melts the welding wire in GMAW. Decoupling the base metal current from the gun current may promise opportunities for new applications. This paper studies one method that can decouple the base metal current from the gun current in GMAW as shown in Fig. 1.

The system shown in Fig. 1 is obtained by adding a plasma arc welding (PAW) power supply and torch to a GMAW welding power supply and gun. The current supplied by the PAW power supply flows from the welding wire (GMAW gun) to the PAW orifice of the PAW tungsten electrode and to the tip of the PAW torch with a 30-deg PAW torch-electrode angle. The current supplied by the GMAW power supply flows from the gun to the contact tube of the GMAW gun and to the tip of the PAW torch. The current supplied by the PAW power supply flows from the PAW orifice to the contact tube of the GMAW gun and to the tip of the PAW torch. The current supplied by the PAW power supply flows from the PAW orifice to the contact tube of the GMAW gun and to the tip of the PAW torch.

The current that flows through and melts the filler metal will be the sum of the bypass and base metal currents, and is referred to as the melting current. Because two gun electrodes are used and the method is basically similar to GMAW except for the current bypass, the proposed method is referred to as the double-electrode GMAW or DE-GMAW.

Experimental Conditions

The GMAW gun was placed ahead of the PAW torch with a 30-deg PAW torch-normal and GMAW gun-normal angle. All gases used were pure argon. The PAW torch's plasma gas and shielding gas flow rates were 7 and 10 ft³/h, respectively. The diameter of the PAW tungsten electrode and the orifice were both ¼ in. (3.2 mm). The PAW torch's pilot arc current was 15 A. The welding wire used was 0.045-in.-diameter ER70S-6.

Two 12×6×0.5-in. plates were used to form a 60-deg groove as shown in Fig. 1, then were joined using PAW as a root pass before being used in the double-electrode GMAW experiments. Two torches were aimed at a same “focal” point on the “imagined surface” that connected the upper edges of the two plates. The distances from the “focal” point to the orifice of the PAW and to the tip of the contact tube of the GMAW gun were both 1 in. The gun and torch traveled in a straight line with no welding at 6.6 in./min. (The use of larger power supplies and a larger PAW torch or alternative larger second electrode promise a much higher travel speed.) The wire feed speed was 500 in./min for all experiments. The GMAW power supply ran in the constant-voltage mode with a 30-V voltage setting. The PAW power supply ran in the constant-current mode.

Several experiments were done using different bypass or PAW currents Ibp. When the bypass current changed, the current supplied by the GMAW power supply or the base metal current Ibm varied accordingly because the wire feed speed and thus the heat needed to melt the welding wire were fixed. In this way, the same deposition rate was obtained using different base metal currents Ibm. Table 1 lists the parameters used.

Results and Discussion

Table 1 — Welding Parameters and Results for One Double-Electrode GMAW Pass at 6.6 in./min Travel Speed, and 500 in./min Wire Feed Speed

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Setting (Ibp)</th>
<th>Reading (Ibm)</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100 A</td>
<td>250 A</td>
<td>Sufficient bond</td>
</tr>
<tr>
<td>2</td>
<td>70 A</td>
<td>185 A</td>
<td>Sufficient bond</td>
</tr>
<tr>
<td>3</td>
<td>0 A</td>
<td>250 A</td>
<td>Melt-through</td>
</tr>
</tbody>
</table>

Figure 2 displays the cross sections of the welds made in Experiments 1 and 2. It appears that both Experiments 1 and 2 produced sufficient fusion between the droplets and the base metal. This suggests that the heat imposed on the base metal in both experiments was sufficient to produce the needed bonding on the sides of the groove with the detached droplets. Experiment 3 was actually a conventional GMAW. In that experiment, the heat imposed on the base metal was much higher than the levels used in Experiments 1 and 2. The increased heat imposed on the base metal caused deeper penetration and a larger weld pool. When the full penetration was formed, the large weld pool fell and melt-through resulted. This suggests the heat imposed on the base metal in that experiment was greater than necessary. To avoid melt-through, the heat...
imposed on the base metal must be reduced by decreasing the wire feed speed, thus the welding current if the travel speed is not changed. The deposition rate is consequently reduced.

Careful observation shows that the weld pool in Experiment 2 is wider than that in Experiment 1, but their depths of penetration are about the same. In fact, when the heat imposed on the base metal increased, the penetration increased in different directions. However, for a melt-in process like GMAW, because most of the base metal current grounds near the top surface of the workpiece, the penetration tends to decrease toward the bottom of the groove. As a result, when the base metal current increases, the weld pool width vs. depth ratio increases.

It is desired for deposition applications that the penetration in different directions be just sufficient for solid bonding rather than being excessive. This implies that the amount of the heat imposed on the base metal has an optimum for each particular application. Once this amount is exceeded, the penetration may become more than necessary, causing material property degradation and weld pool enlargement. If the current has to be increased to melt the welding wire faster so that the increased heat imposed on the base metal results in full penetration, the corresponding large weld pool with large mass will fall much more easily than a smaller one. Hence, the amount of the heat imposed on the base metal should be optimized and fixed at an optimal level for the specific application. The proposed double-electrode GMAW process provides a method to decouple the base metal current from the melting current so that the melting current can be increased without increasing the base metal current. The heat imposed on the base metal can thus be maintained at a desired level. Experiments have verified the feasibility of the proposed double-electrode GMAW process in decoupling the currents.

Acknowledgments

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The partially completed sculpture of an Argentinosaurus shown in front of the Las Vegas Natural History Museum. Local Ironworkers have donated their time and skills in building the 75-ft-long, 20-ft-tall sculpture.

Dinosaur Project Teaches Ironworkers New Skills

Every now and then, forward thinking can mean taking an enormous step back in time. For the members of Las Vegas Ironworkers Union Locals 416/433, building a dinosaur has not only broadened their skills, but has generated more work and fostered goodwill throughout the community. Until recently, the Ironworkers were largely limited to structural steel jobs that required the shielded metal arc welding (SMAW) or flux cored arc welding (FCAW) processes to build high rises, schools, and bridges. However, with proper training and extensive volunteer efforts, they are learning to work with a variety of metals to ensure more local jobs, including the creation of an aluminum replica of an Argentinosaurus. — Fig. 1.

Because much of the work in Las Vegas requires working with miscellaneous metals or ornamental iron, union Ironworkers need skills that fulfill these types of jobs to retain and acquire work. In the past, Ironworkers lost jobs to other trades because jurisdictional work was being awarded to trade groups with more diversified welding skills. Further, Ironworker facilities were not equipped for working with miscellaneous metals. While contractors often have an allegiance to a particular trade, they also need to hire workers who can get the job done no matter what trade they belong to. And once the work is sent elsewhere, it's hard to get it back.

Now, as more jobs include such work as stainless steel handrails and statues in malls and hotels, Ironworkers seek to expand their skills. To help, union facilities have diversified their offerings to Local members in an effort to train them. Now, when contractors come to the hall looking for help on a particular project, they can man the job with qualified people.

Groundwork

As part of the effort, the Field Ironworkers Apprenticeship and Retraining Center for Locals 416/433 conducted a pilot training class in October 2003. The class began after a contractor, who was performing work in a local mall, needed trained workers to weld stainless steel for a handrail project. Local 416/433 members wanted to broaden their skills to fulfill this type of work, as well as other jobs, so what began as answering one contractor's need has developed into a variety of unconventional applications, such as the 75-ft-long, 20-ft-tall aluminum Argentinosaurus exhibit. When complete, the dinosaur will stand permanently outside the Las Vegas...
When Marilyn Gillespie, executive director of the museum, approached the Field Ironworkers Apprenticeship and Retraining Center for help, it was clear she had very large plans — and very little funds — for building the dinosaur. Even Fred Baptiste, coordinator for the Ironworker program in Las Vegas, knew the project would be challenging. Concerns about cost and time involved in such a large project seemed overwhelming, but eventually a long-term vision materialized. The project would require considerable training and a willingness to donate time and hard work on behalf of the community.

First, the Ironworkers needed to learn new skills. Miller Electric Mfg. Co. provided its expertise by custom developing the curriculum and teaching the class. For the Las Vegas Ironworkers, whose facility was one of the first in the country to get involved in this type of program, training meant progressing beyond the FCAW and SMAW techniques used on steel structures. Additional processes they learned included gas metal arc welding (GMAW) and gas tungsten arc welding (GTAW) of aluminum and stainless steel. For many members, this was their first experience working with these processes and metals.

“They’re structural guys,” said Baptiste. “Most of their work is ‘blow and go’ and their welds are covered by a building. However, the welds on the dinosaur will be exposed for all to see, plus you’re talking lots of money for the material they’re welding on.”

A major part of the Ironworkers' instruction covered the different types of welding equipment available for doing ornamental iron work. Next, they learned how to set up equipment to perform particular welding processes, such as changing from direct current electrode positive to direct current electrode negative when transitioning from GMAW to GTAW. Classroom training focused on the characteristics of the materials, including melting temperatures, dos and don'ts, and cleaning guidelines.

The Ironworkers were given the opportunity to work with sophisticated equipment and learn new technology in the classroom. Considering many jobs include working with aluminum, and the dinosaur would be constructed from all-aluminum tubing, a great deal of time was spent teaching students how to gas metal arc weld aluminum using Miller XMT® multiprocess inverters and Spoolmatic® 30-A spool guns. For welding stainless steel, the inverters were paired with 22-A bench-top-style feeders.

For GTAW on aluminum, the Ironworkers used Miller Syncrowave® 250 DX AC/DC power sources. Instructors ran a Millermatic® 251 all-in-one GMAW machine with McKay® stainless steel 308L flux cored wire on some heavier materials and McKay stainless steel solid electrodes for light-gauge materials.

Instruction about solid wire centered on such items as the differences between...
Gas Metal Arc Welding of Aluminum

Whenever possible, fabricators working with aluminum and the GMAW process avoid using the short circuit transfer mode. Generally speaking, this transfer method does not provide sufficient energy to overcome aluminum’s excellent thermal conductivity. As a result, short circuit transfer welds on aluminum are prone to poor fusion, excess spatter, and porosity.

Because aluminum needs more energy, the GMAW spray transfer method is usually the first process people master. This transfer method provides excellent fusion and bead appearance with little or no spatter. However, because it typically requires at least 180 A of current, it is not suitable for thin-gauge applications.

Because aluminum has certain qualities different than steels, welding techniques and parameter settings are different. To obtain optimum results, follow these guidelines:

- Use a wire feed system designed specifically for aluminum, either a spool gun or a push-pull system, to ensure good feeding performance. Trying to “push” aluminum through a GMAW gun designed for steel will almost certainly result in excess downtime due to bird’s nesting the wire at the drive rolls and the electrode melting back to the contact tip. Also, dedicate the feeding system to aluminum, as switching between steel and aluminum wires will result in steel particles contaminating the aluminum.
- Make sure the power source is set for direct current electrode positive.
- 100% argon shielding gas is generally used for GMAW of aluminum. The flow rate ranges between 20 and 40 ft³/h.
- Use the largest diameter wire suited for the application. It will be easier to feed.
- Acceptable weld quality can be obtained by selecting the electrode wire recommended for a particular metal. For general welding, the most commonly used wire types are ER4043 and ER5356. ER4043 is commonly used for noncritical work and is adaptable to many aluminum base metals. ER5356 is a stiffer wire than ER4043 and is used when more rigid, higher strength properties are needed (such as working with 6000 series aluminum).
- Because of its higher magnesium content, the ER5356 wire has a faster melt-off rate than ER4043. For this reason, ER5356 needs more wire feed speed for the same diameter electrode. Additionally, although ER4043 is a very popular welding wire, ER356 is stiffer and easier to feed if the application allows it.
- When exposed to air, aluminum forms a hard, oxide layer that completely covers the aluminum surface. The melting point of this aluminum oxide is approximately 3700°F (2040°C), compared to the melting point of aluminum, which is approximately 1200°F (650°C). Because of this difference in melting points, it is necessary to remove the oxide layer prior to welding in order to obtain an acceptable weld. Brush the area to be welded with a stainless steel wire brush (used only on aluminum) to help break up the oxide layer. The welding action will finish removing the oxide layer.
- It is better to start on the high side of the wire speed range and work down, if necessary, to help reduce the risk of melt-back.
- The most important thing to remember when welding aluminum, especially for users used to welding steel, is to use a push, or forehand, welding technique. This provides better cleaning action (oxide removal) and better gas coverage for the molten aluminum.
- To ensure good starts, clip the end of the wire off at an angle to remove the balled end that may have formed during welding. This will help prevent stumbling, cold starts.
- Gas metal arc welding of aluminum progresses at a faster travel rate than for steel. Due to the high thermal conductivity of aluminum, the travel speed will increase as the welding progresses. If travel speed is not increased, there is a chance of melt-through on thin aluminum parts.
- At the end of the weld, make sure the crater is properly filled. If not properly filled, the crater will be a weak point where cracking can occur. The crater can be filled by dwelling in the pool at the end of the weld without switching off the arc.

Beyond welding techniques, Ironworkers focused on the mechanics of the equipment and parts. Instructors stocked one of the booths with a power source and spool gun and left a GTAW torch hanging. Ironworkers had to remove the spool gun, put on the GTAW torch, get an arc on the torch, remove the torch, put the spool gun back on, and strike another arc — Fig. 3. By physically taking the equipment apart and putting it back together, the Ironworkers not only learned how they made mistakes (typically the wrong polarity), but also how to correct them, and set up the equipment on their own.

The equipment training wouldn’t be effective without a full understanding of the properties of the various metals used. Through charts that displayed the various properties of miscellaneous metals, as well as the equipment and settings that should be used to weld on the metals, the Ironworkers became well versed on melting temperatures, cleaning, and shielding gas. While they may have already known that the shielding gas used in steel welding is 75%Ar, 25%CO₂ (commonly called “75/25” or “C25”), they also learned that solid wire stainless steel requires a “trimix” gas consisting of 90%H₂/7.5% Ar/2.5%CO₂. For flux cored stainless, 75/25 will work well because there are oxidizers and additives in the flux that remove contaminative oxygen. However, for using GTAW on stainless steel, only an inert gas, such as argon, is used. For more penetration, helium may be added.

Looking Ahead

Miller donated its time and expertise to the training program so that instructors from the Ironworker facility can eventually develop their own curricula. All instructors from Locals 416/433 attend the classes and expect to take over the teaching at some point. Classes run for four days, from 4 to 8 p.m., with an optional fifth day. And while the class doesn’t generate a weld certification, it does help Ironworkers to prepare for it, and also provides them with the skills to perform a
Fig. 3 — To learn how to set up equipment properly, the Ironworkers' training included tearing down a system set up for GMAW, connecting the proper equipment for GTAW, then successfully striking a GTAW arc.

Fig. 4 — Dwarfed by the incomplete Argentinosaurus sculpture are (from left) Neal Borchert, Miller business development manager, Marilyn Gillespie, executive director of the Las Vegas Natural History Museum, and Fred Baptiste, coordinator for the Ironworkers Apprenticeship and Retraining Center. Note that the Ironworkers will cap off the ends of the tubes, which are shown open here, to protect the sculpture from nesting birds.

number of miscellaneous metal jobs that don't require certification, including the dinosaur project.

To become certified, Ironworkers attend classes at the center, which is accredited with the National Ironworkers Welding Certification Program and overseen by the American Welding Society (AWS). With the help of Ed Abbott of the Ironworkers National Training Fund and Mike McDonald, AWS assessor for the Ironworkers National Welding Certification Program, the school already offers a flux cored stainless steel certification and plans to put aluminum and stainless GTAW certifications in place. Further, the school's four-year apprenticeship program is accredited to the community college. The union pays for tuition and books, and at the end of the program, most apprentices are just a couple of classes short of earning an Associate of Science degree.

Community Support

The training and materials come with some costs attached, of course. Gene Vick, director of the state of California Ironworkers Apprenticeship, and Dick Zampa, president of the Ironworkers District Council, state of California and vicinity, have offered support and allowed for funds to cover some of the equipment and materials involved in the training. Notably, the time the Ironworkers devote to the classroom and building the dinosaur is all voluntary, but the project still requires financing. For a private, nonprofit museum, summoning community resources for the dinosaur has been more challenging.

"We are a young museum in a community not known for its philanthropy," said Marylin Gillespie, executive director. "This is the toughest market in the world for museums because we're in the entertainment capital of the world. We take a backseat to the things that happen on the Strip, but the kids here — and we're a community of 1.5 million people — deserve to have the same kind of resources that kids in other cities do."

Materials haven't come easy either, particularly with a shortage of aluminum in Las Vegas. Aluminum for the project was eventually donated, but many contractors rejected the museum's requests for materials. So although the project had a rough start, the Ironworkers' support and enthusiasm for a community service project is helping the dinosaur finally come together.

"Because we receive no public funds, it is absolutely necessary for this museum to go into the community for support for all of our projects, which is what I've done with the Ironworkers and this dinosaur project," said Gillespie.

The Public Eye

The Argentinosaurus was originally built for a traveling exhibit, and Las Vegas, as the last stop, seemed like a good place to retire at least some of the pieces. Gillespie petitioned the Los Angeles County Natural History Museum and received the head and parts of the body — a good start. She felt the exhibit needed a more definitive, lifelike shape that could be achieved only by completing the sculpture. The dinosaur will be completed in three phases, starting with the fabrication, which will be done primarily at the Ironworkers' training facility. From there, it will be taken to the museum where it will be assembled and finally welded into place.

In the end, the aluminum dinosaur, with a new backbone and tail, will stand outside supported by steel "trees" (see lead photo). Because it must withstand the elements — and birds — the Ironworkers will use their aluminum welding skills to weld and cap off the open ends of the aluminum pipe (representative of bones) to prevent rain damage and birds from nesting in them — Fig. 4. Welding on the dinosaur began about Labor Day of this year, and up to 100 Ironworkers are expected to donate their time (mostly weekends) before the project is finished.

Most of the capping will take place in the Ironworkers' training center using the AC GTAW process because it provides better heat control on the thin aluminum. When metal thickness, joint configuration, and good fit-up on the caps permit, the Ironworkers may use GMAW. It is
important to note that good fit-up is essential with GMAW spray transfer on aluminum to prevent melt-through.

Unlike traditional GTA welding equipment used in the shop, which can weigh 400 lb, the Ironworker's GMAW system also offers portability for field work. Field welding on the dinosaur mostly involves welding structural members 1/2 in. thick, such as the aluminum base plates for the feet. The GMAW equipment includes a 50-A spool gun for positive wire feeding performance, and the inverter power source, which weighs about 80 lb, can be easily hand carried by two workers.

While there is no official date for completion, there will be a high-profile unveiling at the museum, where an official press conference will include the mayor, city councilmen, and one very large dinosaur. "This thing is so huge that you'll be able to see it from down the street," said Baptiste. "This thing is going to stand out. It's not hidden; it's not covered up; it's going to be exposed." For the Ironworkers who only used to weld steel, the exposure will be a huge step forward toward showcasing their new welding skills.

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Vertical Welding Solves a Pressure Vessel Challenge

When it comes to welding challenges, it doesn't get more interesting than trying to create 40-ft-tall stainless steel tanks that can be up to 1.5 in. thick. And that is exactly what Harris Thermal Transfer Products, located in Newberg, Oreg., was faced with.

Originally established as Harris Ice Machine Works in 1888, the company has grown to become a long-time leader in custom engineering and manufacturing relating to industrial process equipment. Currently, it operates out of two main plants: a 6.25-acre site with 32,000 sq ft under one roof and a 1-acre plant in Portland that houses a 34,000-sq-ft work space featuring barge and rail access.

While the company services many industries, including pulp and paper, food processing, petroleum, and others, the work it is doing in the area of nuclear waste storage has required an innovative use of technology.

Superintendent Jeff Ferrell was looking for a way to reduce welding time and establish a standardized weld procedure for work the company was conducting for Bechtel, making pressure vessels. However, these are no ordinary pressure vessels. These monsters are made of stainless steel up to 1.5 in. thick, span 38 ft in diameter, stand four stories tall, and weigh in the neighborhood of 448,000 lb each. These vessels typically take welds 8 to 10 ft long inside and out.

“In the past, we had to lay the vessels on their sides and do everything by hand for vertical welds,” Ferrell said. “While this worked, it wasn’t efficient and, more importantly, it was really difficult to get the type of high-quality, consistent weld that our work with Bechtel demanded.”

Switching from manual welding to a more automated system produces higher-quality vertical welds on vessels for nuclear waste storage

BY JEFF FERRELL AND PHIL FORMENTO

JEFF FERRELL is Superintendent, Harris Thermal Systems, Newberg, Oreg. PHIL FORMENTO, who is based in Portland, Oreg., is Manager, Pacific Northwest for ESAB Welding and Cutting Products (www.esabna.com).
To solve this problem, Ferrell turned to ESAB Welding and Cutting Products. He decided to start using an innovative system ESAB developed and customized for work on the vessels.

Harris Thermal put a Railtrac FW 1000 FlexiWeaver, a rail-mounted, digitally controlled and programmable tractor, in combination with the programmable AristoMig welding system into operation — Fig. 1. This change in the equipment increased productivity by 300%. The brain behind this expansive welding project is the AristoPendant U8, which keeps everything operating with precision.

The tractor, attached by magnets, guides the weld along a track that allows the fabricator to run the welds uphill using flux cored stainless wire inside and out. The fabricator uses the tractor in conjunction with the welding machine to create a fully programmable, “intelligent” welding system.

For example, now that the automated system is in place, a weld on one of the vessels that typically took up to 24 hours to complete can now be done in 4 to 8 hours. By using a remote control, it can easily be stopped and started and can change the welding or cutting speed and direction.

“Now that we have switched from a hand welding process that had lots of room for wormholes and other inconsistencies to an automated system, we produce X-ray-quality welds in no time,” Ferrell said. “The consistency of the welds is unbelievable. This work requires that all the welds look the same, and now they do no matter who is operating the equipment.”

Harris Thermal started with one of these systems and now has six in operation. By putting a more automated system in place, it is now able to have more control over its profit margin, materials used, and employee time. The incorporation of automated systems into its operations is helping to keep the company competitive. As North American welding companies look to compete with overseas companies for work, automated systems can be instrumental in leveling the playing field by increasing productivity and lowering labor costs.

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

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

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

Sincerely,

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

(please type or print in black ink)

DATE____________________ NAME OF CANDIDATE____________________
AWS MEMBER NO.____________________ YEARS OF AWS MEMBERSHIP____________________
HOME ADDRESS____________________
CITY____________________ STATE____ ZIP CODE____ PHONE____________________
PRESENT COMPANY/INSTITUTION AFFILIATION____________________
TITLE/POSITION____________________
BUSINESS ADDRESS____________________
CITY____________________ STATE____ ZIP CODE____ PHONE____________________

ACADEMIC BACKGROUND, AS APPLICABLE:
INSTITUTION____________________
MAJOR & MINOR____________________
DEGREES OR CERTIFICATES/YEAR____________________
LICENSED PROFESSIONAL ENGINEER: YES____ NO____ STATE____________________

SIGNIFICANT WORK EXPERIENCE:
COMPANY/CITY/STATE____________________
POSITION____________________ YEARS____________________
COMPANY/CITY/STATE____________________
POSITION____________________ YEARS____________________

SUMMARIZE MAJOR CONTRIBUTIONS IN THESE POSITIONS:
____________________________________________________________________
____________________________________________________________________

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

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

SUBMITTED BY:
PROPOSER________________________________ Print Name____________________
AWS Member No.____________________
The proposer will serve as the contact if the Selection Committee requires further information. The proposer is encouraged to include a detailed biography of the candidate and letters of recommendation from individuals describing the specific accomplishments of the candidate. Signatures on this nominating form, or supporting letters from each nominator, are required from four AWS members in addition to the proposer. Signatures may be acquired by photocopying the original and transmitting to each nominating member. Once the signatures are secured, the total package should be submitted.

NOMINATING MEMBER:____________________ Print Name____________________
AWS Member No.____________________
NOMINATING MEMBER:____________________ Print Name____________________
AWS Member No.____________________
NOMINATING MEMBER:____________________ Print Name____________________
AWS Member No.____________________
NOMINATING MEMBER:____________________ Print Name____________________
AWS Member No.____________________

SUBMISSION DEADLINE FEBRUARY 1, 2005
American Welding Society

Nomination of AWS Counselor

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

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

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

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

III. NUMBER OF COUNSELORS TO BE SELECTED
Maximum of 10 Counselors selected each year.

Return completed Counselor nomination package to:

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

SUBMISSION DEADLINE: February 1, 2005
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- Torch Positioners
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- Sensors & Accessories
- Wire Feeders & Welding Power Sources

4544 S. Pinemont, Suite 200 • Houston, Texas 77041
phone: 713.462.2118 • fax: 713.462.2503
website: www.cweldtech.com • email: cwt@cweldtech.com

Circle No. 29 on Reader Info-Card
Events

**COMING EVENTS**

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

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

AEM Annual Conference. Nov. 7-9, Ritz-Carlton, Amelia Island, Fla. Sponsored by the Association of Equipment Manufacturers. Details and online registration at www.aem.org/education.


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


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


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Visit our website: www.diamondground.com

Circle No. 34 on Reader Info-Card

NOVEMBER 2004


Educational Opportunities


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

Laser Welding and Processing Seminar. Feb. 15, 2005. A seven-hour seminar discusses Nd:YAG, CO₂, disk, and fiber lasers, including basics, metallurgy, joint design, and safety. Registration is $1050. Contact: Hobart Institute of Welding Technology, www.welding.org; e-mail: hiwt@welding.org; (800) 332-9448, ext. 5300.

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

Robotic Arc Welding Seminar. April 12, 2005. This one-day seminar covers robotic equipment, systems, applications, and economic justifications for implementation. Presented by instructors from Edison Welding Institute. Registration is $1050. Contact: Hobart Institute of Welding Technology, www.welding.org; e-mail: hiwt@welding.org; (800) 332-9448, ext. 5300.

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

T.E.S.T. NDT, Inc., Courses. CWI preparation, ultrasonic, eddy current, radiography, x-ray penetrant, magnetic particle, and visual inspection at Levels 1, 2, and 3. Meet SNT-TC-1A and NAS-410 requirements. On-site training available. T.E.S.T. NDT, Inc., 193 Viking Ave., Brea, CA 92821; (714) 255-1500; FAX (714) 255-1580; e-mail: ndtguru@aol.com; www.testndt.com.
Boiler and Pressure Vessel Inspectors Training Courses and Seminars. Courses and seminars cover such topics as ASME Code Sections I, IV, VIII (Division 1), IX, and B31.1; Writing Welding Procedures; Repairing Pressure Relief Valves; Understanding How Boilers and Pressure Vessels Are Constructed and Inspected; and others. To obtain the 2004 schedule of training courses and seminars offered by the National Board of Boiler and Pressure Vessel Inspectors at its Training and Conference Center in Columbus, Ohio, contact: Richard McGuire, Manager of Training, (614) 888-8320, e-mail: rmcguire@nationalboard.org; www.nationalboard.org.

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

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

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

## Educational Opportunities

### AWS 2004–2005 Schedule

#### CWI/CWE Prep Courses and Exams

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

<table>
<thead>
<tr>
<th>City</th>
<th>Exam Prep Course</th>
<th>CWI/CWE Exam</th>
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</thead>
<tbody>
<tr>
<td>Anchorage, Alaska</td>
<td>Mar. 20–25</td>
<td>Mar. 26</td>
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<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
<td></td>
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<tr>
<td>Atlanta, Ga.</td>
<td>May 15–20</td>
<td>May 21</td>
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<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
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<tr>
<td>Bakersfield, Calif.</td>
<td>Apr. 24–29</td>
<td>Apr. 30</td>
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<td>(API 1104 Clinic also offered)</td>
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<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
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<tr>
<td>Beaumont, Tex.</td>
<td>June 5–10</td>
<td>June 11</td>
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<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
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<tr>
<td>Birmingham, Ala.</td>
<td>Feb. 6–11</td>
<td>Feb. 12</td>
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<tr>
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<td>(API 1104 Clinic also offered)</td>
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<tr>
<td>Birmingham, Ala.</td>
<td>EXAM ONLY</td>
<td>Mar. 28</td>
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<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
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<tr>
<td>Boston, Mass.</td>
<td>EXAM ONLY</td>
<td>May 14</td>
</tr>
<tr>
<td>Columbus, Ohio</td>
<td>Apr. 25–29</td>
<td>Apr. 30</td>
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<td></td>
<td>(NBBPV1)</td>
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<tr>
<td>Corpus Christi, Tex.</td>
<td>EXAM ONLY</td>
<td>Feb. 19</td>
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<tr>
<td>Corpus Christi, Tex.</td>
<td>EXAM ONLY</td>
<td>Apr. 16</td>
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<tr>
<td>Corpus Christi, Tex.</td>
<td>EXAM ONLY</td>
<td>May 21</td>
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<tr>
<td>Dallas, Tex.</td>
<td>Jan. 9–14</td>
<td>Jan. 15</td>
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<tr>
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<td>(API 1104 Clinic also offered)</td>
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<tr>
<td>Dallas, Tex.</td>
<td>Mar. 21–26</td>
<td>No Test</td>
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<tr>
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<td>(API 1104 Clinic also offered)</td>
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<tr>
<td>Denver, Colo.</td>
<td>Feb. 21–26</td>
<td>No Test</td>
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<tr>
<td>Fargo, N.Dak.</td>
<td>June 5–10</td>
<td>June 11</td>
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<td>(API 1104 Clinic also offered)</td>
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<tr>
<td>Fresno, Calif.</td>
<td>Jan. 9–14</td>
<td>Jan. 15</td>
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<td>(API 1104 Clinic also offered)</td>
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<tr>
<td>Hartford, Conn.</td>
<td>Feb. 27–Mar. 4</td>
<td>Mar. 5</td>
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<td>(API 1104 Clinic also offered)</td>
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<tr>
<td>Knox, Tenn.</td>
<td>EXAM ONLY</td>
<td>Jan. 15</td>
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<tr>
<td>Las Vegas, Nev.</td>
<td>Mar. 6–11</td>
<td>Mar. 12</td>
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<td></td>
<td>(API 1104 Clinic also offered)</td>
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<tr>
<td>Long Beach, Calif.</td>
<td>May 22–27</td>
<td>May 28</td>
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<td></td>
<td>(API 1104 Clinic also offered)</td>
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<tr>
<td>Miami, Fla.</td>
<td>EXAM ONLY</td>
<td>Jan. 20</td>
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<td>(API 1104 Clinic also offered)</td>
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<tr>
<td>Miami, Fla.</td>
<td>EXAM ONLY</td>
<td>Feb. 17</td>
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<td>(API 1104 Clinic also offered)</td>
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<tr>
<td>Mobile, Ala.</td>
<td>EXAM ONLY</td>
<td>Mar. 17</td>
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<td>(API 1104 Clinic also offered)</td>
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<tr>
<td>Milwaukee, Wis.</td>
<td>May 1–6</td>
<td>May 7</td>
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<td>(API 1104 Clinic also offered)</td>
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<tr>
<td>Nashville, Tenn.</td>
<td>Mar. 6–13</td>
<td>Mar. 12</td>
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<td>(API 1104 Clinic also offered)</td>
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<tr>
<td>Newark, N.J.</td>
<td>May 1–6</td>
<td>May 7</td>
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<td>(API 1104 Clinic also offered)</td>
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<td></td>
<td>9-Year Recertification Course</td>
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<td>(API 1104 Clinic also offered)</td>
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<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
<td></td>
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<tr>
<td>Perryburg, Ohio</td>
<td>EXAM ONLY</td>
<td>Mar. 12</td>
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<tr>
<td>Pittsburgh, Pa.</td>
<td>May 22–27</td>
<td>May 28</td>
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<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
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<tr>
<td>Pittsburgh, Pa.</td>
<td>June 27–July 2</td>
<td>No Test</td>
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<tr>
<td></td>
<td>9-Year Recertification Course</td>
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<tr>
<td>Sacramento, Calif.</td>
<td>Apr. 4–9</td>
<td>No Test</td>
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<tr>
<td></td>
<td>9-Year Recertification Course</td>
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<tr>
<td>Sacramento, Calif.</td>
<td>June 5–10</td>
<td>June 11</td>
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<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
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<tr>
<td>St. Louis, Mo.</td>
<td>May 15–20</td>
<td>May 21</td>
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<td></td>
<td>(API 1104 Clinic also offered)</td>
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<tr>
<td>San Juan, P.R.</td>
<td>May 22–27</td>
<td>May 28</td>
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<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
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<tr>
<td>San Francisco, Calif.</td>
<td>Mar. 20–25</td>
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<td>(API 1104 Clinic also offered)</td>
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<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
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<tr>
<td>Spokane, Wash.</td>
<td>May 1–6</td>
<td>May 7</td>
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<tr>
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<td>(API 1104 Clinic also offered)</td>
<td></td>
</tr>
<tr>
<td>Waco, Tex.</td>
<td>EXAM ONLY</td>
<td>May 7</td>
</tr>
<tr>
<td>York, Pa.</td>
<td>EXAM ONLY</td>
<td>Mar. 26</td>
</tr>
</tbody>
</table>
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• Qualification for Procedures and Personnel
• Fabrication
• Inspection
• Stud Welding,
• Strengthening and Repair of Existing Structures

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• Details newest allowable stress range formulae
• Latest restrictions on pre-qualified FCAW and GMAW power sources
• Most current tolerances for PJP and CJP groove welds
• Adjusts welder qualification essential variables
• Adjusts pre-qualification figure details
• Latest revision of the pre-qualified base metal list

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

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Circle No. 22 on Reader Info-Card
Semiautomatic Gas Metal Arc Welding

The gas metal arc welding (GMAW) process can be used either semiautomatically, machine welding, or automatically. The basic equipment consists of a welding gun, electrode feed motor and associated gears or drive rolls, welding control, welding power source, regulated supply of shielding gas, source of electrode, and interconnecting cables and hose. Typical semiautomatic components are shown in Fig. 1.

Welding gun and accessories. The welding gun is used to introduce the electrode and shielding gas into the weld zone and to transmit electrical power to the electrode. Water or air cooling and curved or straight styles are available for both heavy and lightweight guns. Air cooling allows operation up to 600 A at a reduced duty cycle; the same current capacity is available for continuous operation with a water-cooled gun. The following are basic accessories of these arc welding guns: contact tube (or tip), shielding nozzle, electrode conduit and liner, gas hose, water hoses, power cable, and control switch.

The contact tube is usually made of copper or a copper alloy. It transmits the welding power to the electrode and directs the electrode toward the workpiece. Since the electrode must feed easily through the tube and also make good electrical contact, the tube's inner surface is very important. The instructions that come with every gun will list the correct size contact tube for each electrode size and material.

Electrode feed motor. The electrode feed motor is usually a direct current type and provides the means for driving the electrode through the gun and to the workpiece. Constant speed units are usually shunt-wound or permanent-magnet types. They are designed basically for use in conjunction with constant voltage (CV) power sources. When a constant current power source is used, a control is provided for variable electrode feed rates during operation. These motors can be series-wound, shunt-wound, or permanent-magnet types. In this case, the feed motor speed control circuit will respond to arc voltage fluctuations to increase or decrease the wire feed speed to maintain a constant arc length.

Welding control. The welding control and electrode feed motor for semiautomatic operation are available in an integrated package — Fig. 1. The welding control's main function is to regulate the speed of the electrode feed motor, usually through the use of an electronic governor in the control. Motor speed is manually adjustable to provide variable wire feed speed.

Shielding gas regulators. A system is required to provide constant shielding gas pressure and flow rate during welding. The regulator reduces the source gas pressure to a constant working pressure regardless of variations at the source. Regulators may be single or dual stage and may have a built-in flowmeter. Dual-stage regulators provide a more constant delivery pressure. The shielding gas source can be a high-pressure cylinder, liquid-filled cylinder, or a bulk liquid system.

Power source. The welding power source delivers electrical power to the electrode and workpiece to produce the arc. For the vast majority of GMAW applications, direct current electrode positive is used; therefore, the positive lead must go to the gun and the negative to the workpiece. The major types of DC power sources are the engine-generator (rotating) and the transformer-rectifier (static) type. Constant current machines were originally preferred for GMAW because they could also be used for shielded metal arc welding. Constant current machines maintain a relatively fixed current level during welding, regardless of variations in arc length. As GMAW applications increased, it was found that constant voltage (CV) machines provided improved operation, particularly with steels. The CV power source, used in conjunction with a constant wire feed speed, maintains a constant voltage during welding. The major reason for selecting CV power is the self-correcting arc length inherent with this type of system.

Figure 2 shows the typical static output and volt-ampere characteristics of both constant current and constant voltage power sources.

Excerpted from AWS C5.6-94R, Recommended Practices for Gas Metal Arc Welding.
Congratulations...

SkillsUSA

...to the following students and their instructors for being selected as the top welding students under 22 years of age to participate in the AWS/SkillsUSA Welding Pre-trial Training and Evaluation program! These students, should they choose to take on the challenge, will be asked to prepare projects over the next 6 months to showcase their skills. The top six participants will then compete in the US Open Weld Trials at the annual AWS Welding Show in Dallas, Texas, for the honor of representing the US at the World Skills Competition.

The US OPEN Weld Trial participants will receive the following awards and prizes: The SkillsUSA representative to the World Skills Competition will receive a $40,000, four-year scholarship through the AWS Foundation and sponsored by Miller Electric Mfg. Co., up to $1,000 in AWS publications, a four-year complimentary AWS membership and AWS Certification, for which he or she qualifies at the trials. Runners-up will receive a $1,000 scholarship for books, tuition or lab fees, a one-year complimentary AWS membership and AWS Certification, for which he or she qualifies at the Trials.

Travel and lodging expenses will be furnished for the US Open Weld Trials winner and the winner's instructor for the trip to Helsinki, Finland to compete in the World Skills Competition. Travel expenses for the US Open Weld Trials competitors are provided for the six finalists from the Welding Pre-Trials.

If these students are in your area WISH THEM LUCK!

ALABAMA

Gadsden State Community College
Student: Mark Lasty
Instructor: David Smith

IOWA

Montachusett Regional Voc-Tech
Student: Daniel Bagley
Instructor: Kevin Carter

KENTUCKY

Wayne County Area Technology Center
Student: Brandon Lester
Instructor: Karl Watson

MICHIGAN

Pike Central High School
Student: Dustin Schmitt
Instructor: Kevin Carter

MINNESOTA

North Dakota State College of Science
Student: Lance Stanfield
Instructor: Joel Johnson

NEBRASKA

Southeast Community College-Milan
Student: David Wagner
Instructor: Jeff Foster

NEVADA

Regional Technical Institute
Student: Cameron Galloway

OKLAHOMA

Oklahoma State University<br>Student: Jesse Roberts
Instructor: Kyle Roberts

SOUTH DAKOTA

Western Dakota Tech Institute
Student: Troy Barry
Instructor: Luke Stimme

TENNESSEE

Tennessee Technology Center
Student: Josh Burgess
Instructor: Joe Lees

UTAH

College of Eastern Utah
Student: Cole Murray
Student: Chase Walker

WISCONSIN

Madison Area Technical College
Student: Michael Froehnich
Instructor: Greg Froehnich

Wyoming

Eastern Wyoming College
Student: Christian Polito
Instructor: Krist McVea

Instructor: Clint Henson

American Welding Society

Founded in 1919 to Advance the Science, Technology and Application of Welding.
Titanium Howitzer Benefits from NJC Welding Technology

The Navy Joining Center (NJC) recently completed a project supporting the M777 howitzer for the Joint Project Management Office (JPMO) at Picatinny Arsenal, N.J., and BAE Systems.

The M777 is a lightweight 155-mm cannon engineered to meet the increased operational needs of the Marine Corps and U.S. Army well into the 21st century.

The M777 is the first 155-mm howitzer in the world designed to weigh less than 9000 lb. It also represents the first large-scale use of titanium for ground-based artillery systems. The M777's supporting base structure is fabricated from a titanium alloy that is 40% lighter than steel and exhibits an excellent strength-to-weight ratio.

The structures that make up the base of the M777 include welded fabrications made from cast and wrought titanium. These material forms present unique welding challenges for both the initial manufacture and in-service field repair.

The welds on the M777 are required to have complete penetration and high quality to ensure the long life of the weapon system. Satisfactory fatigue properties of the welds are one of the major factors that must be achieved to assure the design life of this howitzer. The welding procedures used for the M777 must not only be well controlled, but they also must be highly productive to meet life-cycle cost targets for this system.

The NJC project team improved the productivity of the welding processes used for the M777 and ensured that its welded joints will have satisfactory fatigue life. The project team's activity focused on two primary areas: 1) developing innovative mechanized welding techniques for cast and wrought titanium components and; 2) assuring that the welds meet the requirements for fatigue and strength.

Innovative mechanized welding procedures and tooling were developed that improve productivity, ensure quality, and reduce distortion.

Fabrication of the M777 involves welding several unique joint configurations, including tang and slot joints that improve productivity by permitting the use of simple fixtures and tooling. Special consumable titanium inserts were developed for V-groove, U-groove, and tang and slot joint preparations.

Evaluations by both EWI and BAE revealed that these inserts greatly facilitated the use of mechanized welding for the howitzer assemblies. The mechanized welding procedure developed using these inserts demonstrated these inserts were able to accommodate variable joint fit-up, while producing consistent weld penetrations and head profiles. This development effort required the design of specialized mechanized welding heads for gas tungsten arc welding of tang and slot joints, as well as a custom plasma arc welding head for making the butt joint welds to join circular plates to cast components.

Gas tungsten arc and plasma arc welding procedures were developed and validated by extensive mechanical testing, including fatigue tests, of weld joints in both wrought and cast titanium alloy.

The fatigue data expanded the design rules for as-welded and stress-relieved titanium welds to support the design of the M777. The project measured the effects of structural conditions on the fatigue properties of welds in titanium butt joints, slot welds, and corner welds under a range of test conditions.

The fatigue life was measured for welds as a function of weld discontinuities and postweld heat treatments. These data were not available prior to this project.

The results of this NJC project to improve the producibility of the M777 howitzer have already been successfully implemented. BAE has introduced the mechanized keyhole plasma welding procedures into its manufacturing process for the M777 cradle assembly.

The fatigue design developed during this project will permit welded titanium structures to meet all of the performance requirements for this weapon system.

For further details, contact John Lawmon, principal engineer, Arc Welding & Automation group at EWI. Phone: (614) 688-5054; e-mail: John.Lawmon@ewi.org.
Exhibiting at the AWS Welding Show 2005 is the most cost-effective way to gain broad exposure in a short time. As an AWS exhibitor, you will have the opportunity to meet those buyers who need your products. The AWS Welding Show has more to offer than any other show in the metal-fabricating and construction industries.

Big benefits for exhibitors before, during, and after the Show.

- Advance multi-media ad and direct mail campaign promoting the Show.
- Local newspaper and media coverage.
- Listing in the official Show Program and Buyers' Guide distributed at the Show.
- Use of the AWS Press Room.
- Discounts on freight, car rentals, and room rates, as well as free shuttle buses from AWS-sponsored hotels to the Show.
- On-site staff to assist you during the Show and to help provide a hassle-free exit at the end.
- AWS website, which is used as a year-round tool by manufacturers, distributors and end-users looking for products and services.
- A targeted demographic attendee list will be available from Show management.
- Our marketing staff will be available for consultation on lead follow-up and tracking.

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

Seven exciting Special Pavilions give attendees new reasons to come to the Show:

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- Resistance Welding
- Laser Welding and Cutting
- Nondestructive Testing and Inspection

WELDING SHOW 2005
April 26-28, Dallas, Texas
DALLAS CONVENTION CENTER

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AWS Welding Show 2005
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Dallas Convention Center

Sponsored by the American Welding Society
Circle No. 52 on Reader Info-Card
The Education Committee goes to school

Shown during a recess at the U.S. Army Ordnance Mechanical Maintenance School (OMMS) at Aberdeen Proving Ground, Aberdeen, Md., AWS Education Committee members are (from left) Dennis Klingman, Chris Pollock, Larry Heckendorn, guide Sgt. Brian Corley, Steve Houston, Wyatt Swaim, Mike Harris, Jim Brook, Sean Moran, Ed Abbott, Sue Benton, Cheryl Rigsby, and David Hamilton. The school provides training for Army, Marines, Air Force, Navy, and Coast Guard welders. They train together for certain basic courses, then each military service provides custom training for the specific welding tasks expected in the field. The Committee took advantage of the invitation to study the military's operations August 20 and 21, where they observed the AWS S.E.N.S.E. educational programs integrated into the training curricula.

American societies to help rebuild Iraq

The American Welding Society, along with a number of other U.S. standards-developing organizations, has donated its technical products to ensure engineering excellence in the rebuilding of the ravaged infrastructures of Iraq. The AWS standards will be implemented to verify that the welding procedures employed to rebuild the Iraqi infrastructures will conform to the technically sound and time-proven standards used in the U.S. and other countries worldwide.

The standards requested for this project are A2.4, Standard Symbols for Welding, Brazing and Nondestructive Examination; A3.0, Standard Welding Terms and Definitions; D1.1/D1.1M:2004, Structural Welding Code — Steel; D1.3, Structural Welding Code — Sheet Steel; D1.4, Structural Welding Code — Reinforcing Steel; D1.5M/D1.5:2002, Bridge Welding Code, All Metric; D1.6:1999, Structural Welding — Code Stainless Steel.

"AWS is proud to contribute to the rebuilding efforts in Iraq," said Andrew Davis, managing director, Technical Services Department. "As one of the premier standards-developing organizations in the world, the American Welding Society is pleased to extend its quality products to the citizens of Iraq."

The AWS involvement in the rebuilding effort was facilitated by the U.S. Department of Commerce and the Iraq Investment Reconstruction Task Force, Washington, D.C., in cooperation with the Iraq Ministry of Construction and Housing in Baghdad.

Other American societies volunteering their products to the rebuilding of Iraq are the American Society for Testing and Materials (ASTM International), American Concrete Institute, American Society of Mechanical Engineers (ASME International), Federal Highway Administration, International Association of Plumbing and Mechanical Officials, International Code Council, National Fire Protection Association, American Society of Heating, Refrigeration, and Air-Conditioning Engineers, and American Association of State Highway and Transportation Officials.
2004 high achievers recognized

The Board of Directors has established the Student Chapter Member Award, with the purpose of recognizing AWS Student Members whose Student Chapter activities have produced outstanding school, community, or industry achievements. This award provides an excellent opportunity for Student Chapter Advisors, Section Officers, and District Directors to recognize outstanding students affiliated with AWS Student Chapters, as well as to enhance the image of welding within their communities.

The recipients of this award are
Don Gibbons and Jeff Yannette
Both are members of the Somerset County Vo-Tech AWS Student Chapter, New Jersey Section, District 2.

To qualify for this certificate award, one must be an AWS Student Member affiliated with an AWS Student Chapter. For criteria and nomination forms, visit www.aws.org/sections/awards/student_chapter.pdf or call (800) 443-9353 ext. 269, for more information.

2004 District/Section Awards

District Meritorious Award
District # — Member — Section
1. Jim Shore, Boston
2. Vince Murray, New Jersey
3. Ray O'Leary, Long Island
4. Ted Alberts, Southwest Virginia
5. Jim Hollowell, N.E. Carolina
6. Lee Clemens, Florida West Coast
7. Lou Vitucci, Cincinnati
8. Carl Smith, Tri-State
9. R. Paul Miller, N.E. Mississippi
10. Charles Lewis, Jr., Acadiana
11. Dave Poydock, Baton Rouge
12. Teresa Hart, Mobile
14. Richard West, N.W. Ohio
15. Larry Blake, N.W. Ohio
16. Ronald Grenda, Detroit
17. Bill Butler, Fox Valley
18. Roger Edge, Milwaukee
20. Walt Stein, Chicago
21. Mike Anderson, Indiana
22. Todd Fradd, Tulsa
23. Andy Divin, North Texas
24. Dennis Eck, Houston
25. James Bobo, Lake Charles
26. Eric Waterfield, British Columbia
27. Phil Fuerschbach, Albuquerque
28. Dale Flood, Sacramento
29. Mike Urioste, San Francisco

Section Meritorious Awards
2. Kevin Klein, Philadelphia
3. Steven Dagnall, New Jersey
4. Gilbert Barrientos, New Jersey
5. Alex Dushere, Long Island
6. Thomas Colasanto, New York
7. Ed Wyatt, Southwest Virginia
8. Greg McGuay, Southwest Virginia
9. Gary Stobaugh, N.E. Carolina
10. Paul Hebert, Tidewater
11. Ron Davis, Tidewater
12. Greg Pike, Tidewater
13. Paul Beck, Tidewater
14. Cyril Pritchard, Tri-State
15. Uwe Aseheimer, Cincinnati
16. Chris Anderson, Dayton
17. Charles Slayton, N.E. Mississippi
18. Steve W. Latham, N.E. Mississippi
19. Ricky E. Collier, N.E. Mississippi
20. Robbin A. Stull, N.E. Mississippi
22. Bob G. Fellers, W. N. Carolina
23. Bernard Eich, W. N. Carolina
24. John Folk, Nashville
25. Robert W. O'Neal, Nashville
26. James E. Kirby, Jr., Nashville
27. Ronald C. Abner, Nashville
28. Christopher S. Shipe, Nashville
29. Phillip M. Cranford, West Tennessee
30. Rodney N. Russell, West Tennessee
31. Elizabeth Thomas, West Tennessee
32. Jimmy D. Kee, West Tennessee
33. Robert J. Pepper, West Tennessee
34. Joseph T. Smith, Greater Huntsville
35. David Paul Hamilton, Chattanooga
36. Don J. Russell, Jr., Chattanooga
37. Gary T. Yeager, Chattanooga
38. Ronnie W. Smith, Chattanooga
40. Timmy H. Singleton, N.E. Tennessee
41. Mark Wayne Richey, N.E. Tennessee
42. Charles E. Bloomer, Holston Valley
43. Joshua Sanders, Mobile
44. Luther Davis, New Orleans
45. Chris Tierroano, New Orleans
46. Marcie Jacquet, Acadiana
47. Anthony Blankeney, Baton Rouge
48. Jim Casey, Birmingham
49. Lee Smith, N.W. Ohio
50. Victor Hunter, Blackhawk
51. Larry Clevenger, Blackhawk
52. Deborah Woodruff, J.A.K.
53. Mark Kerley, Peoria
54. Bernard Pietrowksi, Illinois Valley
55. Mike Gibson, Louisville
56. Lisa Osborne, Louisville
57. Leroy Schaaf, St. Louis
58. Steve Mechtroft, Indiana
59. Tim Starkey, Indiana
60. Gary Dugger, Indiana
61. Bob Hl asc, Central Arkansas
62. Joe Dawson, Oklahoma City
63. William Drake, Ozark
64. Bridget Emery, Corpus Christi
65. Asif Latif, Houston
66. Sudhanshu Ogale, Sabine
67. Clarence Hall, San Antonio
68. Eric Waterfield, British Columbia
69. Paul Tremlay, E. Idaho/Montana
70. Jim Corbin, Colorado
71. Len Leonard, Albuquerque
72. Mike Thomas, Albuquerque
73. Shane Kynaston, Utah
74. Richard Samanich, Nevada
75. Alex Gutierrez, Santa Clara Valley
76. Jeff Gilman, Santa Clara Valley
77. Fred Mattner, Fresno

District Educator Award
1. Warren Ballard, Boston
2. Joe Kass, Long Island
3. Chris Overfelt, Southwest Virginia
4. Edward Dent, Charlotte
5. Ray Lafferriere, Florida West Coast
6. Steve Brin, Florida West Coast
7. Tom Bryant, Syracuse
8. Tina Buchanan, Mid-Ohio Valley
9. Jimmy D. Kee, West Tennessee
10. James Sullivan, Mobile
11. Hugh Hughes, Mahoning Valley
12. Paul Boes, Central Michigan
13. Charles Hunt, Northern Michigan
14. Mike Spangler, J.A.K.
15. Mike Merriman, Blackhawk
16. Norman King, Blackhawk
17. Craig Tielchel, Chicago
18. Kevin Corgan, St. Louis
19. Ed Wyatt, Indiana
20. John Husfeld, Houston
21. Jerry Campbell, Sabine
22. Emilio Gonzalez, S. Colorado
23. Mark Baugh, Utah
24. Michael Rado, Sacramento Valley
25. Richard Martella, Sacramento Valley

Section Educator Award
1. Robert Curry, Boston
2. Kenneth Messmer, Long Island
3. Herbert Browne, New Jersey
4. Gerald Hubbard, Carolina
5. Randy Owens, Carolina
6. Michael Bryant, S.W. Virginia
7. Bobby Perkins, N.E. Carolina
8. John Cavenaugh, N.E. Virginia
9. Doug Dupree, Tidewater
10. Ricky Collier, N.E. Mississippi
11. Gary Gammill, N.E. Mississippi
12. Doug Rosser, Chattanooga
13. Dale Kite, Mobile
14. Tim Turner, Birmingham
15. Huck Hughes, Mahoning Valley
17. Dave Cook, Cleveland
19. Kerwin Brown, Peoria
20. Art Suprenant, J.A.K.
21. Joe Villareal, Illinois Valley
22. Art Suprenant, J.A.K.
23. Tim Kimrey, Blackhawk
24. Mark Anderson, St. Louis
25. Ross Kimbrell, St. Louis
26. Dennis Mueller, St. Louis
22. Sam C. Flores, Santa Clara Valley
22. Kerry Shatell, Sacramento Valley
21. Nanette Samanich, Nevada
20. Galen Altman, Colorado
20. Farren Elwood, Colorado
20. Bruce Madigan, E. Idaho/Montana
20. Stephen Liu, Colorado
20. Ruben Vinton, Colorado
20. Mike Tryon, Utah
20. Jeff Tanaguchi, Utah
19. Jay Dwight, Puget Sound
18. Randy Howell, Sabine
17. Kirk Jordan, North Texas
17. Mike Needham, North Texas
14. Brenda Cottrell, Louisville
14. Richard Kemlase, St. Louis
13. Ron Ashelford, Blackhawk
13. Norman King, Blackhawk
18. Andy Davis, Lake Charles
17. Kenny McCoy, Ozark
13. Wayne Abarca, Illinois Valley
12. Scot Forbes, Fox Valley
10. Mike Medal, Stark Central
9. Larry Boyette, Baton Rouge
9. Charles S. Ary, Nashville
9. Bobby Perkins, N.E. Carolina
9. Sam Glass, Carolina
8. Matt Casanova, San Antonio
8. Richard "Woody" Cook, Utah
8. Ron Richter, Houston
8. Russell Newell, Syracuse
8. Steven L. Leach, N.E. Mississippi
6. Carl Matricardi, Atlanta
5. Christopher Eure, South Carolina
4. Sam Glass, Carolina
4. Bobby Perkins, N.E. Carolina
4. Ron Ashelford, Blackhawk
4. Richard Kemlase, St. Louis
4. Brenda Gottrell, Louisville
4. Mike McCloud, Nashville, TN
4. Judy Powell, Triangle
4. Gary Dugger, Sangamon Valley
4. David King, Tidewater
4. Corey Robbins, Tidewater
4. Mike Gillinwaters, Tidewater
4. Jack Wright, Tidewater
4. Tom Swankler, Tidewater

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<th>District CWI of the Year Award</th>
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<td>1. Robert Curry, Boston</td>
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<td>2. Robert Loven, New Jersey</td>
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<td>3. Judy Powell, Triangle</td>
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<td>4. Bobby Perkins, N.E. Carolina</td>
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<td>6. Randy Woolintgon, N.E. Miss.</td>
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<td>16. Greg Verkhan, Chicago</td>
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<td>17. Carl Schmitz, St. Louis</td>
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<td>18. Mike Johnson, Indiana</td>
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<td>19. Joseph M. Vincet, Kansas City</td>
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<td>20. John Marx, Oklahoma City</td>
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<tr>
<th>Membership Counts</th>
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<tbody>
<tr>
<td>Sustaining companies .................. 417</td>
</tr>
<tr>
<td>Supporting companies* ................ 207</td>
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<tr>
<td>Educational institutions .............. 318</td>
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<tr>
<td>Affiliate companies .................. 239</td>
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<tr>
<td>Welding distributor companies .......... 53</td>
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<tr>
<td>Total corporate members .............. 1,234</td>
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<tr>
<td>Individual members .................. 43,174</td>
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<td>Student + transitional members ........ 4,213</td>
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<td>Total members ....................... 47,387</td>
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<tr>
<th>New AWS Supporters</th>
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<tr>
<td>Affiliate Companies</td>
</tr>
<tr>
<td>Abex Welding &amp; Mfg. Corp.</td>
</tr>
<tr>
<td>10313 Malcolm Cir., Ste. B</td>
</tr>
<tr>
<td>Cokesville, MD 21030</td>
</tr>
<tr>
<td>Aero Enterprises, Inc.</td>
</tr>
<tr>
<td>431 Duquette Rd.</td>
</tr>
<tr>
<td>West Chazy, NY 12992</td>
</tr>
<tr>
<td>Atlas Metal Parts &amp; Fabricating, Inc.</td>
</tr>
<tr>
<td>1342 Pearl St.</td>
</tr>
<tr>
<td>Waukesha, WI 53186</td>
</tr>
<tr>
<td>AZ Industries</td>
</tr>
<tr>
<td>Blvd. Harold R. Pape #2002</td>
</tr>
<tr>
<td>P.O. Box 428</td>
</tr>
<tr>
<td>Monclova Coah. 25730</td>
</tr>
<tr>
<td>Mexico</td>
</tr>
<tr>
<td>C&amp;C Welding Service, Inc.</td>
</tr>
<tr>
<td>1338 W. Main St.</td>
</tr>
<tr>
<td>Waynesboro, VA 22980</td>
</tr>
<tr>
<td>Flexible Flyer Acquisition Corp.</td>
</tr>
<tr>
<td>100 Tubb Ave.</td>
</tr>
<tr>
<td>West Point, MS 39339</td>
</tr>
<tr>
<td>Liberty Steel, Inc.</td>
</tr>
<tr>
<td>2400 Arrowhead Dr.</td>
</tr>
<tr>
<td>Carson City, NV 89706</td>
</tr>
<tr>
<td>Distributor Member</td>
</tr>
<tr>
<td>Air/Arc Supply, Inc.</td>
</tr>
<tr>
<td>617 Houston St.</td>
</tr>
<tr>
<td>West Sacramento, CA 95691</td>
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<tr>
<td>Educational Institutions</td>
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<tr>
<td>Centro Tecnologico de</td>
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<td>Soldaduras ELSA</td>
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<tr>
<td>Jr. Jorge Salazar Araos #195</td>
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<tr>
<td>Lima 13, Peru</td>
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<td>FUNDAHTEC</td>
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<tr>
<td>Calle Rosa Fragante #10</td>
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<tr>
<td>Urbanizacion el Rosal</td>
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<td>Santo Domingo Este</td>
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<td>Dominican Republic</td>
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<tr>
<th>District Private Sector Educator Award</th>
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<tr>
<td>4. Dave Schaefer, Carolina</td>
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<td>4. Gary Roy, Tidewater</td>
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<td>6. Russell Newell, Syracuse</td>
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<td>8. Steven L. Leach, N.E. Mississippi</td>
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<td>9. Danny Venable, Baton Rouge</td>
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<td>9. C. Lavon Mills, Mobile</td>
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<td>11. Daniel Hayes, Sr., Louisville</td>
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<td>12. J. Jones, North Texas</td>
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<td>12. Ron Richter, Houston</td>
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<td>13. Kermit Babaz, Lake Charles</td>
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<td>14. Patrick Mulville, S. Colorado</td>
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<td>15. Louis DeFreitas, Santa Clara Valley</td>
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<td>16. Tim Youngberg, Fresno</td>
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<th>Section Private Sector Educator Award</th>
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<tr>
<td>4. Judy Powell, Triangle</td>
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<td>4. Mike Robinson, Tidewater</td>
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<td>4. Jack Wright, Tidewater</td>
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<td>4. Tom Swankler, Tidewater</td>
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Who will win 'Image of Welding' awards?

You probably know a candidate worthy of winning an Image of Welding award. It is easy to enter their name, but you must enter before January 26 to be considered for the 2005 presentations. The Image of Welding Award competition, sponsored by the AWS Welding Equipment Manufacturers Committee (WEMCO), recognizes individuals, companies, and organizations in seven categories for their activities enhancing the image of welding.

1. Individual Image Award
A person who shows exemplary dedication to the promotion of welding.

2. AWS Section Image Award
A Section that has excelled in projects to promote the image of welding in its community.

3. Large Business Image Award
A business with more than 200 employees that has funded and/or conducted projects aimed at promoting the image of welding locally or nationally.

4. Small Business Image Award
A business with fewer than 200 employees that has funded and/or conducted projects aimed at promoting the image of welding locally or nationally.

5. Distributor Image Award
A distributor of welding-related products that has funded or assisted in the promotion of the image of welding nationally or locally.

6. Educator Image Award
An educator who has demonstrated an exemplary commitment to furthering the image of welding.

7. Educational Facility Image Award
An educational facility that has demonstrated an exemplary commitment to furthering the image of welding.

To enter your nominees, just e-mail a description of their qualifications to Amy Nathan nathan@aws.org, or call 800-443-9353, ext.308.

The winners will be cited at the Image of Welding awards-presentation program to be held Thursday, April 28, 2005, at the AWS Welding Show in Dallas, Tex.

AWS and WEMCO to sponsor overseas pavilions

The Welding Equipment Manufacturers Committee (WEMCO) and AWS will sponsor welding pavilions at the Beijing- Essen Welding and Cutting Show (Beijing, China, Nov. 10-13); Expo Manufactura (Monterrey, Mexico, Feb. 22-24, 2005); and Schweissen & Schneiden (Essen, Germany, Sept. 12-17, 2005).

These expos are the largest and most influential metalworking exhibitions in their respective countries.

Jeff Weber, AWS associate executive director, said, “The decision to sponsor these welding pavilions is our response to the growing international market, and the need within the industry to expand our global marketplace. We are pleased to have this opportunity to be a part of these prestigious metalworking and manufacturing exhibitions.”

The AWS/WEMCO Welding pavilions will feature advanced technologies and processes that are in great demand in the international marketplaces.

Note: There is still time for your company to display at these welding pavilions. Contact Mary Ellen Mills at memills@aws.org, or call (800) 443-9353, ext.444.

member-get-a-member campaign

Listed below are the people participating in the 2004-05 Member-Get-A-Member Campaign. For campaign rules and a prize list, please see page 69 of this Welding Journal.

If you have any questions regarding your member proposer points, call the Membership Department at (800) 443-9353, ext. 480.

Winner’s Circle
(AWS Members who have sponsored 20 or more new Individual Members between June 1, 2004, and May 31, 2005.)

M. Karagoulis, Detroit — 43

President’s Circle
(AWS Members who have sponsored 20 or more new Individual Members, per year, since June 1, 1999.)

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

() Denotes the number of times the member has achieved Winner’s Circle status.

Status is awarded at the close of each membership campaign year.

President’s Guild
(AWS Members sponsoring 20 or more new Individual Members between June 1, 2004, and May 31, 2005.)

J. Krall, Dayton — 2
P. Layola, International — 2
S. Salamon, New Jersey — 2
G. Schroeter, Puget Sound — 2
T. Shirk, Tidewater — 2

Student Sponsors
(AWS Members sponsoring 3 or more new AWS Student Members between June 1, 2004, and May 31, 2005.)

J. Compton, San Fernando Valley — 2
J. Campbell, Racine-Kenosha — 2
J. Cantlin, Southern Colorado — 2
J. Martin, Southern Colorado — 2
J. Compton, San Fernando Valley — 2
E. Ezell, Mobile — 2
G. Fudala, Philadelphia — 2
G. Gardner, St. Louis — 2
P. Harper, Baton Rouge — 2
J. Jaeger, Kansas — 2
D. Keesner, Long Beach/Orange Cty — 2

J. Krall, Dayton — 2
P. Layola, International — 2
S. Salamon, New Jersey — 2
G. Schroeter, Puget Sound — 2
T. Shirk, Tidewater — 2

Student Sponsors
(AWS Members sponsoring 3 or more new AWS Student Members between June 1, 2004, and May 31, 2005.)

J. Krall, Dayton — 2
P. Layola, International — 2
S. Salamon, New Jersey — 2
G. Schroeter, Puget Sound — 2
T. Shirk, Tidewater — 2

Student Sponsors
(AWS Members sponsoring 3 or more new AWS Student Members between June 1, 2004, and May 31, 2005.)

J. Krall, Dayton — 2
P. Layola, International — 2
S. Salamon, New Jersey — 2
G. Schroeter, Puget Sound — 2
T. Shirk, Tidewater — 2

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S. Salamon, New Jersey — 2
G. Schroeter, Puget Sound — 2
T. Shirk, Tidewater — 2

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S. Salamon, New Jersey — 2
G. Schroeter, Puget Sound — 2
T. Shirk, Tidewater — 2

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S. Salamon, New Jersey — 2
G. Schroeter, Puget Sound — 2
T. Shirk, Tidewater — 2

Student Sponsors
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S. Salamon, New Jersey — 2
G. Schroeter, Puget Sound — 2
T. Shirk, Tidewater — 2

Student Sponsors
(AWS Members sponsoring 3 or more new AWS Student Members between June 1, 2004, and May 31, 2005.)

J. Krall, Dayton — 2
P. Layola, International — 2
S. Salamon, New Jersey — 2
G. Schroeter, Puget Sound — 2
T. Shirk, Tidewater — 2

Student Sponsors
(AWS Members sponsoring 3 or more new AWS Student Members between June 1, 2004, and May 31, 2005.)
DISTRICT 1
Director: Russ Norris
Phone: (603) 433-0855
MAINE
SEPTEMBER 14
Activity: The Section held a planning session to finalize details for the next SkillsUSA competitions. Chair Jeff Fields of Bath Iron Works led the program. Dave Watson of Lincoln Electric presented Fields with the Chairman's Appreciation Award. District 1 Director Russ Norris spoke on the activities of other Sections in District 1. The meeting was held at Village Cafe in Portland.

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

DISTRICT 3
Director: Alan J. Badeaux, Sr.
Phone: (301) 934-9061
YORK CENTRAL PA.
AUGUST 26
Activity: The Section held an executive board meeting at Starlight Diner in York, Pa. The agenda included setting the calendar of events for the coming year.

DISTRICT 4
Director: Ted Alberts
Phone: (540) 674-3600, ext. 4314
CAROLINA
MARCH 30
Activity: Carolina Section members served as judges in the SkillsUSA contest held at Guilford Technical Community College, Greensboro, N.C. The judges included Walt Sperko, David Schaffer, Mike McCraw, Sam Glass, Secretary Gerald Hubbard, and Chair Randy Owens.

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

SOUTH CAROLINA
SEPTEMBER 15
Speakers: Marvin Tallent, Jr., QA manager, Palmetto Bridge Constructors; and Justin Davis, inspector, S.C. DOT.

Topic: Construction of the new Cooper River Bridge in Charleston, S.C.
Activity: Section Chair Gale Mole hosted the meeting, attended by 21 members.
Pictured at the Detroit program are (from left) John Bohr, Jeff Hardesty, Raymond Angus, Jason Reinhold, Kirk Webb, Troy Genow, Jeremy Olszowy, David Jedele, James Cuhel, Kelly Feenstra, Matthew Cox, Ken Kuk, Jeff Spustack, Martin Keasel, and Rod Bereznicki.

Shown at the Detroit Section's scholarship presentation program are (from left) Mark Rotary, Shawn Jedniak, Lance Kujawski, Richard Neifert, Justin Ferguson, David Dowd, and Martin Keasel, Section chair.

Ken Kuk (left) accepts a speaker gift from Ray Roberts, Detroit Section vice chair, in September.

DISTRICT 9
Director: John Bruskotter
Phone: (504) 394-0812

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

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

DETROIT
SEPTEMBER
Speaker: Ken Kuk, professor
Affiliation: Ferris State University
Activity: The Section hosted its annual Students Night program for 54 attendees. The Section awarded $20,000 in scholarships to 19 college students from Ferris State University and Michigan Technological University, which were presented by Scholarship Chairman Martin Keasel, and Assistant Chair Mark Rotary. In addition, the top 12 finishers in the 31st High School Welding Contest held May 1 received $5300 in vocational money and savings bonds, as well as a free class from Schoolcraft College. The participating high schools were Flat Rock High, Utica High School, William D. Ford Vocational Center, Woodhaven High School, Oakland Vo-Tech Center, Golightly Vocational Center, and St. Clair Vocational Center. Students participating in the High School Welding Contest took home more than $13,800 in gifts and prizes.

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

DISTRICT 13
Director: Jesse L. Hunter
Phone: (309) 359-8358

PEORIA
APRIL 22-24
Activity: The Section hosted the state SkillsUSA/VICA events in Springfield, Ill. The welding contest was held April 23. Robert Salaz, an active member of the Peoria Section's Student Chapter, earned second-place honors in the welding contest.

SEPTEMBER 15
Activity: The Peoria Section toured the
The 2004-2005 AWS Member-Get-A-Member Campaign*

RECRUIT NEW MEMBERS... WIN GREAT PRIZES

A simple way to give back to your profession, strengthen AWS and win great prizes is by participating in the 2004-2005 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. Plus, you become part of an exclusive group of AWS Members who get involved. 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. Who better than you to encourage someone to join AWS?

AWS MEMBER BENEFITS CHECKLIST:

- Annual subscription to the Welding Journal.
- A 25% discount on hundreds of first-rate AWS technical publications and 140+ industry codes.
- Deep discounts on 120+ technical training events every year.
- Access to widely recognized AWS Certification programs.
- New Members can save nearly 90% off an AWS publication. Choose from four of our most popular titles (see reverse).
- AWS Membership Certificate and Card.
- Networking opportunities through local Section meetings, the AWS Welding Show and an online bulletin board on the AWS website at <www.aws.org>.
- Members'-only discounts on auto insurance, car rentals, credit cards and more.
- Connection to career opportunities through AWS JobFind - at www.awsjobfind.com
- The American Welder section of the WJ geared toward front-line welders.
- And much more!

GET INVOLVED TODAY, AND WIN!

PRIZE CATEGORIES

President's Honor Roll:
Recruit 1-5 new Individual Members and receive a welding ball cap.

President's Club:
Recruit 6-10 new Individual Members and receive an American Welder™ polo shirt.

President's Roundtable:
Recruit 11-19 new Individual Members and receive an American Welder™ polo shirt, American Welder™ T-shirt and a welding ball cap.

President's Guild:
Recruit 20 or more new Individual Members and receive an American Welder™ watch, 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 the 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 2005).

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 2006 AWS Welding Show, and recognition at the AWS Awards Luncheon at the AWS Welding Show.

Student Sponsor Prize:
AWS Members who sponsor two or more Student Members will receive a welding ball cap.

The AWS Member who sponsors the most Student Members will receive a free, one-year AWS Membership and an American Welder™ polo shirt.

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 2004, as well as in February and June 2005.

Prizes Include:
- American Welder™ T-shirt
- one-page, black/white ad in the Welding Journal
- Complimentary AWS Membership renewal
- American Welder™ polo shirt
- American Welder™ baseball cap

SUPER SECTION CHALLENGE

The AWS Section in each District that achieves the highest net percentage increase in new Individual Members before the June 2005 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.

American Welding Society
550 N. W. LeJeune Rd. • Miami, FL 33126
Visit our website http://www.aws.org

*The 2004-2005 MGM Campaign runs from June 1, 2004 to May 31, 2005. Prizes are awarded at the close of the campaign.
The Kansas City Section members and guests are shown during their tour of the Kansas Speedway in September.

CNH Manufacturing facility in Goodfield, Ill. Attendees included the students from the Illinois School of Welding, East Peoria High School, and Illinois Central College. The tour guides were Bob Anderson and Mark Kerley who displayed the company's welding and fabricating departments and the painting and assembly areas.

The Section announced plans to feature a blacksmith demonstration at its October 20 meeting.

DISTRICT 14

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

DISTRICT 15

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

DISTRICT 16

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

KANSAS CITY

SEPTEMBER 9
Speaker: Robert Simmons
Affiliation: The Lincoln Electric Co.
Topic: GMA and GTA welding of race cars
Activity: The program was held at the Lincoln Electric Garage at Kansas Speedway. Following the talk, the 53 attendees toured the speedway's facilities.

NEBRASKA

SEPTEMBER 4
Speaker: Rob Luckey
Topic: Accidents in the workplace and OSHA regulations

DISTRICT 17

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

EAST TEXAS

SEPTEMBER 16
Speaker: Charles Blalack
Affiliation: Kilgore College, instructor
Topic: OSHA regulations
Activity: The program was held at Kilgore College in Kilgore, Tex.
The Houston Section board members are shown with Past President Ernest Levert (fourth from the right) during their planning meeting in September.

Awardees shown at the Houston program are (seated from left) Kathy Garcia, Julie Theiss, Melba Beaulieu, and Chau Hoang; (standing, from left) Asif Latif, John Husfeld, Jerry Koza, Fred Schweighardt, Ron Richter, Ron Theiss, Larry Smith, District 18 Director John Mendoza, and Houston Section Chair Dennis Eck.

Melba Beaulieu accepts her Private Sector Instructor Award from District 18 Director John Mendoza at the Houston Section program in September.

Ron Theiss (left) accepts the proclamation naming a new Houston Section Scholarship fund in his name from Chairman Dennis Eck in September.

OZARK
SEPTEMBER 16
Speaker: Steve Keiffer
Affiliation: Walter Surface Technologies, district manager
Topic: Testing abrasives
Activity: Jim Bridwell was cited for his outstanding service as Section Chair 2003-2004. The program was held at Western Sizzlin in Springfield, Mo.

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

HOUSTON
SEPTEMBER 15
Activity: The Houston Section board met with AWS Past President Ernest Levert, Sr., in Houston, Tex. Chairman Dennis Eck honored Ron Theiss by establishing a new Section-sponsored scholarship fund in his name.

District 18 Director John Mendoza presented numerous awards. Julie Theiss and Larry Smith received District Director Awards. Kathy Garcia, Jerry Koza, Fred Schweighardt, and Asif Latif were named to receive Section meritorious Awards.

Chairman Dennis Eck received the District Meritorious Award. Melba Beaulieu received the Section Level Private Sector Instructor Award, and Ron Richter accepted the District Level Private Sector Instructor Award. The District Educator Award was earned by John Husfeld, and the CWI of the Year Award presented to Chau Hoang.

DISTRIBUTION 18
SEPTEMBER 14
Speaker: Mike Grendel
Affiliation: Midco Sling of San Antonio
Topic: Rigging safety

SAN ANTONIO
SEPTEMBER 16, 17
Activity: The Section hosted the AWS C3 Brazing and Soldering Committee meeting in San Antonio.
Members of the AWS C3 Brazing and Soldering Committee pose during their business meeting in San Antonio.

Sacramento Valley Section members are shown at the September program.

visit jobfind

You have free access to the job listings posted on the AWS Jobfind Web site. You can post your public or confidential résumé in a searchable database, then apply directly online for jobs posted by the employers. You may edit your résumé at any time. Check out Jobfind first; it's online at www.aws.org/jobfind.

Employers can post, edit, and manage their job listings easily, have access to a résumé database of a wide range of qualified people, look for candidates who match your employment needs for full- or part-time work, and use either a 30-day or unlimited monthly postings at reasonable cost.

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

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

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

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

SACRAMENTO VALLEY
SEPT 15
Speaker: Kevin Korabik, technical sales representative
Affiliation: The Lincoln Electric Co.
Topic: Lincoln's "Next Weld" technology
Activity: The program was held at Luau Gardens Restaurant in Sacramento, Calif.
Errata found in five published standards

AWS A5.1/A5.1M:2004, Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding
Page 2, Table 1, in column titled "Welding Position" change "H-fillet" to "H" for the following electrode classifications:
- E6010/E4310
- E6011/E4311
- E6012/E4312
- E6013/E4313
- E6018/E4318
- E6019/E4319
- E7014/E4914
- E7015/E4915
- E7016/E4916
- E7018M/E4918M
- E7048/E4948

Page 2, Table 1, Note a, first line, add "H" after "F" at the beginning of the line; add "H = Horizontal," after "F = Flat," and change "H-fillets = Horizontal fillet" to "H-fillet = Horizontal fillet" Page 12, Fig. 5, Detail (B) JOINT PREPARATION, for the included angle, change "50°" to "60°"

AWS A5.8M/A5.8:2004, Specification for Filler Metals for Brazing and Braze Welding
Page 6. In Table 4, titled "Chemical Composition Requirements for Copper, Copper-Zinc, and Copper-Phosphorous Filler Metals," change the UNS number for BCuP-9 to C55385.

AWS B2.1-8-005:2002, Standard Welding Procedure Specification (SWPS) for Gas Metal Arc Welding (Short Circuiting Transfer Mode) of Austenitic Stainless Steel (M-8, P-8, or S-8), 18 through 10 Gauge, in the As-Welded Condition, with or without Boring
Page 3, Electrical Characteristics Table, under "Volts" column heading, change all entries as follows:
- 70-90 to 16-19
- 76-94 to 16-19
- 82-99 to 16-19
- 88-103 to 16-19
- 94-108 to 17-20
- 100-112 to 17-20
- 106-117 to 17-20
- 113-121 to 17-20
- 120-125 to 17-20

AWS D1.2/D1.2M:2003, Structural Welding Code -- Aluminum
Page iii, Personnel -- Add "H. H. Campbell...Bay Limited" to list of committee members.
Page 14, Section 3.11.2 - Incorrect reference to 5.14.5, 5.14.6, and 5.14.7. Change to read 5.15.1, 5.15.2, and 5.15.3.

ISO standards for public review

Copies of the following Draft International Standards are available for review and comment through your national standards body, which in the United States is ANSI, 25 West 43rd Street, Fourth Floor, New York, NY 10036; telephone (212) 642-4900. Any comments regarding ISO documents should be sent to your national standards body.

In the United States, if you wish to participate in the development of International Standards for welding, contact Andrew Davis at AWS, 550 N.W. LeJeune Rd., Miami, FL 33126; telephone (305) 443-9353 ext. 466, e-mail: adavis@aws.org. Otherwise, contact your national standards body.

ISO/DIS 15011-4, Health and safety in welding and allied processes -- Laboratory method for sampling fume and gases -- Part 4: Fume data sheets
ISO/DIS 15614-7, Specification and qualification of welding procedures for metallic materials -- Welding procedure test -- Part 7: Overlay welding
ISO/DIS 24034, Welding consumables -- Solid wires and rods for fusion welding of titanium and titanium alloys -- Classification.
Guide to AWS Services
550 NW LeJeune Rd., Miami, FL 33126
Phone (800) 443-9353; (388) WELDING; FAX (305) 443-7550
internet: www.aws.org
Phone extensions appear in parentheses.

AWS PRESIDENT
James E. Greer...profjmg@aoa.edu
Moraine Valley Community College
245 Circletag Rd., New Lenox, IL 60451

ADMINISTRATION
Executive Director
Ray W. Shook...rshook@aws.org ........(246)
Deputy Executive Directors
Jeffery R. Hufsey...hufsey@aws.org ....... (264)
CFD/Deputy Executive Director
Frank R. Tarea...taraf@aws.org ........ (252)
Associate Executive Director
Cassie R. Burrell...charrell@aws.org ... (253)
Corporate Director of Quality
Linda K. Henderson...lindah@aws.org .... (296)
Executive Assistant for Board Services and IIW
Gricelda Manalich...gricelda@aws.org ... (294)

COMPENSATION + BENEFITS
Director
Luisa Hernandez...luisa@aws.org .......... (266)

DATABASE ADMINISTRATION
Corporate Director
Jim Lackford...jiml@aws.org ............. (214)

INTERNATIONAL INSTITUTE OF WELDING
Information...iiw@aws.org ................ (319)
Provides liaison activities involving other professional societies and standards organizations, nationally and internationally.

GOVERNMENT LIAISON SERVICES
Hugh K. Webster...hwebster@wc-k.com
Webster, Chamberlain & Bean
Washington, D.C.
(202) 466-2976; FAX (202) 835-0243
Identifies funding sources for welding education, research, and development. Monitors legislative and regulatory issues of importance to the industry.

BRAZING AND SOLDERING MANUFACTURERS’ COMMITTEE
Jeff Weber...jweber@aws.org ............. (246)

WEMCO-WELDING EQUIPMENT MANUFACTURERS’ COMMITTEE
Mary Ellen Miles...memill@aws.org ........ (444)

WIN-WELDING INDUSTRY NETWORK
Mary Ellen Miles...memill@aws.org ........ (444)

CONVENTION & EXPOSITIONS
Exhibiting Information ..........(242, 295)
Associate Executive Director/Sales Director
Jeff Weber...jweber@aws.org ........ (246)
Director of Convention & Expositions
John Ospina...jospina@aws.org .......... (462)
Organizes the annual AWS Welding Show and Convention. Regulates space assignments, registration materials, and other Expo activities.

CERTIFICATION OPERATIONS
Director
Terry Perez...tperez@aws.org ..........(470)
Information and application materials on certifying welders, inspectors, and educators. (273)

INTERNATIONAL BUSINESS DEVELOPMENT
Director
Weller Herrera...whele@aws.org ..........(475)

AWS AWARDS, FELLOWS, AND COUNSELORS
Managing Director
Wendy S. Reeve...wreeve@aws.org ..........(293)
Coordinates AWS awards and AWS Fellow and Counselor nominees.

TECHNICAL SERVICES
Department Information ..........(340)
Managing Director
Andrew R. Davis...adavis@aws.org ..........(466)
International Standards Activities, American Council of the International Institute of Welding (IIW)
Director, National Standards Activities
Peter Howe...phowe@aws.org ..........(309)
Manager, Safety and Health
Stephen P. Hedrick...shedick@aws.org .......... (305)

Technical Publications
Senior Manager
Rosalinda O’Neill...roNeill@aws.org .......... (451)
AWS publishes more than 200 technical standards and publications widely used in the welding industry.

Technical Committee Secretaries
Harold P. Ellisson...ellisson@aws.org .......... (299)
John L. Gayler...gayler@aws.org ..........(472)
Structural Welding, Welding Iron Castings.
Rakesh Gupta...rgupta@aws.org ..........(301)

Ross Hancock...rhancock@aws.org .......... (226)
Welding Qualification, Friction Welding, Railroad Welding, Joining of Metals and Alloys.
Cynthia Jenney...cjjenney@aws.org .......... (304)
Definitions and Symbols, Brazing and Soldering, Brazing Filler Metals and Fluxes, Technical Editing.

Brian McGrath...bmcgrath@aws.org .......... (311)

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

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

For full profile information on these individuals, visit the AWS web site.
Nominees for National Office

Only Sustaining Members, Members, Honorary Members, Life Members, or Retired Members who have been members for at least three years shall be eligible for election as a Director or National Officer.

It is the duty of the National Nominating Committee to nominate candidates for national office. The committee shall hold an open meeting, preferably at the Annual Meeting, at which members may appear to present and discuss the eligibility of all candidates.

To be considered a candidate for positions of President, Vice President, Treasurer, or Director-at-Large, the following qualifications and conditions apply:

President: To be eligible to hold the office of President, an individual must have served as a Vice President for at least one year.

Vice President: To be eligible to hold the office of Vice President, an individual must have served at least one year as a Director, other than Executive Director and Secretary.

Treasurer: To be eligible to hold the office of Treasurer, an individual must be a member of the Society, other than a Student Member, must be frequently available to the National Office, and should be of executive status in business or industry with experience in financial affairs.

Director-at-Large: To be eligible for election as a Director-at-Large, an individual shall previously have held office as Chairman of a Section, as Chairman or Vice Chairman of a standing, technical, or special committee of the Society, or as Director.

Interested parties are to send a letter stating which particular office they are seeking, including a statement of qualifications, their willingness and ability to serve if nominated and elected, and 20 copies of their biographical sketch.

This material should be sent to Thomas M. Mustaleski, Chairman, National Nominating Committee, American Welding Society, 550 NW LeJeune Rd., Miami, FL 33126.

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

Honorary-Meritorious Awards

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

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

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

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

International Meritorious Certificate Award: This award is given in recognition of the candidate's significant contributions to the worldwide welding industry. This award should reflect “Service to the International Welding Community” in the broadest terms. The awardee is not required to be a member of the American Welding Society. Multiple awards can be given per year as the situation dictates. The award consists of a certificate to be presented at the awards luncheon or at another time as appropriate in conjunction with the AWS President's travel itinerary, and, if appropriate, a one-year membership in the American Welding Society.

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

AWS Mission Statement

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

It is the intent of the American Welding Society to build AWS to the highest quality standards possible. The Society welcomes your suggestions. Please contact any of the staff listed on the previous page or AWS President James E. Greer, Moraine Valley Community College, 248 Ciregiate Rd., New Lenox, IL 60451.
The AWS Foundation is pleased to present the Research Fellowship recipients for 2004 – 2005

**Timothy Anderson**
Lehigh University, Dr. John N. DuPont, Advisor
NJC Fellowship

"Alloy Development of a Robust Filler Metal for the Superaustenitic Stainless Steel AL-6XN"

**Reginald Crawford**
Vanderbilt University, Prof. George E. Cook, Advisor
Miller Electric Fellowship

"Friction Stir Welding at High Spindle Speeds"

**Morgan Gallagher**
The Ohio State University, Dr. John C. Lippold, Advisor
NJC Fellowship

"An Investigation of Hot Cracking in Hastelloy Alloy C-22"

**Amit Kumar**
The Pennsylvania State University, Prof. T. DebRoy, Advisor
Glenn J. Gibson Fellowship

"A Smart Model for Welding Engineers to Achieve Target Fusion Zone Geometry in Gas Metal Arc Fillet Welding"

Circle No. 17 on Reader Info-Card
Patents and Trademarks Explained for Lay Persons

Patents and Trademarks Plain & Simple

Michael H. Jester

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

AASHTO Releases New Publications Catalog

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

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

Automated Deburring with Brushes Explained

A 12-page brochure details automated processes for deburring parts using wire and abrasive nylon filament (Nylox®) brushes. The guide is intended to help determine the best brush and deburring system design for specific applications. A burr classification system is presented to help the reader select the best brush type (wheel, disk, cup, end, and tube) for each job.

Weiler Corporation
One Wildwood Dr., Cresco, PA 18326-0149

Plasma Arc Cutting System Illustrated in Literature

A 4-page, full-color brochure presents all features and specifications for the Cutmaster™ 51 air plasma cutting system for non-HF start automation applications. Detailed is the technology behind the Torch™ plasma torch, and how the machines can be used in combination with existing cutting tables for ¼-in. (6-mm) production cut capacity and ½-in. (15-mm) edge start capacity.

Thermal Dynamics Corp.
Ste. 300, 16852 Swingley Ridge Rd., Chesterfield, MO 63017

Catalog Features Four Abrasive Product Lines

The master catalog and price list illustrates and describes the company's lines

— continued on page 84
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American Welding Society

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You decide.

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

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

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

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

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

Send your check, payable to AWS ISO Participation Fund, with 25 words of copy to:
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Miami, FL 33126

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

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

American Welding Society
Founded in 1919 to Advance the Science, Technology and Application of Welding
The National Association of Corrosion Engineers (NACE) has appointed Ralph Pontillo as executive director. Previously, Pontillo served as president of the Manufacturers' Association of Northwest Pennsylvania, and was publisher/managing editor for Business magazine.

ASTM Honors Two Innovators

James A. Joyce and Stephen W. Hopkins have been cited by ASTM International, W. Conshohocken, Pa., for their outstanding contributions to the development of standards.

Joyce received the George R. Irwin Award for “pioneering efforts in developing methodologies and standards for the practical applications of fracture mechanics, especially those related to efficient laboratory measurements of material fracture toughness and the consequent enhanced ability to compare experiments with analytical and computational predictions.”

Hopkins received the Edward T. Wessel Award “in recognition of his exceptional leadership, his role as a mentor in the development of standards based on fracture mechanics technology, and his exemplary citizenship.”

President Named at Airgas

Airgas, Inc., Radnor, Pa., has appointed Jeff Finch as president of Airgas Gasprom, its newest regional company operating in Hawaii. Previously, Finch served six years as vice president for the company’s West Division.

INEEL Scientist Selected for Congressional Fellowship

Eric Loewen, an engineer at the U.S. Department of Energy’s Idaho National Engineering and Environmental Laboratory (INEEL), has been chosen to serve as the American Nuclear Society’s Glenn T. Seaborg Congressional Science and Engineering Fellow for 2005. The honor provides an opportunity for Loewen to work in a Congressional office for one year, beginning next January, furnishing advice on nuclear science and engineering matters to a member of Congress and his or her staff. The goal of the fellowship is to bring credible information about nuclear matters to Congress and to act as a resource for Congress in the areas of science and engineering. Loewen won’t learn which Congressional member he will serve until after November.

Hypertherm Announces Staff Changes Here and Abroad

John Canterberry has been appointed to the position of manager, North American OEM and Integration Sales at Hypertherm, Hanover, N.H. Canterberry joined the company in 1997 as a district sales manager, and most recently served as leader of the North American sales team’s continuous improvement activities team.

Recently, the company completed its three-year program to change from a country-based to a single European sales and service team operation, with the following leadership changes. Pete Vickers has been promoted to director, Europe; Theo Cornielje promoted to director, OEM Sales for Europe; Cesare Cozzi appointed to manager, OEM Business Development; and Bas Riede named to continue as leader of the European Technical Service operations, working with George Gkatzimas, team leader EDC.

Phil Winslow has been named VP Hypertherm Asia, coordinating efforts with Soo Kam Tatt, managing director, Hypertherm Singapore, and Yasushi Araga, sales manager, Hypertherm Japan.

RMEL Presents Its Industry Leadership Award

The Rocky Mountain Electrical League (RMEL) has presented its Industry Leadership Award to Kurt Yeager. Yeager, recently retired president and CEO of the Electric Power Research Institute, was cited for his initiation of the Electricity Technology Roadmap, an ongoing collaborative exploration of the opportunities and threats for electricity-based innovation over the next 50 years.

--- continued on page 84 ---

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Join us at the 9th Annual Welding Equipment Manufacturers' Committee Meeting being held in Tucson, Arizona. We're hosting a gathering of some of the most prestigious companies in the industry. If your company is involved in the manufacturing of welding equipment or welding-related items, you need to take advantage of this opportunity!

Our unsurpassed speaker program will include:

- B. Beaulieu, Institute for Trend Research—The Economic Elevator: Going UP!
- Brian Polowniak, Solution Strategies, Inc. — The New Customer Approach for the Future
- Attorney Samuel J. Erkonen, Howe & Hutton, Ltd.—Managing Risk & Avoiding Product Liability. What to do if Litigation is Looming!
- Attorney Jonathan Howe, Howe & Hutton, Ltd.—How to Prepare When 60 Minutes Calls
- Kevin Watts, New Balance Athletic Shoe Corporation—How New Balance Continues to Make Shoes in the U.S.
- Karen Vogelsang, Essen Trade Shows—Schweissen & Schneiden World's Fair for Joining, Cutting, Surfacing and Welding being held on September 12-17, 2005, Essen, Germany.

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We look forward to seeing you in Tucson!

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Meeting Reservations: reply by e-mail to memills@aws.org or call (800) 443-9353, Ext #444
PERSONNEL
— continued from page 82

The Roadmap has amassed support from 150 organizations representing various industries, government agencies, research organizations, and other public and private stakeholders. The award is presented to an individual who is currently active in the field and has demonstrated singular dedication, service, and leadership to the electric utility industry.

Product Manager Appointed at Techalloy

Techalloy, Baltimore, Md., has appointed Gary Powell product manager at its Baltimore Welding Division. Powell, an employee with the company for nine years, previously served as manager of customer service.

Petters Elected to Key Post at Northrop Grumman

Northrop Grumman Corp., Los Angeles, Calif., has elected C. Michael Petters as corporate VP and president of the company’s Newport News sector, succeeding Thomas C. Schievelbein who has retired. Petters, with the company for 17 years, previously served as the sector’s VP of human resources, administration and trades.

Obituaries

C. E. WHITEY GRUBBS

World renowned underwater welding expert C. E. Whitey Grubbs, 85, died June 12, near Baton Rouge, La.


Mr. Grubbs chaired the Chapter Committee on Underwater Welding and Cutting for the AWS Welding Handbook, Eighth Edition, Volume 3; served on the D3 Committee on Welding in Marine Construction, founded and chaired the D3B Subcommittee on Underwater Welding and Cutting, served on the executive committee on Safety and Health, was a member of the American Council of the IWI, and was technical representative for the AWS District 9 Academy Section.

Mr. Grubbs was a member of the IWI Commission VIII on Hygiene and Safety; the Select Committee on Underwater Welding; and Commission II, Arc Welding. He chaired Work Group D, Commission VIII, Safety in Underwater Welding and Cutting, and was a delegate in the American Council to the Select Commission on Underwater Welding.

For the U.S. National Research Council, he was a member of the Materials Advisory Group of the Committee on Marine Structures, Technical Advisory Committee to the SHIP Structure Committee on Project SR-1283, Performance of Underwater Weldments, and served on the Panel on Undersea Facilities. He was a consultant for the Marine Board panel on Underwater Electrical Safe Practices and the Marine Board Panel on Certification of Offshore Structures.

Mr. Grubbs was a consultant for the U.S. Department of the Interior, Mineral Management Service, Technology Assessment and Research Branch.

He chaired the Executive Committee for the Joint Industry Underwater Welding Development Program.

He authored more than 40 technical papers on underwater welding, including 15 international presentations.

Mr. Grubbs is listed in Who’s Who in Science and Engineering (1998 and 2002) for his contributions to the science of underwater welding. He received one AWS Meritorious Certificate Award for his outstanding achievements in the science of welding in 1987, and another for serving as chair and director (1975–1988) of the D3B Subcommittee on Underwater Welding.

Mr. Grubbs was granted three U.S. patents: a method for underwater welding using pressurized welding electrode transfer capsule and dry welding electrode in situ storage; a viewing scope for turbid environments and use in underwater welding; and a method of underwater welding using a viewing scope.

PHILIP A. MOROCO

Philip A. Moroco, an AWS member since 1969, died September 14 in Sharon, Pa. Mr. Moroco was CEO and principal shareholder of American Cap Co., Inc., based in Westland, Pa.

Under his leadership, American Cap Co. grew in fifteen years from a small niche producer of high-pressure cylinder accessories to a diversified manufacturing company producing a variety of stamped metal and deep-drawn products for the industrial gas, specialty gas, and welding supply industries.

He also served on the board of directors of Penn Northwest Development Corporation. His past affiliations include the Keystone Blind Association, Shenango Valley Jaycees, St. Joseph’s Church in Sharon, Pa., and many local organizations.

Mr. Moroco is survived by his wife, Judith, four children, and eight grandchildren.

NEW LITERATURE
— continued from page 78

A 4-page, full-color brochure details the HPR130 HyperPerformance™ mechanized plasma metal cutting system. Shown are an exploded view of the electrode assembly, and close-ups of the control panels. Specifications and operating data are presented in easy-to-read chart form. Included are charts showing cost comparisons, cut speeds for mild steel, and consumables life projections.

Hypertherm Inc.
116

Craft Skills Covered in Text

Core Curriculum: Introductory Craft Skills, 3rd edition, a 490-page, full-color text, covers basic communication and employability skills, safety, construction math, hand tools, power tools, blueprints, and basic rigging. Published by Prentice Hall for the National Center for Construction Education and Research (NCCER), the volume is available in several formats priced at about $40 each, and as individual subject study modules at $14 each. For complete information, contact NCCER Customer Service toll-free at (888) 622-3720.
Whatever you wear and wherever you are, WeldAcademy puts welding knowledge at your fingertips. Just log your computer onto this convenient Internet-based introductory professional-development course.

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WeldAcademy offers a great entry point if you’re new to welding, or an engaging refresher course to confirm previous knowledge. Its ten modules cover the basics, including safety, welding processes, welding inspection, and metallurgy. Over 30 pre- and post-assessment questions for each module reinforce key learning objectives.

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<tr>
<td>E. Free Distribution Outside the Mail (Carriers or other means)</td>
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<td>None</td>
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<td>F. Total Free Distribution</td>
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<td>G. Total Distribution</td>
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<td>J. Percent Paid and / Requested Circulation</td>
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<td>99.1%</td>
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16. **Statement of Ownership**

   - The statement of ownership will be printed in the November 2004 issue of this publication.
   - I certify that the statements made by above are correct and complete:
     - Andrew Cullison, Publisher
Physical and Welding Metallurgy of Gd-Enriched Austenitic Alloys for Spent Nuclear Fuel Applications — Part I: Stainless Steel Alloys

The solidification temperature range of these alloys was found to be very large, leading to poor hot ductility and weldability

BY J. N. DuPONT, C. V. ROBINO, J. R. MICHAEL, R. E. MIZIA, AND D. B. WILLIAMS

ABSTRACT. The development of Gd-enriched austenitic alloys is currently being considered for nuclear criticality control in spent nuclear fuel storage applications. In this research, the physical and welding metallurgy of Gd-enriched austenitic alloys has been investigated with a combination of differential thermal analysis, Varestraint and Gleeble tests, and various microstructural characterization techniques. The results of Gd additions made to a 316L stainless steel-type matrix are presented in this article, and similar information is provided for Gd-enriched Ni-based alloys in the Part II companion article.

Type 316L stainless steel alloys with up to 6 wt-% Gd were observed to solidify in the primary ferrite mode and terminate solidification by a peritectic reaction involving (Fe,Ni,Cr)3Gd intermetallic that is rich in Ni and Gd. The ferrite partially transforms to austenite after solidification by a solid-state transformation, producing a final microstructure that has an austenitic matrix with remnant ferrite at the dendrite cores and interdendritic (Fe,Ni,Cr)3Gd. Essentially no Gd is dissolved in either the ferrite or austenite phases. Heating of the as-cast alloys leads to liquidation of the (Fe,Ni,Cr)3Gd intermetallic at ~1060°C, and this phase reforms at a similar temperature during solidification. As a result, the solidification temperature range of these alloys is very large (360°C-400°C, depending on Gd concentration). The large solidification temperature range leads to poor hot ductility and weldability, and limits production of these materials on a commercial basis. In Part II of this article, it is demonstrated that the solidification response and resultant hot ductility and weldability are significantly improved with the use of Ni-based matrix compositions.

Introduction

Safe disposition of spent nuclear fuel owned by the United States Department of Energy requires the development of thermal neutron absorbing structural materials for nuclear criticality control. As shown schematically in Fig. 1, these materials will be used for the internal baskets that separate spent fuel assemblies and are required for structural support, spent nuclear fuel geometry control, and nuclear criticality safety. Given the large quantity of material required for this application, the material should be producible with conventional fabrication methods such as ingot casting and hot working. Ultimately, the material will be formed and welded into an internal structure that will cradle the fuel and maintain a specified geometry (Ref. 1), so the material must also exhibit good weldability. In addition, the basket materials must be corrosion resistant under the projected storage conditions.

Previous research on selection of candidate alloys that could meet these requirements considered stainless steels containing boron (Refs. 2, 3). While these alloys are available as ASME code-approved materials, gadolinium (Gd) is significantly more effective than boron as an alloy addition for neutron absorption for two reasons. First, Gd has a significantly higher neutron absorption cross section than boron (765 barn for boron compared to 48,800 barn for Gd) (Ref. 4). Thus, Gd additions could potentially provide a means for handling the highly enriched fuel that cannot currently be handled with boron-containing stainless steel alloys. The higher thermal neutron absorption capacity may also allow thinner sections of this material to be used which may be important to ensure the total weight of the canister stays within prescribed limits. Second, Gd-containing constituents in the alloy may not dissolve as quickly as chromium borides in the presence of water during basket material degradation due to long-term corrosion (Ref. 4). Therefore, there is interest in the use of Gd-containing alloys for storage, transportation, and disposal of spent nuclear fuel. However, unlike stainless steel alloys containing boron, there has been...
very little research on production and welding of Gd-containing austenitic alloys.

There have been very few studies of Gd-alloyed materials produced by conventional ingot metallurgy practice (Refs. 5–8). In addition, there are very little data available concerning the physical metallurgy of Gd-enriched alloys that can be used as a guide to develop weldable alloys that can be produced by conventional methods. Phase equilibria data are virtually nonexistent, and the only available information concerning the relevant ternary systems consists of a partial isothermal section (at 25°C) for the Fe-Ni-Gd system (Ref. 5). Phase diagrams for the relevant binary systems, e.g., Fe-Gd, Ni-Gd, and Cr-Gd, are available (Ref. 6), and these indicate that the Fe-Gd and Ni-Gd systems both contain numerous intermetallic phases and complex solidification reaction sequences. In particular, peritectic reaction sequences appear to dominate the formation of intermetallic compounds in these systems (with the notable exception for low Gd levels in the Ni-Gd system, where a eutectic reaction is observed). A detailed study of phase equilibria and solidification paths in the related Fe-Mo-Gd system (Ref. 7) revealed extremely complex solidification behavior in these alloys. In this system, nine binary invariant solidification reactions and eight ternary invariant reactions were observed. It is known that a very limited quantity of Gd-alloyed austenitic stainless steel was produced in the 1960s by a major stainless steel supplier (Ref. 8). However, the results of that work are considered proprietary by the producer, so that little is known of the composition ranges examined, processing response, microstructures, or resultant weldability.

The objective of this research is to investigate the development of weldable, Gd-enriched austenitic alloys for spent nuclear fuel storage applications. The results of Gd additions made to a stainless steel matrix are provided in this first article. These results revealed significant technical chal-

Fig. 1 — Illustration of standardized canister assembly for transportation and long-term storage of spent nuclear fuel owned by the Department of Energy.

Fig. 2 — LOM photomicrographs. A, B — 1.08 wt-% Gd alloy; C, D — 4.00 wt-% Gd alloy.
Challenges to the development of weldable Gd-enriched stainless steel alloys produced with conventional hot working techniques. Subsequent research has shown that these obstacles can be surmounted with Gd additions made to a nickel alloy matrix, and the results of that research are summarized in the Part II companion article (Ref. 9).

Experimental Procedure

Eight stainless steel alloys with various Gd concentrations were melted by vacuum induction heating. The ingots were ~100 mm square by 75 cm long. Details on the melting procedure can be found in Ref. 10. The compositions of these heats are provided in Table 1. A Gd-free 316L stainless steel was prepared as a baseline for comparison and is labeled 316L in Table 1. The remaining Gd-enriched alloys are identified according to their target nominal Gd concentrations (0.4, 1, 2, 4, and 6 wt-% Gd). The nominal compositions were selected to provide a Type 316L matrix composition that would be expected to solidify in a primary ferrite mode. Results of recent research (Ref. 11) has shown that these alloys form a Ni-rich (Fe,Ni,Cr)3Gd intermetallic phase that depletes the matrix of Ni and enriches the matrix in Cr, Mo, and Mn. Thus, in order to produce a matrix composition similar to that of 316L, adjustments to the nominal Ni, Cr, Mo, and Mn concentrations are required to compensate for these alloy enrichment and depletion effects. (This is described in more detail in the Discussion section.) Two heats were produced of alloys 0.4 and 1 wt-% Gd. The heats marked "A" were used in the as-cast condition for differential thermal analysis and hot ductility testing. These test results were needed to select optimum hot working temperatures for the as-cast ingots. Alloys 0.4-B, 1-B, and 2 were reduced into plates by hot forging. (Alloys 4 and 6 were used for testing only in the as-cast form.) Initial forging attempts and subsequent hot ductility results indicated that the alloys were sensitive to hot tearing at temperatures above approximately 1060°C and that the maximum ductility was achieved at approximately 950°C. Thus, the hot forging was conducted in two separate steps. In the first step, the ingots were heated to 950°C and hot forged to a thickness of approximately 50 mm. Individual reductions of 12 mm were used. Each ingot received one or two reductions at a time before it was returned to the furnace for reheating. After reduction to approximately 50 mm, the ingots were allowed to cool and then sectioned into smaller lengths for easier handling in the hot forge. The smaller lengths were then reheated to 950°C and given a final reduction to plate that was approximately 19 mm thick and 115 mm wide. The final reduction was accomplished in two to three sets of smaller reductions. After reduction, the ingots were annealed at 980°C for one hour and water quenched.

Gleeble hot ductility tests were conducted on cylindrical bars 102 mm long and 6.35 mm in diameter with threaded ends. The samples were heated in the Gleeble to the test temperature of interest at a rate of 100°C/min and held for 1 min at temperature. During this 1 min, the temperature was adjusted to the desired test temperature. The sample was then pulled in tension at a cross-head speed of 1 mm/s. Type K thermocouples were used to monitor the temperature. Testing was done in a vacuum of ~100 millitorr to reduce oxidation and prevent detachment of the thermocouples. The reduction in area of the failed samples was determined as a measure of the hot ductility.

Reaction temperatures during melting and solidification were measured using differential thermal analysis (DTA). The DTA was conducted on a Netzsch STA 409 differential thermal analyzer using 500- to 550-mg samples. The DTA system was calibrated to within 2°C using a pure Ni standard (melting point = 1455°C). Samples were melted and solidified under flowing
Table I — Experimental Heat Compositions (values in wt-%)

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Fe</th>
<th>Ni</th>
<th>Cr</th>
<th>Mo</th>
<th>Mn</th>
<th>Si</th>
<th>Gd</th>
<th>P</th>
<th>S</th>
<th>N</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>316L</td>
<td>Bal.</td>
<td>11.52</td>
<td>16.64</td>
<td>2.76</td>
<td>1.73</td>
<td>0.12</td>
<td>—</td>
<td>&lt;0.001</td>
<td>0.002</td>
<td>0.009</td>
<td>0.005</td>
</tr>
<tr>
<td>0.4-A</td>
<td>Bal.</td>
<td>11.66</td>
<td>16.52</td>
<td>2.70</td>
<td>1.70</td>
<td>0.14</td>
<td>0.45</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.009</td>
<td>0.008</td>
</tr>
<tr>
<td>0.4-B</td>
<td>Bal.</td>
<td>11.45</td>
<td>16.47</td>
<td>2.75</td>
<td>1.62</td>
<td>0.11</td>
<td>0.38</td>
<td>0.002</td>
<td>0.002</td>
<td>0.003</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>1-A</td>
<td>Bal.</td>
<td>11.94</td>
<td>16.30</td>
<td>2.63</td>
<td>1.69</td>
<td>0.10</td>
<td>1.08</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.008</td>
<td>0.012</td>
</tr>
<tr>
<td>1-B</td>
<td>Bal.</td>
<td>11.81</td>
<td>16.37</td>
<td>2.74</td>
<td>1.91</td>
<td>0.13</td>
<td>0.89</td>
<td>0.003</td>
<td>0.002</td>
<td>0.004</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>2</td>
<td>Bal.</td>
<td>12.22</td>
<td>16.12</td>
<td>2.74</td>
<td>1.60</td>
<td>0.09</td>
<td>1.89</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.001</td>
<td>0.008</td>
</tr>
<tr>
<td>4</td>
<td>Bal.</td>
<td>13.06</td>
<td>15.30</td>
<td>2.50</td>
<td>1.55</td>
<td>0.17</td>
<td>4.00</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.001</td>
<td>0.006</td>
</tr>
<tr>
<td>6</td>
<td>Bal.</td>
<td>13.86</td>
<td>14.69</td>
<td>2.38</td>
<td>1.48</td>
<td>0.18</td>
<td>5.84</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.001</td>
<td>0.005</td>
</tr>
</tbody>
</table>

argon in alumina crucibles, and pure alumina was used as the reference material. The samples were packed in alumina powder to prevent oxidation. Preliminary tests were conducted to establish the liquidus temperature of each alloy. After these preliminary tests, the samples were heated at a rate of 5°C/min to approximately 10°C above their liquidus. The samples were then cooled at 5°C/min to determine the temperatures of reactions that occur during solidification. Reaction temperatures were taken as deviations from the local baseline. Weldability tests were conducted with the Varestraint test. The Varestraint tests were conducted on alloys 0.4-B, 1-B, and 2. The samples were removed from the annealed plate and machined to 165 mm long × 25 mm wide × 6.4 mm thick. The welding parameters were 100 A, 9 V, and 3 mm/s travel speed. A constant augmented strain level of 3.5% was used.

Light optical microscopy (LOM) was conducted on samples polished through 0.04-μm colloidal silica. Scanning electron microscopy (SEM) was performed using a JEOL 6300 field emission gun scanning electron microscope (FEG-SEM) at an accelerating voltage of 15 kV. Electron probe microanalysis (EPMA-WDS) was conducted on a JEOL 733 probe at an accelerating voltage of 15 kV and beam current of 20 nA. All EPMA samples were mounted in thermal setting epoxy, polished flat to a 0.03-μm finish using an alumina slurry, ultrasonically cleaned in acetone, and carbon coated prior to analysis. Pure element standards were used for calibration, and raw data were reduced to weight percentages using a ZAF algorithm (Ref. 12).

Backscattered electron Kickuchi patterns, also known as electron backscattering patterns (EBSP), were collected using a JEOL 6400 SEM and a charge-coupled device (CCD) based camera system. Patterns were obtained from samples using a 20-kV accelerating voltage, 10-nA beam current, and 70-deg specimen tilt. The patterns were collected by stopping the electron beam on the feature or area of interest. The CCD camera acquisition time is controlled by automatic blanking of the SEM electron beam. Typical exposure
times for this study were in the range of 2
to 10 s. The raw patterns were corrected
for the background intensity using a flat-
fielding procedure. Qualitative chemistry
information was obtained through energy
dispersive X-ray spectrometry (EDS), and
the crystallographic information was auto-
matically extracted from the patterns
using software developed at Sandia Na-
tional Laboratories. The crystallographic
information along with the qualitative
chemistry information were used to search
the International Center for Diffraction
Data (ICDD) Powder Diffraction File
(PDF).

Specimens for transmission electron
microscopy (TEM) were prepared by ini-
tially cutting samples into 2-mm-thick
slices. The slices were ground from both
sides to a thickness of approximately 150
μm using a series of 300, 600, 800, and
1200 SiC sandpapers. Slices were then cut
into a 3-mm-diameter disc using a Gatan
punch. The discs were polished to approx-
imately 80 μm and thinned again to ap-
proximately 30 μm by dimpling. Final
preparation of the foils was accomplished
by ion beam thinning in a precision ion
polishing system. Thin foils were exam-
ined using a JEOL 2000FX transmission
electron microscope (TEM) equipped with an Oxford 2000 II energy-dispersive
spectrometer (EDS) for qualitative chem-
ical analysis. The accelerating voltage was
200 kV, and a double tilt specimen holder
was used so that the specific orientation
could be obtained. Imaging was con-
ducted in both dark and bright field
modes. Crystal structure information was
obtained with the selected area diffraction
(SAD) technique.

Results

As-Cast Microstructures

As previously mentioned, no informa-
tion exists in the open literature on phase
Table 2 — Distribution of Alloying Elements in Austenite, Interdendritic Ferrite, and \((Fe,Ni,Cr)_3Gd\) Phases Observed in Alloy 6 (All values listed in wt-%.)

<table>
<thead>
<tr>
<th>Phase</th>
<th>Fe</th>
<th>Ni</th>
<th>Cr</th>
<th>Mo</th>
<th>Si</th>
<th>Gd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austenite</td>
<td>66.6</td>
<td>11.4</td>
<td>15.7</td>
<td>2.6</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>Ferrite</td>
<td>66.7</td>
<td>2.9</td>
<td>23.5</td>
<td>4.2</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>((Fe,Ni,Cr)_3Gd)</td>
<td>19.6</td>
<td>27.8</td>
<td>1.7</td>
<td>&lt;0.1</td>
<td>1.5</td>
<td>49.0</td>
</tr>
</tbody>
</table>

Table 3 — WRC Nieq and Creq Values and Expected Solidification Mode for Each Alloy

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Nieq</th>
<th>Creq</th>
<th>Solidification Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4-A</td>
<td>11.9</td>
<td>19.2</td>
<td>FA</td>
</tr>
<tr>
<td>0.4-B</td>
<td>11.9</td>
<td>19.2</td>
<td>FA</td>
</tr>
<tr>
<td>1-A</td>
<td>12.5</td>
<td>18.9</td>
<td>FA</td>
</tr>
<tr>
<td>1-B</td>
<td>12.2</td>
<td>19.1</td>
<td>FA</td>
</tr>
<tr>
<td>2</td>
<td>12.5</td>
<td>18.9</td>
<td>FA</td>
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<tr>
<td>4</td>
<td>13.3</td>
<td>17.8</td>
<td>AF</td>
</tr>
<tr>
<td>6</td>
<td>14.1</td>
<td>17.1</td>
<td>AF</td>
</tr>
</tbody>
</table>

Fig. 9 — Reduction in area as a function of temperature for 0.4, 1.0, and 6.0 wt-% Gd alloys.

Fig. 8 — Bright field image and selected area diffraction patterns from major and thin gadolinium-containing constituents.

Thus, this section summarizes the types of phases that form during solidification of the ingots, which, as shown later, have a strong influence on the hot ductility and weldability of these alloys. Figure 2 shows typical low and high magnification LOM photomicrographs of alloys 1-A and 4 in the as-cast condition. Apart from the relative phase fractions, the microstructural features observed in these two alloys were typical of the remaining experimental alloys. Figure 3 shows a backscattered electron photomicrograph of alloy 4 in which the various phases are labeled, and Fig. 4 shows typical backscattered diffraction patterns acquired from each phase that were utilized for the phase identification. The as-cast microstructures contain four phases: the austenite matrix, delta ferrite, sigma, and an intermetallic \((Fe,Ni,Cr)_3Gd\) phase. The \((Fe,Ni,Cr)_3Gd\) phase appears light in the backscattered image of Fig. 3 due to its high atomic number (from the high Gd concentration). The amount of this phase was observed to increase with increasing Gd concentration. The delta ferrite appears in two phases throughout the microstructure — in the cell cores and in the interdendritic regions. Often, there is a very thin Gd-rich phase adjacent to the major \((Fe,Ni,Cr)_3Gd\) phase in the interdendritic area, which was too small to identify with EBSD. This Gd-containing region is generally connected to the major gadolinide at its ends (in the two-dimensional polished section), and surrounds the interdendritic delta ferrite (see circled regions in Fig. 3).

Figures 5 and 6 show a backscattered SEM image (labeled BSE) and EDS spectrum images that qualitatively illustrate the distribution of alloying elements in the austenite, ferrite, and Gd-rich phases present in the interdendritic region. EDS maps for Fe, Ni, Cr, Mo, and Gd are shown. The delta ferrite is enriched in Cr and Mo, and depleted in Ni relative to the austenite matrix. This segregation behavior is typically observed between ferrite and austenite in stainless steels (Ref. 12). Cr and Mo each have identical crystal structures as delta ferrite (body-centered cubic) and thus exhibit higher solubility in the delta ferrite. Similarly, Ni and the austenite matrix are each face-centered cubic, and Ni preferentially segregates to the austenite. There is a subtle difference between Figs. 5 and 6 that is important to note. In Fig. 5, the thin Gd-rich phase is present on each side of the larger \((Fe,Ni,Cr)_3Gd\) phase. When this morphology was observed, ferrite was also present on each side of the larger \((Fe,Ni,Cr)_3Gd\) phase. However, as shown in Fig. 6, when the thin Gd-rich phase was not present on one side of the larger \((Fe,Ni,Cr)_3Gd\) phase, the ferrite was not observed on that side either. In addition, as the circled areas on the BSE images of Figs. 5 and 6 show, the thin Gd-rich constituent and the major gadolinide often have oscillating features along their interfaces with the intervening ferrite. In cases where the oscillating features are present on both the thin and major constituents (as in Fig. 5), it often appears that the oscillations are coupled. The significance of these observations are discussed later when the transformation sequence of these alloys is described.

Electron probe microanalysis was con-
ducted on alloy 6 to determine the composition of each phase, and the results are listed in Table 2. Note that the target austenite matrix composition is very close to that required for 316L (10–14 wt-% Ni, 16–18 wt-% Cr). The slightly low Cr in the austenite results from the high Cr content observed in the interdendritic ferrite (23.5 wt-% Cr). The composition of the (Fe,Ni,Cr)₃Gd is consistent with the stoichiometry of this phase. There is essentially no solubility of Gd in the austenite matrix or ferritic constituents. This indicates that essentially all the Gd is contained in the Gd-rich intermetallic constituents.

As described above, the (Fe,Ni,Cr)₃Gd phase in the interdendritic regions is relatively coarse and often accompanied by a very thin (< 0.1 μm) Gd-rich phase. Positive identification of this thin Gd-rich phase was not possible by EPMA or EBSD because its size is beyond the resolution limit of these techniques. Thus, a TEM investigation of thin foils was performed. For this study, a region of alloy 6 was selected that contained both the coarse (Fe,Ni,Cr)₃Gd intermetallic and the smaller Gd-rich phase. Figure 7 shows a dark field TEM image in which each Gd phase is identified. The major (Fe,Ni,Cr)₃Gd constituent was identified previously by EBSD and the smaller Gd phase is labeled Gd2 in Fig. 7. Energy-dispersive spectrometry spectra were obtained from both phases and were identical within the expected errors of counting statistics, which is ±10% relative (only one spectra is shown in Fig. 7). The EDS spectra from the intervening ferrite are reduced in Ni compared to the EDS spectrum from the austenite. The austenite is relatively low in Cr and enriched in Fe. These data compare well with the EDS spectrum images displayed in Figs. 5 and 6. The TEM-EDS spectra provide a preliminary indication that the two Gd phases are identical. However, diffraction evidence is required for positive identification since it is possible for two phases to have similar compositions, but different crystal structures.

Figure 8 shows a bright field image and SAD patterns from the (Fe,Ni,Cr)₃Gd and Gd2 constituents. The similarity of the two SAD patterns indicate that the two Gd phases are identical. However, diffraction evidence is required for positive identification since it is possible for two phases to have similar compositions, but different crystal structures. Thus, the TEM data confirm that both Gd-containing constituents have identical structure and orientation and, when combined with the EDS and EBSD data, prove that both are (Fe,Ni,Cr)₃Gd.

Hot Ductility and Solidification Behavior

The hot ductility behavior of engineering alloys is important from both hot working and weldability perspectives. In general, alloys that possess good ductility at temperatures approaching the melting temperature can typically be hot worked easily and welded without cracking problems in the heat-affected zone. Conversely, loss of ductility at temperatures well below melting usually signals poten-
Fig. 11 — Variation in liquidus and liquation temperatures with gadolinium concentration.

tial problems with hot working and heat-affected zone cracking. Similarly, the solidification behavior (e.g., solidification temperature range and amount/type of phases that form during solidification) provide an indication of resistance to solidification cracking. In this regard, alloys that show a relatively narrow solidification temperature range typically exhibit good resistance to solidification cracking. The hot ductility and solidification behavior of the experimental alloys are discussed in this section.

Hot ductility testing was conducted on alloys 0.4-A, 1-A, and 6, and the results are shown in Fig. 9. The reduction in area of each alloy reaches a maximum at ~950°C, and decreases significantly at temperatures below and above 950°C. In addition, the maximum ductility is a function of the Gd concentration, where increasing Gd reduces the peak reduction in area. The ductility is completely lost at temperatures above approximately 1060°C.

Figure 10 shows typical DTA scans acquired from alloys 1-A, 4, and 6. The heating scans are shown for alloys 1-A and 4, while both the heating and cooling scans are shown for alloy 6. The representative scans shown here are typical of those observed for the remaining alloys. For each alloy, there is a reaction that initiates at approximately 1060°C on heating. Note that the area under the peak, which is proportional to the energy released during the transformation and, therefore, the amount of phase that transforms during the reaction, increases with increasing Gd concentration. Considering that the volume fraction of (Fe, Ni, Cr)₃Gd increases with increasing Gd level (Ref. 10), it is reasonable to conclude that the reaction initiating at ~1060°C is liquation of the interdendritic Gd constituent. In addition, note that this liquation temperature is in excellent agreement with the hot ductility curve shown in Fig. 9, where the ductility approaches zero near 1060°C. Liquation of a secondary phase is well known to induce significant reductions in ductility (Ref. 13). With continued heating, the liquation reaction is completed around 1090°C. There is often evidence of two separate liquation peaks in the DTA scans (e.g., for the 4 and 6 wt-% Gd alloys), suggesting there are two separate liquation events that occur on heating. The solidification behavior also exhibits two separate peaks on cooling — Fig. 10D. Figure 11 summarizes the DTA data, in which the average liquation and liquidus temperatures are plotted as a function of Gd concentration. The liquidation temperature is essentially constant at ~1060°C, while the liquidus temperature decreases with increasing Gd concentration. It is important to note that the melting temperature range of these alloys in the as-cast condition varies from approximately 360°C to 400°C. This range is extremely large and is responsible for the poor hot ductility displayed in Fig. 9.

A series of interrupted DTA scans was conducted in order to confirm that the low-temperature peaks were associated with liquation of the (Fe, Ni, Cr)₃Gd constituent. A 6 wt-% Gd sample was heated to a peak temperature of 1070°C, which is just above the liquation start temperature, and cooled. Similarly, a sample was heated to 1135°C, which is just above the liquation finish temperature, and cooled. These DTA samples were then metallographically compared to a sample that was heated to 1460°C where it was completely melted and then resolidified. Figure 12 shows the DTA samples from these three scans. The sample heated to 1460°C (Fig. 12A) shows a microstructure identical to the as-cast ingots, thus demonstrating that

Fig. 12 — LOM photomicrographs showing DTA samples heated to the following: A — 1460°C; B — 1070°C; and C — 1135°C.
the temperatures derived from the DTA tests accurately reflect the reaction temperatures of the large-scale heats, and these are discussed further below in terms of the reaction sequences. The only exception here is formation of the sigma phase, which is not observed in the DTA samples. For the sample heated to 1070°C (Fig. 12B), there is direct evidence of liquation between the (Ni,Fe,Cr)3Gd and the interdendritic ferrite. This suggests that liquation occurs in two separate steps, where the interdendritic ferrite first reacts with the surrounding (Ni,Fe,Cr)3Gd, followed by a second step where the remaining (Ni,Fe,Cr)3Gd begins to react with the austenite. When the sample is heated above the liquation finish temperature, the original as-cast microstructure consisting of the full (Ni,Fe,Cr)3Gd/ferrite/(Ni,Fe,Cr)3Gd morphology is restored, demonstrating that the entire interdendritic constituent was completely molten at this temperature.

Weldability

Figure 13 shows the Varestraint data in terms of both the maximum and total crack lengths for the Gd-free 316L alloy in addition to alloys 0.4-B, 1-B, and 2. Microstructural examination of the as-cast ingot of the Gd-free alloy confirmed that it solidified by primary ferrite. Thus, this alloy is expected to exhibit good resistance to solidification cracking. The Varestraint results show that the solidification cracking susceptibility is very sensitive to the Gd concentration of the alloy, where extensive cracking is observed with increasing Gd concentration. In fact, as shown in Fig. 14, Varestraint samples exhibited severe cracking outside of the test zone (i.e., in the region where no external strain was applied).

Discussion

Microstructural Evolution

The information presented in the previous sections can be used to understand the general microstructural evolution, hot ductility, and weldability of Gd-enriched stainless steels. The as-cast alloys exhibit four distinct phases: the austenite matrix, ferrite, (Ni,Fe,Cr)3Gd, and sigma. Ferrite is observed both in the cell cores and interdendritic regions. The DTA samples show peaks corresponding to these constituents, with the exception that sigma does not form under the DTA cooling conditions. There is essentially no Gd dis-
that were expected to produce a predominantly austenitic matrix. These observations demonstrate that selection of bulk composition aimed at forming an austenitic matrix must consider formation of the (Ni,Fe,Cr),Gd phase, and its concomitant effect on the matrix composition and phase stability. A quantitative mass balance technique for this purpose has recently been derived (Ref. 11) and was applied to the alloy compositions originally presented in Table 1 to produce austenitic alloys that solidified in the FA mode. The fact that all the alloys exhibited a matrix that was predominately austenite with ferrite at the dendrite cores confirms that the technique is valid for these alloys.

The information presented above is used to propose a phase transformation sequence that accounts for the types and morphologies of phases observed experimentally. This transformation sequence is shown schematically in Fig. 15. Ferrite is observed in the cell cores, which indicates that solidification starts by the formation of primary ferrite. Primary ferrite solidification is known to be accompanied by rejection of Ni (and Gd) to the liquid and segregation of Cr and Mo to the ferrite (Ref. 13). Thus, the ferrite at the dendrite core is depleted in Ni and enriched in Cr and Mo relative to the ferrite in the interdendritic region. Since Gd is essentially insoluble in the ferrite (and austenite) phases, Gd segregates aggressively to the liquid during solidification. Primary ferrite solidification and Gd enrichment in the liquid continues until, at approximately 1100°C, the peritectic Liquid + Ferrite → (Ni,Fe,Cr),Gd reaction initiates in the interdendritic regions. For much of the solidifying volume this reaction continues to completion — Figs. 3, 15. In other regions, however, a thin (Ni,Fe,Cr),Gd rim is also formed. This thin gadolinide constituent was shown to be connected to the major gadolinide, and to have the same composition, structure, and crystallographic orientation as the major gadolinide. It was also shown that when the thin rim is present, ferrite is always present between the rim and the major gadolinide. Finally, some interfaces on the rim were seen to display oscillating features that were correlated spatially to similar features on the major gadolinide — Fig. 5.

The reasons for this interesting behavior are not readily apparent, but recent work by Tevudi and coworkers (Refs. 14–17) and summarized by Boettinger et al. (Ref. 18) provides at least a qualitative basis for understanding the microstructural development. Through experimental and modeling approaches, the referenced work has shown that a wide variety of microstructures (at least six variants have been classified) can develop in peritectic systems. In turn, these microstructures are strongly dependent on the convective and diffusion conditions prevalent during solidification. In particular, both hand-mixed and peritectic phases and oscillatory structures (in which the primary and peritectic phases grow in oscillating continuous tree-like structures) appear to be present in the Gd-stainless steels. In this case, it is speculated that fluctuations in the local convection and thermal fields occasionally give rise to conditions favoring these microstructural variants. Following formation of a thin layer of peritectic gadolinide, in these locations new "secondary" ferrite is also formed (at approximately 1060°C). It is also assumed that this process also occasionally gives rise to the oscillatory structures. Just following solidification (i.e., before subsequent solid-state transformations), this sequence would produce a microstructure with the following spatial morphology: primary ferrite/ (Ni,Fe,Cr),Gd"secondary" ferrite/ (Ni,Fe,Cr),Gd, as observed experimentally in the rimmed regions. However, the primary ferrite is not stable during subsequent cooling and will transform to austenite by a diffusional transformation that involves rejection of Cr and Mo at the advancing austenite/ferrite boundary (Ref. 13). The transformation temperature of the ferrite → austenite reaction is composition dependent, and regions of relatively high Ni and low Cr concentrations will transform at higher temperatures (Ref. 20). Since the interdendritic ferrite is higher in Ni and lower in Cr relative to that at the dendrite core, the ferrite → austenite reaction is expected to initiate during cooling at the interdendritic region, with the austenite/ferrite boundary advancing back toward the dendrite core during subsequent cooling. The high Cr and Mo contents of the first ferrite that forms stabilize the ferrite at the dendrite core to lower temperatures, which accounts for the remnant primary ferrite observed at the dendrite cores.

The formation of austenite from the ferrite would lead to Cr and Mo rejection at the advancing interface, thus producing...
Table 4 — Summary of Proposed Transformation Sequence

<table>
<thead>
<tr>
<th>Reaction</th>
<th>Solidification</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Liquid → Ferrite</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2) Liquid + Ferrite → (Ni,Fe,Cr)_3Gd</td>
<td>Liquid enriched in Ni and Gd</td>
<td></td>
</tr>
<tr>
<td>2a) In isolated regions. Liquid + &quot;Secondary&quot; Ferrite → (Ni,Fe,Cr)_3Gd</td>
<td>&quot;Secondary&quot; Ferrite depleted in Ni and enriched in Cr, Mo</td>
<td></td>
</tr>
<tr>
<td>3) Primary Ferrite → Austenite</td>
<td>Causes Cr and Mo enrichment at primary ferrite/austenite boundary</td>
<td></td>
</tr>
<tr>
<td>4) Sigma nucleation and growth at ferrite/austenite boundary</td>
<td>Only observed in large-scale ingots (slower cooling rate)</td>
<td></td>
</tr>
<tr>
<td>5) Secondary Ferrite persists when surrounded by (Ni,Fe,Cr)_3Gd phase</td>
<td>(Ni,Fe,Cr)_3Gd phase acts as nucleation barrier to Ferrite → Austenite transformation</td>
<td></td>
</tr>
</tbody>
</table>

locally elevated Cr and Mo concentrations at the primary ferrite/austenite boundary. Sigma phase is known to nucleate at the austenite/ferrite boundaries where the local Cr and Mo content is high (Ref. 21), and this accounts for the presence of sigma observed at the austenite/ferrite boundaries in the large-scale heats. The lack of sigma at this location in the DTA samples is apparently related to cooling rate. Since sigma forms by a diffusional transformation, the cooling rate of the DTA samples after solidification was apparently too high for the solid-state reaction of sigma to occur. Lastly, comparison of Figs. 5 and 6 showed that ferrite persisted in the interdendritic regions only when the (Ni,Fe,Cr)_3Gd was present on both sides of the ferrite. According to the transformation sequence proposed here, this is the so-called "secondary" ferrite that forms after the first Liquid + Ferrite → (Ni,Fe,Cr)_3Gd peritectic-type reaction. As mentioned above, subsequent solid-state transformation of this ferrite to austenite requires redistribution of Cr and Mo. However, the Liquid + Ferrite → (Ni,Fe,Cr)_3Gd peritectic-type reactions can cause the secondary ferrite to be enveloped by the (Ni,Fe,Cr)_3Gd phase. Subsequent transformation of the secondary ferrite to austenite then requires diffusion of Cr, Mo, and Ni through the (Ni,Fe,Cr)_3Gd phase, but the diffusion rate of these substitutional elements is expected to be extremely slow through the intermetallic (Ni,Fe,Cr)_3Gd phase. Thus, the (Ni,Fe,Cr)_3Gd phase acts as a diffusion barrier and prevents subsequent solid-state transformation of the secondary ferrite. This explains why the secondary ferrite is stable to room temperature only when surrounded by the (Ni,Fe,Cr)_3Gd phase on each side — Fig. 5. When the (Ni,Fe,Cr)_3Gd phase is absent from one side, solid-state diffusion of Cr and Mo can occur on this side (Fig. 6), thus permitting transformation of ferrite to austenite. The proposed transformation sequence is summarized in Table 4. The sequence proposed here accounts for the type and morphologies of phases observed experimentally and the dual peak observed in the DTA scans near 1060°C.

Solidification Cracking and Hot Ductility

The solidification cracking susceptibility is controlled primarily by the solidification temperature range and amount of terminal liquid that forms at the end of solidification. Alloys that exhibit a large solidification temperature range and form less than about 5–7 vol-% terminal liquid in a continuous or semicontinuous film along the grain boundaries and interdendritic regions are known to be most susceptible to cracking (Ref. 22). At larger volume fractions of terminal liquid, generally beyond 7–10 vol-%, backfilling of cracks by the terminal liquid can begin to occur, and cracking susceptibility is reduced with increasing amounts of terminal liquid.

The DTA results showed that these alloys exhibit a very wide solidification temperature range (360–400°C). The amount of (Ni,Fe,Cr)_3Gd provides an indication of the amount of terminal liquid. Since there is essentially no Gd dissolved in the austenite or ferrite phases, all of the Gd is consumed in formation of the (Ni,Fe,Cr)_3Gd phase, and the amount of terminal Gd-rich liquid is expected to increase with increasing Gd concentration. This was observed experimentally. Figure 16 shows quantitative image analysis results in which the amount of (Ni,Fe,Cr)_3Gd phase was measured on small-scale Gd-enriched stainless steels with compositions similar to that used in this work (Ref. 11). As expected, these results show that the amount of (Ni,Fe,Cr)_3Gd increases with increasing Gd concentration. The results for alloys with less than 2 wt-% Gd are of interest to the weldability response. While alloys within this Gd concentration range show an increase in (Ni,Fe,Cr)_3Gd content with increasing Gd concentration, the volume fraction is always less than 5% when the Gd concentration is below 2 wt-%. Thus, no appreciable backfilling is expected in these alloys. The Varestraint test results show that hot cracking susceptibility increases substantially with increasing Gd concentration. Figure 11 shows that the solidification temperature range decreases moderately with increasing Gd concentration. Thus, the trend shown in Fig. 13 cannot be attributed to any factor related to the solidification temperature range because the solidification temperature range slightly decreases with increasing Gd concentration. Comparison of Figs. 13 and 16 shows that the maximum and total crack lengths increase with increasing (Ni,Fe,Cr)_3Gd content. Based on these observations, the poor resistance to solidification cracking can generally be attributed to the very low Liquid + Ferrite → (Ni,Fe,Cr)_3Gd reaction temperature and concomitantly large solidification temperature range, while the increase in cracking susceptibility observed with increasing Gd concentration can be attributed to larger amounts of the low-temperature liquid that form as the Gd level is increased. As shown in Fig. 9, the hot workability is also significantly affected by the low-temperature (Ni,Fe,Cr)_3Gd phase since there is no substantial ductility above the liquidation temperature of the (Ni,Fe,Cr)_3Gd phase.

Finally, it is interesting to note that, based on the Fe-Gd or Ni-Gd binary phase diagrams, formation of the (Ni,Fe,Cr)_3Gd phase is not expected for alloys with the Gd levels considered here. Based on these binary systems, (Fe,Ni)_3Gd would be the first intermetallic expected to form during solidification for alloys within the Gd concentration range considered here. In the Ni-Gd system, the Ni_3Gd phase forms by a peritectic reaction that is followed by a eutectic reaction for Gd levels below approximately 13 wt-% Gd. In the Fe-Gd system, the Fe_2Gd forms first by a peritectic reaction that is followed by a eutectic reaction involving the Fe_2Gd and Fe_Gd phases. Solidification then terminates with a eutectic reaction involving the Fe_2Gd phase. In any case, the equilibrium microstructure (based in the simple binary diagrams) is expected to be austenite and (Fe,Ni)_3Gd. The liquid temperature of the Fe_2Gd and Ni_3Gd phases is appreciably higher than that of the (Fe,Ni)_3Gd phase that is observed experimentally (1335°C in the Fe-
Gd system and 1275°C in the Ni-Gd system. This implies that heat treating of the as-cast material may promote dissolution of the low-temperature (Fe, Ni, Cr)₃Gd phase and formation of the higher-temperature (Fe, Ni, Cr)₃Gd phase. However, a wide range of heat treatment temperatures (900°C to 1270°C) and times (2 to 16 h) was recently investigated for this purpose, and it was found that the low-temperature (Fe, Ni, Cr)₃Gd phase cannot be dissolved under these heat treatment conditions. In fact, new higher gadolinides with even lower liquidation temperatures were observed. Details of this study can be found in Ref. 10.

Conclusions

The physical and welding metallurgy of Gd-enriched stainless steels has been investigated with a combination of differential thermal analysis, Varestraint and Gleeble tests, and various microstructural characterization techniques. The following conclusions can be drawn from this research.

1) Solidification of these alloys occurs in the primary ferrite mode and terminates by a peritectic reaction involving the (Fe, Ni, Cr)₃Gd phase. The ferrite partially transforms to austenite after solidification with a solid-state transformation, producing a final microstructure that has an austenitic matrix with remnant ferrite at the dendrite cores and interdendritic (Fe, Ni, Cr)₃Gd. Locally complex convection and thermal fields can occasionally give rise to complex variants in the peritectic microstructures.

2) The solidification temperature range of these alloys is very large (300°C to 400°C, depending on Gd concentration) due to formation of the (Fe, Ni, Cr)₃Gd phase.

3) The hot ductility is lost above ~1060°C due to liquation of the (Fe, Ni, Cr)₃Gd phase, which severely limits the ability to form these alloys by high-temperature deformation techniques such as rolling and hot forging.

4) The alloys exhibit a high susceptibility to solidification cracking. The poor cracking resistance observed for all the Gd-containing alloys is attributed to the large solidification temperature range associated with the peritectic formation of the (Fe, Ni, Cr)₃Gd phase. The increase in cracking susceptibility observed with increasing Gd concentration is attributed to increased amounts of Gd-rich liquid that exist at the end of solidification.

Acknowledgments

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The Effect of Welding Procedure on 
ANSI/AWS A5.29-98 E81T1-Ni1 Flux Cored 
Arc Weld Metal Deposits

BY H. G. SVOBODA, N. M. RAMINI DE RISSONE, L. A. DE VEDIA, AND E. S. SURIAN

ABSTRACT. The objective of this work was to study the effects that different shielding gases (CO\textsubscript{2} and a mixture of 80\% Ar/20\% CO\textsubscript{2}), welding position (flat and uphill), arc energy (1.0 vs. 1.9 kJ/mm) and number of passes per layer (two and three) have on the all-weld-metal microstructure and mechanical properties of an ANSI/AWS A5.29-98 E81T1-Ni1 flux cored wire, 1.2 mm diameter. Hardness, tensile, and impact tests were used to assess the mechanical properties, and quantitative metallographic analyses were performed to identify the resulting microstructures. In general, ANSI/AWS A5.29-98 E81T1-Ni1 (E81T1-Ni1M) mechanical requirements were comfortably satisfied under Ar/CO\textsubscript{2}, but significant variations were found with different welding procedures. These variations have been rationalized in terms of the microstructure and chemical composition of the weld deposits. The strength and toughness of welds produced with Ar/CO\textsubscript{2} were quite sensitive to minor changes in heat input, while the CO\textsubscript{2} welds exhibited little deviation in these properties with nearly identical changes in heat input.

Introduction

During the last twenty to thirty years, there has been a worldwide trend toward replacing shielded metal arc welding using flux covered electrodes with other processes that have higher deposition rates and lend themselves to automation (Ref. 1). In spite of some negative features, the shielded metal arc process (Ref. 2) will not be completely replaced in the foreseeable future, but it is estimated that approximately 70\% of the deposited weld metal will come from more efficient processes in the future. Continuous wires are increasingly used, and among them, flux and metal cored wires. These welding consumables are very versatile because relatively small quantities of electrodes can be produced with a wide variety of weld deposits and different chemical compositions, which exhibit adequate mechanical properties for most welding applications (Refs. 3-5). Among the different cored wire types, those using gas protection are flux covered and metal cored wires. They present different characteristics, advantages, and disadvantages. It is known that flux cored wires provide improved joint penetration, smooth arc transfer, low spatter levels, and, most important, are easier to use than solid wires (Refs. 6, 7). It is also possible to achieve high deposition rates (Ref. 6, 7) with them.

On the other hand, it is well known that the employment of different shielding gases as well as changes in the welding procedure parameters lead to variations in the deposit characteristics (Refs. 8-15). Generally, the most frequently used gas for welding with rutile-type flux cored wires is CO\textsubscript{2}, but it is also possible to use Ar/CO\textsubscript{2} mixtures. This type of mixture results in improved appearance, less spatter, and better arc stability (Ref. 8). On the other hand, in all arc welding processes, the arc energy influences metallurgical transformations and resulting mechanical properties and microstructure (Refs. 9-13), so it is very important to control it. In multipass welding, changes in welding parameters lead to different arc energies and different numbers of passes per layer for the same joint design (Refs. 9, 10). The welding position is another important variable (Ref. 16). The objective of this work was to study the effect of shielding gas type (CO\textsubscript{2} and Ar/CO\textsubscript{2} mixture), flat and uphill welding positions, arc energy, and number of passes per layer (two and three) on the all-weld metal mechanical properties and microstructure obtained from ANSI/AWS A5.29-98 E81T1-Ni1 flux cored wire.

Experimental Procedure

Weldments/Electrodes

The consumable employed in this work was a commercial product that, according to the manufacturer, is classified as ANSI/AWS A5.29-98 (Ref. 17) E81T1-Ni1 flux cored wire, 1.2-mm diameter.

Test Specimens

With this wire, eight all-weld-metal test coupons were prepared for flat welding according to ANSI/AWS A5.29-98 standard (Ref. 17), which is shown in Fig. 1A. The preparation included the following:

1. Two shielding gases: pure CO\textsubscript{2} and a mixture of 80\% Ar-20\% CO\textsubscript{2} (Ar/CO\textsubscript{2}).
2. Two arc energies: high (two beads per layer) and low (three beads per layer).
3. Flat and uphill welding positions.

The key to the identification of the weld test specimens is C means welding under CO\textsubscript{2} and A welding under Ar/CO\textsubscript{2} shielding; 2 and 3 represent the number of passes per layer, while F and V the flat and uphill welding positions, respectively. Welding parameters employed are shown in Table 1.
Fig. 1 — A — Location of test specimens in plan view (left) and cross section showing joint preparation (right); B — location of impact and tensile test specimens in perspective.

### Table 1 — Welding Parameters Used for the All-Weld-Metal Test Coupons

<table>
<thead>
<tr>
<th>Weld Type</th>
<th>Protection</th>
<th>No. Passes per Layer</th>
<th>No. Layers</th>
<th>Intensity (A)</th>
<th>Tension (V)</th>
<th>Welding Speed (mm/s)</th>
<th>Heat Input (kJ/mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C2F</td>
<td>CO₂</td>
<td>2</td>
<td>6</td>
<td>230</td>
<td>30</td>
<td>4.4</td>
<td>1.8</td>
</tr>
<tr>
<td>C3F</td>
<td>CO₂</td>
<td>3</td>
<td>6</td>
<td>195</td>
<td>28</td>
<td>4.8</td>
<td>1.3</td>
</tr>
<tr>
<td>A2F</td>
<td>Ar/CO₂</td>
<td>2</td>
<td>6</td>
<td>210</td>
<td>28</td>
<td>3.3</td>
<td>1.9</td>
</tr>
<tr>
<td>A3F</td>
<td>Ar/CO₂</td>
<td>3</td>
<td>6</td>
<td>200</td>
<td>27</td>
<td>5.2</td>
<td>1.2</td>
</tr>
<tr>
<td>C2V</td>
<td>CO₂</td>
<td>2</td>
<td>6</td>
<td>170</td>
<td>23</td>
<td>2.5</td>
<td>1.7</td>
</tr>
<tr>
<td>C3V</td>
<td>CO₂</td>
<td>3</td>
<td>6</td>
<td>153</td>
<td>21</td>
<td>3.1</td>
<td>1.2</td>
</tr>
<tr>
<td>A2V</td>
<td>Ar/CO₂</td>
<td>2</td>
<td>6</td>
<td>170</td>
<td>22</td>
<td>2.3</td>
<td>1.9</td>
</tr>
<tr>
<td>A3V</td>
<td>Ar/CO₂</td>
<td>3</td>
<td>6</td>
<td>154</td>
<td>21</td>
<td>3.4</td>
<td>1.0</td>
</tr>
<tr>
<td>AWS</td>
<td></td>
<td>2 or 3</td>
<td>5 to 8</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

Coupools were welded in the flat and uphill positions with different gas shielding. Preheating temperature was 150°C. Interpass temperature was in the range of 140-150°C. The plates were buttered with the same electrode used as filler metal and preset to avoid excessive distortion. Electrode extension was 20 mm in all cases. Gas flow: 20 L/min. NS: not specified. (a): only for flat welding position.

### Results and Discussion

**All-Weld Metal Chemical Composition**

Table 2 presents the all-weld-metal chemical composition. A marked variation in the oxygen levels was observed, with higher values in the welds made with CO₂ protection. Due to this difference, carbon, manganese, and silicon values were lower for this type of gas. Nitrogen values were very low, as well as residual elements such as P, S, Cr, Mo, V, Cu, Co, and Al showing a very clean weld deposit. No influence of the heat input was detected (two or three passes per layer). Considering the chemical composition under Ar/CO₂, the AWS requirements were satisfied.

It has been shown (Ref. 5) that when the same wire is used with the Ar/CO₂ gas mixture instead of pure CO₂, the O content in the gas mixture, which originates from the decomposition of CO₂, decreases, as well as the O partial pressure in the arc. With Mn and Si being deoxidants in addition to alloying elements, a smaller amount of these elements will be oxidized under Ar/CO₂ than under CO₂, leading to a higher recovery of them in the weld metal.

### Metallographic Analysis

#### General

Table 3 shows the area fraction of columnar and reheated coarse- and fine-grained zones (HAZ), corresponding to the Charpy V-notch location. It was seen that the proportion of columnar zones was always larger in samples welded with
lower arc energy (three passes per layer) as previously found (Refs. 9, 10, 21, 22). This observation is mainly related to the geometrical distribution of the weld beads in relation to the location of the Charpy V-notch and the relative increment of the columnar zone with respect to the reheated zone when heat input is reduced (Ref. 22).

When compared to the samples welded in the flat position, those welded in the uphill position presented a larger proportion of columnar zones, as shown by Evans (Ref. 16) for shielded metal arc weld deposits of the ANSI/AWS A5.1-91 E7018 type, and smaller amount of fine-grained recrystallized zones as found previously (Ref. 22). The largest proportion of reheated zones and within these the largest amount of fine-grained recrystallized zones were found in the welds welded in the flat position under Ar/CO₂ shielding.

### Columnar Zone — As-Welded

Table 4 shows the percentages of microconstituents present in the columnar zone of the last bead of each weld. A lower proportion of acicular ferrite (AF), a higher amount of grain boundary primary ferrite (PF[G]), along with a higher proportion of intragranular primary ferrite (PF[I]) and higher ferrite content with second phase, aligned (FS[A]) and not aligned (FS[NS]), were found for CO₂ shielding than for the Ar/CO₂ gas mixture. No effect of the variation of heat input was detected. The higher amount of PF(G) found in the coupons welded under CO₂ may be related to the corresponding higher oxygen content in the weld metal that could increase the amount of inclusions present in the primary grain boundaries that acted as nucleation sites for grain boundary ferrite (Refs. 23, 24). Additionally, the C, Mn, and Si contents in the CO₂ welds were lower than in Ar/CO₂ welds, reducing the hardenability of the weld metal and increasing the proportion of PF(G).

Table 4 also shows the average columnar grain widths, which were measured only in deposits obtained under CO₂ shielding due to the very low amount of grain boundary ferrite in welds made under Ar/CO₂. For both welding positions, it was observed that lower values of prior austenite grain size were achieved for lower heat inputs, as found previously (Refs. 9, 10, 22).

### Reheated Zones (HAZ)

The results from the measurements of the fine-grained size of the reheated zone (HAZ) are also presented in Table 4. For flat welding position, a smaller reheated zone fine-grained size could be seen in deposits welded under Ar/CO₂. In the uphill welding position, no differences were found. Figure 4 shows the microstructure of these regions where this effect can be observed.

### Mechanical Properties

#### Hardness

Table 5 presents the microhardness values obtained in the columnar, coarse, and fine reheated zones, as well as the weighted averages. As a general tendency, columnar and coarse-grained reheated zones presented similar hardness values, but higher than the fine-grained reheated zone. Deposits welded under Ar/CO₂ shielding presented higher HAZ-FG, HAZ-CG, columnar zone, and weighted average values than under
The values of absorbed energy for each test temperature in the Charpy V-notch tests are presented in Table 7. Figures 5 and 6 show the absorbed energy vs. testing temperature for each gas shielding type. Table 8 shows the testing temperatures corresponding to 50 J and 100 J of absorbed energy for each weld.

These welds were very sensitive to welding procedure variations. The best impact properties at low temperatures, particularly at -60°C, were achieved under the Ar/CO₂ mixture, with two and three passes per layer in the flat welding position, and under CO₂ in the uphill position also with two and three passes per layer. The outstanding low-temperature impact behavior for the A2F and A3F welds can be explained by the fact that these deposits presented the lowest O content, intermediate Mn level, the lowest proportion of columnar zone, the highest AF volume fraction, the lowest amount of PF(G) in the columnar zone, and the highest fine-grained recrystallized zone. The A2F weld deposit that presented the best impact properties (on average 120 J at -80°C) also showed the highest percentage of fine-grain reheated zone.

The excellent impact properties in the uphill welds made with CO₂ shielding for both heat inputs can be explained by the intermediate Mn content between 1.3% and 1.4%. In this respect, it is worth noting that weld A3F showed at -60°C somewhat lower impact values than A2F, C2V, and C3V welds. This difference in impact behavior can be the result of weld A3F having a slightly higher Mn level (1.47% Mn) than the other mentioned welds (1.3-1.4% Mn). This difference in impact properties becomes more marked at -80°C. A Mn level between 1.2 and 1.4% was signaled as the optimum by Evans (Ref. 25) to achieve the best impact properties at low temperature in 1% Ni-bearing welds. Figure 7 shows the impact values obtained at -80°C as a function of the Mn content where the optimum Mn level is between 1.3% and 1.4% (Ref. 25).

Additionally, C2V and C3V welds presented the lowest recrystallized fine-grained size, and in particular weld C3V showed the smaller prior austenite average grain width, which is consistent with weld C3V presenting higher impact values than C2V, particularly at -80°C. It is worth noting that very good impact values were obtained with C2V and C3V deposits, notwithstanding that these welds had a relatively low proportion of AF, and a relatively high content of PF(G). This fact points to the limitations of explaining the mechanical behavior of multipass weld deposits in terms of the microstructure of the last bead, since this is not necessarily representative of the microstructure in the region where the notch of the Charpy V specimen is located.

C2F and C3F deposits showed the lowest impact properties at low temperatures. They presented the lowest contents of both AF and Mn, which is consistent with the effect that Mn has in promoting formation of AF. Besides, these welds had the highest proportion of PF(G), leading to a reduction of tensile properties and hardness values. As a general trend in welds made under Ar/CO₂ shielding for both welding positions, a marked reduction in toughness was found in welds made with three passes per layer (lower heat input). In welds made under CO₂, a much smaller effect of heat input on toughness was detected.

Table 9 shows the values of absorbed energy at -29°C. It can be seen that for any welding condition, the AWS requirement of 27 J on average for this temperature, was comfortably satisfied. There was not a single value under the required minimum.
In spite of having found differences in the toughness values for the different welding conditions, the consumable object of this work presented excellent impact properties for all the temperature range considered and for all the conditions studied.

As a final remark, the importance of matching the shielding gas to the consumable should be emphasized, since using Ar/CO₂ shielding gas and consumables designed for use with 100% CO₂ may result in richer-than-expected deposits, which may or may not meet the anticipated mechanical properties.

Conclusions

In all-weld-metal samples produced with 1.2-mm-diameter ANSI/AWS A5.29-98 E81T1-Ni flux cored electrode using CO₂ and Ar/CO₂ shielding, in the flat and uphill welding positions, with high arc energy (two passes per layer) and low arc energy (three passes per layer), the following was found:

- The all-weld-metal test specimens welded under CO₂ presented lower levels of C, Mn, and Si and higher oxygen contents. Carbon, Mn, and Si were also lower in the flat welding position for both shielding gases. Nitrogen contents were all very low. Silicon contents of welds made under CO₂ in the flat position were the lowest.
- For both shielding gases, columnar zone percentages were higher for three passes per layer (lower heat input) and the uphill position.
- Under CO₂ shielding, average columnar grain widths were lower with three passes per layer (lower heat input). Under Ar/CO₂, it was not possible to perform this measurement due to the absence of PF(G).
- In the columnar zones of welds made under CO₂, the AF volume fraction was lower and PF(G) volume fraction was higher than in those made under Ar/CO₂.

Table 6 — All-Weld-Metal Tensile Properties

<table>
<thead>
<tr>
<th>Properties</th>
<th>C2F</th>
<th>C3F</th>
<th>A2F</th>
<th>A3F</th>
<th>C2V</th>
<th>C3V</th>
<th>A2V</th>
<th>A3V</th>
<th>Req. AWS</th>
</tr>
</thead>
<tbody>
<tr>
<td>UTS (MPa)</td>
<td>597</td>
<td>497</td>
<td>572</td>
<td>619</td>
<td>554</td>
<td>560</td>
<td>598</td>
<td>694</td>
<td>550-690</td>
</tr>
<tr>
<td>YS (MPa)</td>
<td>425</td>
<td>424</td>
<td>490</td>
<td>538</td>
<td>483</td>
<td>487</td>
<td>507</td>
<td>642</td>
<td>470 min.</td>
</tr>
<tr>
<td>e (%)</td>
<td>30</td>
<td>26</td>
<td>25</td>
<td>24</td>
<td>25</td>
<td>26</td>
<td>21</td>
<td>18</td>
<td>NR</td>
</tr>
<tr>
<td>A (%)</td>
<td>77</td>
<td>76</td>
<td>79</td>
<td>75</td>
<td>77</td>
<td>73</td>
<td>73</td>
<td>73</td>
<td>NR</td>
</tr>
<tr>
<td>Heat input (kJ/mm)</td>
<td>1.8</td>
<td>1.3</td>
<td>1.9</td>
<td>1.2</td>
<td>1.7</td>
<td>1.2</td>
<td>1.9</td>
<td>1.0</td>
<td>NR</td>
</tr>
</tbody>
</table>

(a) E81T1-Ni classification requires CO₂ protection and E81T1-NiM requires 75%-80%Ar/balanceCO₂ protection.
### Table 7 — All-Weld-Metal Charpy-V Impact Test Results (J)

<table>
<thead>
<tr>
<th>T (°C)</th>
<th>C2F</th>
<th>C3F</th>
<th>A2F</th>
<th>A3F</th>
<th>C2V</th>
<th>C3V</th>
<th>A2V</th>
<th>A3V</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>202</td>
<td>183</td>
<td>178</td>
<td>145</td>
<td>158</td>
<td>159</td>
<td>134</td>
<td>100</td>
</tr>
<tr>
<td>-40</td>
<td>139</td>
<td>134</td>
<td>134</td>
<td>121</td>
<td>133</td>
<td>133</td>
<td>103</td>
<td>56</td>
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<tr>
<td></td>
<td>16</td>
<td>13</td>
<td>120</td>
<td>45</td>
<td>78</td>
<td>100</td>
<td>51</td>
<td>48</td>
</tr>
</tbody>
</table>

The values in the upper line correspond to measurements and the single values in the lower line are their averages.

(a) Req. AWS, -29°C 27 J

### Table 8 — 50 and 100 J Absorbed Energy Transition Temperatures

<table>
<thead>
<tr>
<th></th>
<th>C2F</th>
<th>C3F</th>
<th>A2F</th>
<th>A3F</th>
<th>C2V</th>
<th>C3V</th>
<th>A2V</th>
<th>A3V</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 J, T (°C)</td>
<td>-70</td>
<td>-60</td>
<td>&lt;=-80</td>
<td>-70</td>
<td>&lt;=-80</td>
<td>-70</td>
<td>&lt;=-43</td>
<td></td>
</tr>
<tr>
<td>100 J, T (°C)</td>
<td>-55</td>
<td>-42</td>
<td>&lt;=-80</td>
<td>-59</td>
<td>-67</td>
<td>&lt;=-83</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(a) At the minimum test temperature employed (-190°C), it absorbed 120 J on average.

(b) At the minimum test temperature employed (-20°C), it absorbed 109 J on average.

### Table 9 — Charpy-V Absorbed Energy in J at -29°C

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>-29°C</td>
<td>158</td>
<td>134</td>
<td>175</td>
<td>130</td>
<td>155</td>
<td>148</td>
<td>104</td>
<td>61</td>
<td>27 J min.</td>
</tr>
</tbody>
</table>

-29°C is the AWS test temperature requirement.

Reheated zone fine-grain sizes were larger in the flat welding position and under CO2.

- Hardness in specimens welded under CO2 was lower than specimens made using Ar/CO2 mixture. A similar effect was found with two passes per layer (higher heat input) when compared to specimens with three passes per layer (lower heat input).

- Tensile properties were higher in welds made under Ar/CO2 mixture and with three passes per layer (lower heat input), in correlation to chemical composition and hardness results.

- With Ar/CO2 shielding, impact values were higher in the flat welding position and with two passes per layer (higher heat input).

- With CO2 shielding, the best toughness was obtained in the uphill welding position, but the results were very close for all the welding conditions used with this gas.

- Considering all the welding conditions, the best impact values were achieved in the flat welding position with two passes per layer (higher heat input) and under Ar/CO2, and the lowest values were obtained with the same shielding gas, in the uphill welding position, and three passes per layer (lower heat input).

- The strength and toughness of welds produced with Ar/CO2 were quite sensitive to minor changes in heat input, while the CO2 welds exhibited little deviation in these properties with nearly identical changes in heat input.

- ANSI/AWS A5.29-98 E81T1-Ni (E81T1-Ni1M) requirements were comfortably satisfied under Ar/CO2.

### Acknowledgments

The authors wish to express their gratitude to Air Liquide Argentina S.A. for supplying the consumables and the facilities for the production of the welds; to the Centre Technique des Applications du Soudeage, Air Liquide France, for conducting nitrogen and oxygen determinations; to Conacso-ESAB Argentina for carrying out the chemical analysis; and to the Fundación Latinoamericana de Soldadura, Argentina, for the facilities provided to weld and for machining and mechanical testing. Authors recognize ANPCyT, Argentina, for the financial support.

### References


2. Ferrero, S. E. 1995. New generation of...


ABSTRACT. This paper examines the effects of fusion zone size on failure modes, static strength, and energy absorption of aluminum spot welded samples using a combined experimental, statistical, and analytical approach. The main failure modes for aluminum spot welds are nugget pullout and interfacial fracture. First, static strength tests using coupon configurations of lap shear, cross tension, and coach peel were performed on the joint populations with a controlled fusion zone size. Thirty replicate static strength tests were performed for each coupon configuration. The resulting peak load and energy absorption levels associated with each failure mode were studied using statistical models. Next, an analytical model was developed to determine the failure mode of an aluminum resistance spot weld based on load limit analyses. It was found that fusion zone size, sheet thickness, and the level and location of weld porosity/defects are the main factors influencing the cross-tension failure mode of an aluminum spot weld. Two additional spot weld populations with different fusion zone sizes were then fabricated to validate the analytical failure mode model. Static cross-tension tests were again performed, and the experimental observations confirmed the analytically predicted failure modes for each population.

Introduction

Resistance spot welding (RSW) has been used for decades by automotive and other industries for fabricating sheet metal assemblies. Resistance spot welding is easy to operate, automate, control, and perform, and thus is an ideal joining technology for mass production. Over the years, RSW technology has been perfected for various steel grades and sheet metal thicknesses to deliver high-quality, durable structural joints (Refs. 1–3). Recently, because of their light weight and relatively high strength, more and more aluminum alloys have been used in the construction of automobile body and panel parts to reduce weight and therefore enhance fuel efficiency. As one of the principal joining methods in the automotive industry, the RSW process for aluminum alloys has been studied intensively over the past two decades (Refs. 4–8).

Spot welding of aluminum alloys shares the same overall Joule heating principle as spot welding of steel. However, because of the relatively low density and high thermal and electrical conductivity of aluminum alloys, aluminum spot welding also presents some unique challenges to the automotive industry. Higher welding currents, typically two to three times those of steel, and only one-third of the welding duration (or pulse times) were used. The issues associated with production welding of aluminum alloys include weld porosity, weld expulsion, electrode wear, and inconsistency in failure mode during coupon-level joint quality evaluation (Refs. 17, 18)

As a means of quality control, the domestic automotive industry historically has adopted an approach and criterion for aluminum spot welds similar to those used in spot welds of mild steel; that is, a peel test to determine whether a satisfactory weld has been produced. The common criterion is borrowed from the conventional spot weld criterion for mild steel, in which the minimum weld button diameter \(D\) should be equal to or larger than \(4V_t\) (Ref. 9). Under-sized welds have an average weld button diameter larger than \(2V_t\), but less than \(4V_t\). Defective welds have average weld button diameters less than or equal to \(2V_t\). Any weld that fails in the interfacial fracture mode would be considered a “bad” weld and would be rejected by the quality control inspector.

This criterion works relatively well for mild steel spot welds because the weld nugget has a significantly higher hardness level (therefore yield strength) than the base material; hence, the nugget pullout mode would produce the highest joint strength. On the other hand, the effectiveness of this criterion for the quality evaluation of aluminum spot welds and advanced high-strength steel spot welds has not been adequately studied by the automotive welding community; it was adopted from mild steel spot welds without much in-depth study. Because of the more frequent occurrence of interfacial fracture, many domestic automotive companies do not have confidence in aluminum spot welds and are now pursuing alternative, yet more expensive, joining techniques such as riveting and/or clinching.

The purpose of this paper is to study the effects of fusion zone size and failure modes on the peak load and energy absorption levels of aluminum spot welds. First, two sample weld populations were considered:

1) Weld population ID14: RSW of 2-mm 5182-O to 2-mm 5182-O
2) Weld population ID15: RSW of 2-mm 5182-O to 2-mm 6111-T4

For each weld population, three coupon configurations were included in the static tests: lap shear, cross tension, and coach peel. See Figs. 1–3 for specimen design, dimensions, and fixture design. For each static test, a load vs. displacement curve was recorded, as were the failure mode and nugget size/fusion zone size of the joint sample. The total energy absorption, which is represented by the area under the load vs. displacement curve, was then calculated through numerical integration. Thirty identical static strength tests were performed for each joint con-
Fig. 1 — Lap-shear coupon design and test fixture.

Fig. 2 — Cross-tension coupon design and test fixture.

Fig. 3 — Coach peel coupon design and fixture.

Fig. 4 — Typical metallurgical cross sections for ID14 and ID15.

configuration, and statistical analyses were performed to study the effects of different failure modes on the peak load and energy absorption of the weld joints.

Next, a simple, limit-load-based analytical model was derived to rationalize the experimental observed failure modes for aluminum spot welds with the aid of microhardness measurements of the weld samples. Two additional weld populations with different fusion zone sizes were then fabricated and tested to validate the analytical model. The goal of this study is to provide welding engineers with some insights on the anticipated joint failure modes for a given weld population with certain weld attributes, and to discuss the effects of weld size and weld porosity (irregularity) level on the anticipated levels of weld strength and failure mode.

Experimental Study

The initial experimental work in this investigation consisted of quasistatic tests of lap shear, coach peel, and cross tension of ID14 and ID15. The specimen and test fixture designs are shown in Figs. 1–3. The RSW specimens were fabricated at the Alcoa Technical Center. The following welding parameters were used in the coupon fabrication process:

- **Electrodes**: 0.370-in. face diameter truncated electrode
- **Current**: ~34.0 kA, 80% current, AC welding machine
- **Force**: 1050 lbf
- **Weld time**: 8 cycles
- **Water flow rate**: 2.6 gal/min.

Special efforts were made to ensure that the location of the welds was in the width center of the specimens. Electrode tips were dressed every 15 welds to ensure weld consistency. Peel tests and metallographic cross sections were used to maintain a nugget diameter of ~8 mm for all specimens. Figure 4 shows the typical weld metallurgical cross sections for ID14 and ID15, respectively.

Quasistatic tests at a rate of 10 mm/min were performed on these specimens to determine their load vs. displacement curves. Figure 5 shows the typical experimental results for ID14 under the three loading configurations. Thirty static tests were performed for each joint population and each loading configuration. Tables 1–6 tabulate the test results with peak load, failure mode, and energy absorption for each population and each loading configuration. Nomenclatures used in defining different failure modes are also included at the end of Table 1.

**Lap Shear Tests**

For lap shear samples of both populations ID14 and ID15, interfacial fracture was the only failure mode observed. The average peak failure load for ID14 was 7.16 kN, and the average peak failure load for ID15 was 7.17 kN, with no significant amount of sheet bending deformation observed for either population.

**Cross-Tension Tests**

Both nugget pullout and interfacial fracture modes were observed for the cross-tension samples of ID14 and ID15, and the majority of the samples failed in pullout mode. The average peak loads were 6.05 and 5.95 kN for ID14 and ID15, respectively. A detailed statistical analysis will be presented in the next section to study whether different failure modes have a significant influence on the peak failure loads for these two populations.

**Coach Peel Tests**

Similar to the cross-tension samples, the failure modes for coach peel samples were also a combination of nugget pullout and interfacial fracture. However, in coach peel samples, interfacial fracture and partial interfacial fracture (a combination of interfacial fracture and later stage nugget pullout) were more often ob-
Fig. 5 — Sample load vs. displacement curves for ID14.

Fig. 6 — Weibull distribution comparing ID14 peak load distribution for interfacial fracture and pullout modes.

Table 1 — ID14 Lap-Shear Data Summary

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Peak Load (kN)</th>
<th>Energy (Nm)</th>
<th>Failure Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Joint ID 14 (RSW): 5182-0/5182-0 (2 mm/2 mm)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>14LC-1</td>
<td>7.02</td>
<td>13,129.72</td>
<td>IF</td>
</tr>
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<td>14LC-2</td>
<td>7.11</td>
<td>10,593.42</td>
<td>IF</td>
</tr>
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<td>14LC-3</td>
<td>6.99</td>
<td>12,426.27</td>
<td>IF</td>
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<td>14LC-4</td>
<td>7.64</td>
<td>11,488.31</td>
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<td>14LC-5</td>
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<td>14LC-6</td>
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<td>7.15</td>
<td>9,101.55</td>
<td>IF</td>
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</table>

Nomenclature throughout Tables 1-8:
IF: Interfacial fracture
PO: Nugget pullout
SS: Sheet shearing
PO-IF: Pullout is primary failure mode; interfacial fracture is secondary failure mode

The statistical characteristics of a data set can be analyzed with some mathematical tools such as a probability paper (Ref. 10-11). Following specific mathematical procedures, if all the data points in a data set plot approximately on a straight line on a certain probability paper, the distribution corresponding to that paper may be an appropriate distribution model for the data population under examination. Moreover, the characteristics of the line fitting the data on the probability paper will quantify the mean value and standard deviation of the data population according to the specific distribution type.

Construction of Weibull Plots

To study the effects of different failure modes on the peak load and energy absorption for the weld samples in ID14 and ID15, we took the static test results listed in Tables 2, 3, 5, and 6 and categorized them into two subpopulations based on individual samples' failure modes, namely, nugget pullout failure and interfacial fracture failure. The data points within each subpopulation were then sorted in ascending order in terms of peak load or energy absorption in order to be plotted on Weibull probability paper (Ref. 10). Figures 6 and 8 show the Weibull plots of peak load for ID14 and ID15, respectively, and Figs. 7 and 9 show the Weibull plots of energy absorption levels for ID14 and ID15, respectively. It should be noted that the cases with partial interfacial fracture were grouped as interfacial fracture based on their primary failure modes.

Assuming the available data points in each subpopulation of different failure modes are sufficient for statistical significance, the characteristics of the Weibull plots for interfacial fracture and nugget

\[ F = 1 - \exp \left( -\frac{\sigma}{\sigma_0}^m \right) \] (1)

in which \( F \) denotes median estimator of the cumulative failure probability and is given by \( F = (i - 0.3)/(N + 0.4) \), where \( i \) is the ranking of each specimen with values 1, 2, ..., \( N \) and \( N \) is the total number of specimens, \( \sigma \) is the peak load (or energy absorption), and \( \sigma_0 \) and \( m \) are Weibull parameters. Physically, as may be verified from Equation 1, \( \sigma_0 \) is the peak load (or energy) value corresponding to a failure probability of 63.2%, and \( m \) is the slope of \( \ln \ln \left( \frac{1}{1 - F} \right) \) vs. \( \ln \sigma \) plot, otherwise known as Weibull modulus, or shape parameter (Ref. 11). For a unimodal distribution, \( m \) is analogous to the inverse of the standard deviation expressed as a fraction of mean strength. Therefore, the more vertical the data line is on a \( \ln \ln \left( \frac{1}{1 - F} \right) \) vs. \( \ln \sigma \) plot (or Weibull plot), the higher the value \( m \), and the less scattered the data are in a statistical sense.
pullout modes can provide the median value as well as the degree of scatter for each failure mode. It should be noted that since interfacial fracture was the only failure mode observed for all the lap shear samples of ID14 and ID15, no statistical study was performed on the data listed in Tables 1 and 4.

Cross Tension

The linearity of curve fittings for pullout and interfacial fracture failure modes in Figs. 6–9 suggests that the peak load and energy distribution under cross tension for ID14 and ID15 can be modeled approximately with Weibull distributions with different shape parameters.

For ID14 under cross tension, the Weibull plots in Fig. 6 show that the median peak load for interfacial fracture is about 10% lower than the median peak load for pullout failure. Consistently, the median energy absorption for interfacial fracture is about 10% lower than that of pullout mode for this population. Since the fitted straight lines in Fig. 6 are almost parallel, it is concluded that the interfacial fracture and pullout failure modes have the same shape parameters for Weibull distribution, and therefore the degree of peak load and energy scatter is about the same for these two failure modes for ID14.

For ID15 under cross tension, the Weibull plots in Fig. 8 show that the median peak load levels for the two failure modes are almost identical. However, the interfacial fracture mode shows a higher level of scatter on peak load than the pullout mode. Similar observations can be made for the energy absorption levels for the two failure modes for ID15 under cross tension — Fig. 9.

Coach Peel

Under coach peel loading configuration, the lack of linearity of the data points for ID14 and ID15 indicates that a unimodal Weibull distribution cannot be used to correctly model the entire data population — Figs. 6–9. However, the few cases in the peak load distributions that do not fit on the straight lines are mostly the cases with combined failure modes of nugget pullout and sheet tearing. If we were to consider the majority cases represented by the straight lines, consistent conclusions on peak load distributions under the coach peel condition can again be reached for the two weld populations as those under cross tension: the median peak load for interfacial fracture mode is lower than that of the nugget pullout mode. But the median value difference for the two failure modes is less than 10%.

The distributions for energy absorption under coach peel loading conditions for ID14 and ID15 have a bilinear nature. Therefore, bimodal Weibull distributions may be more suitable for these energy distributions. In Fig. 7, the cases with sheet tearing have distinguishable higher energy levels due to the additional energy absorbed by base metal tearing deformation.

In conclusion, the above statistical analyses indicate that the median peak load for the cases that failed in interfacial fracture mode is about 10% lower than that of the cases that failed in pullout mode for ID14, and that the median peak load is about the same for ID15 with different shape parameters. Similar conclusions can also be reached for the energy absorption levels. These results indicate that, for weld populations ID14 and ID15, the differences in failure modes under cross-tension and coach peel conditions do not produce a significant difference in the specimens’ peak load and energy absorption levels. Nugget pullout mode only produces slightly higher peak load and energy absorption.

It should also be noted that, in general,
Table 3 — ID14 Coach-Peel Data Summary

<table>
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<th>Specimen</th>
<th>Peak Load (N/mm)</th>
<th>Energy Absorption (kJ)</th>
<th>Failure Mode</th>
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</thead>
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</table>

In Equation 2, $A_{total}$ is the total area of the fusion zone on the faying interface, and $A_{porosity}$ is the projected area of porosity in the fusion zone on the faying interface of the weld. The factor $f$ is defined in such a way that a porosity-free weld has an $f$ value equal to 1.0, and a weld that has some degree of porosity on the faying interface has an $f$ value less than 1.0, but greater than 0. We assume that porosity does not concentrate at the weld periphery, such that the existence of porosities does not affect the local stress distribution around the weld tip and therefore would not influence the local crack growth path for the weld under static cross-tension loading.

It should be mentioned that the location of porosity within an aluminum spot weld is a topic that attracts the attention of many researchers. Our assumption here that porosities do not locate at the weld periphery is supported by the typical cross sections of welds in ID14 and ID15 as shown in Fig. 4. Furthermore, the experimental studies by Chuko and Gould (Ref. 18) showed that weld porosity at the nugget edge faying interface held constant at less than 1% and away from the fusion zone periphery for the first 200 spot welds of 1-mm AA5754 sheet with chromate-based coating. Chuko and Gould (Ref. 18) also reported a sharp increase of weld porosity at the nugget edge on the fusion interface (of up to 20% of the nugget edge area) for the first 200 spot welds of 1-mm AA5754 sheet with chromate-based coating. The presence of porosities in the weld nugget edge faying interface has been reported to reduce the strength of the weld by up to 20%.
9%) for the 200th and 300th welds during their electrode life study. Since we do not address the effects of electrode wear on joint strength and failure mode in this study, our assumption on porosity location for the welds made with fresh electrodes should be sufficient.

Assuming axisymmetric deformation under the cross tension loading condition, the peak load for a weld to fail in interfacial fracture mode can be approximated as

\[ F_{IF} = f \cdot A_{nug} \cdot \sigma_y \cdot \text{weld} \]

\[ = f \cdot \pi \cdot d^3 \cdot \sigma_y \cdot \text{weld} \]  

(3)

where \( \sigma_y \cdot \text{weld} \) represents the tensile yield strength of the weld metal. We use tensile yield strength of the weld metal instead of ultimate strength because this is a limit load analysis in which no local material hardening or necking is considered (Ref. 13).

On the other hand, if the spot welds fail in nugget pullout mode, experiments have shown that failure normally occurs by through-thickness shear in the heat-affected zone (Ref. 13). Therefore, the peak load for a weld to fail in nugget pullout mode under cross tension can be approximated as

\[ F_{PD} = \pi \cdot D \cdot t \cdot \sigma_y \cdot \text{HAZ-shear} \]  

(4)

In Equation 4, \( \sigma_y \cdot \text{HAZ-shear} \) represents the shear yield strength of the heat-affected zone. Again, this is a limit load estimation in which yield strength is used instead of ultimate strength because no necking or material hardening in the heat-affected zone are considered. It should be mentioned that Equation 4 also assumes no significant weld indentation. If noticeable weld indentation occurs from the welding process, a reduced level of tensile yield strength should be used, based on the actual residual sheet thickness around the weld periphery.

The failure mode for a specific weld under cross-tension loading condition can then be determined by selecting the failure mode associated with the lower peak load level according to Equations 3 and 4, given the values of \( \sigma_y \cdot \text{weld} \) and \( \sigma_y \cdot \text{HAZ-shear} \). In principle, this methodology should apply for both steel and aluminum spot welds. Here we use aluminum spot welds as an example.

In order to ensure pullout failure for an aluminum spot weld, the following inequality needs to be satisfied:

\[ F_{PD} < F_{IF} \]

(5)

Table 4 — 1D15 Lap-Shear Data Summary

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Peak Load (kN)</th>
<th>Energy (Nmm)</th>
<th>Failure Mode</th>
</tr>
</thead>
<tbody>
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<td>IF</td>
</tr>
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<td>IF</td>
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<td>IF</td>
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</table>

Table 4 — 1D15 Lap-Shear Data Summary

very difficult to obtain accurate shear data on materials that exhibit some ductility, very little data exist on the shear yield strength for the HAZ, \( \sigma_{y-HAZ-shear} \). It is
Table 5 — ID15 Cross-Tension Data Summary

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Cross Tension</th>
<th>Energy (Nmm)</th>
<th>Failure Mode</th>
<th>Nugget Side</th>
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<tbody>
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</table>

Maximum 6.97 67,526.00
Mean 5.95 50,634.27
Minimum 4.38 33,004.00

Generally agreed that the shear yield strength of ductile cast iron is about 0.6 to 0.7 times its tensile yield strength (Ref. 15). Taking a similar approach, we assume here that the shear yield strength of the HAZ is about 70% of its tensile yield strength. Summarizing the above yield strength analyses, we have

\[ \sigma_y \]_weld = \sigma_y \]_base-metal \ (6) \n
\[ \sigma_y \]_HAZ-shear = 0.7 \cdot \sigma_y \]_HAZ \n
\[ = 0.7 \cdot 115\% \cdot \sigma_y \]_base-metal \n
\[ = 0.8 \cdot \sigma_y \]_base-metal \ (7) \n
Substituting Equations 6, 7, 3, and 4 into Inequality 5 produces the condition under which pullout failure mode can be ensured:

\[ D_{critical} > \frac{3.2t}{f} \] (8)

Therefore, for a certain sheet thickness, t, and weld porosity factor, f, the larger the weld diameter D, the better the chance for ensuring a pullout mode of failure. Also, for a certain sheet thickness, t, the lower the value f, i.e., the higher the porosity level, the larger the nugget diameter D is needed to ensure pullout failure.

The failure mode prediction methodology described above can also be illustrated schematically as shown in Fig. 16, in which the heavier lines indicate the predicted failure mode. Given a certain material thickness, t, and porosity factor, f, when D is smaller than D_{critical}, F_{PO} < F_{IF}.

Therefore, interfacial fracture would be the dominant failure mode under cross tension. On the other hand, when D is greater than D_{critical}, F_{IF} < F_{PO}. Therefore, nugget pullout would be the dominant failure mode under cross-tension loading.

If one assumes f = 1.0, i.e., perfect quality aluminum spot welds with no porosity and irregularity, the predicted nugget size of 3.2t for pullout mode can be compared...
with the conventional recommended minimal nugget size of \(4\frac{1}{2}\) mm. If the thickness of the aluminum sheet being welded is less than 1.5625 mm, then the conventional minimal nugget size recommendation of \(4\frac{1}{2}\) mm is sufficient to ensure nugget pullout. On the other hand, if the aluminum sheet thickness is greater than 1.5625 mm, the recommended minimal nugget size of \(4\frac{1}{2}\) mm is smaller than 3.2 mm. Therefore, the recommended minimal nugget size of \(4\frac{1}{2}\) mm is not sufficient to ensure nugget pullout failure under cross-tension loading condition. If one were to take into consideration weld porosity and irregularity of the actual production welds, the nugget size needs to be further increased to ensure nugget pullout.

From another perspective, Fig. 16 also indicates that the cross-tension strength of the weld depends primarily on the weld diameter \(D\) under a certain level of porosity. For weld diameters smaller than \(D_{\text{critical}}\), nugget pullout would be the dominant failure mode, and peak failure load increases linearly with the weld diameter. This conclusion validates the observations obtained in the previous section on the effect of weld size. It is also consistent with the observations reported in Ref. 12, which stated that weld size is an influencing factor in determining the different failure modes for spot welds of 5XXX series of aluminum alloys.

### Model Validation and Discussions

In order to validate the above analytical failure mode model, two additional populations of aluminum spot welds with 2-mm AA5182-O were fabricated for cross-tension testing. Our intention was to make one sample population with a weld size smaller than the original 1D14, and another sample population with a weld size larger than 1D14. We labeled these populations as 1D14-small-weld and 1D14-large-weld. The intended fusion zone diameter for the 1D14-small-weld population was 5.5 to 6.1 mm, and the intended fusion zone size for the 1D14-large-weld population was 9 to 10.6 mm. Typical weld cross sections for 1D14-small-weld and 1D14-large-weld are shown in Fig. 17. Note that the small weld population has the desired weld size of \(4\frac{1}{2}\) mm (Ref. 9). Again, 30 replicates of quasistatic cross-tension tests were conducted for each population, and the resulting peak load and joint failure modes were recorded.

According to Figs. 4 and 17, the area percentage of porosity on the faying interface can be estimated as around 20% for a typical weld in 1D14, 1D14-small-weld, and 1D14-large-weld. Assuming the same level of \(f=0.85\) for all three populations, we derive \(D_{\text{critical}}=7.5\) mm according to Equation 8 for 2-mm AA5182-O sheet. Since the weld sizes for the samples in 1D14 were controlled to be around 8 mm, this may explain why the majority of the cross-tension samples in 1D14 did not fail in nugget pullout mode. The recorded
nugget sizes shown in Figs. 10 and 11 also confirm that all the welds in ID14 that failed in nugget pullout mode have weld diameters greater than 7.5 mm.

Furthermore, when we increased the weld size to 9–10 mm as in population ID14-large-weld, 28 out of the 30 welds tested failed in nugget pullout mode. See Table 7 for the summary of failure mode and nugget size for this population. The two welds that failed in interfacial fracture mode have irregular fusion zone shape, and their minimum fusion zone diameters are measured to be 4.95 and 7.1 mm, respectively.

For ID14-small-weld population, 22 out of the 30 welds tested failed in interfacial fracture mode and 8 welds failed in nugget pullout mode (Table 8). The actual fusion zone size for ID14-small-weld is larger than its intended value, with average fusion zone size around 7.1 mm. Since their average diameter is lower than the predicted critical value, the majority of the welds failed in interfacial fracture mode.

Figure 18 summarizes the experimentally observed failure modes for the original ID14, ID14-small-weld, and ID14-large-weld populations. The dominant failure modes for the three populations change from interfacial fracture to nugget pullout with increasing fusion zone size. Considering the statistical nature of weld size, porosity level, and distribution, the analytical model works reasonably well in predicting the critical weld size for nugget pullout.

Thus far, we have validated Equation 8 on the effect of fusion zone size $D$ for fresh welds with consistent porosity levels. The validations do not include the effects of weld porosity factor $f$. Since the level of porosity and its distributions are closely related to electrode wear (Ref. 18), further validations on the effect of porosity factor $f$ should be investigated in conjunction with studies on electrode wear.

It is worth noting that given the material properties and the nugget size, one can also use Equations 3, 4, 6, and 7 to quickly estimate the anticipated cross-tension strength of a spot weld population. For example, the shear strength of AA5182-O used in ID14 and ID15 is about 140 MPa according to Refs. 16 and 17. Given the sheet thickness of 2 mm and the average nugget size of 8.5 mm, Equation 4 estimates the weld pullout strength to be:

$$F_{P_{\text{p}}} = \pi \cdot D \cdot t \cdot \sigma_y \cdot \text{shear}$$

$$= \pi \cdot 8.5 \cdot 2 \cdot 0.8 \cdot 140$$

$$= 5.98 \text{ kN}$$

The estimated cross-tension strength in Equation 9 is very close to the strength data reported in Tables 2 and 5.

As noted in Equation 4, the actual weld pullout strength under cross-tension loading condition also depends on the degree of weld indentation. Therefore, the facts that a weld has a larger fusion zone diameter and that it fails in nugget pullout mode cannot guarantee it is stronger than a weld with a smaller fusion zone for the same material combination. An example of this is shown in Fig. 19 with the peak loads of ID14, ID14-small-weld, and ID14-large-weld compared. Even though ID14-large-weld has a larger fusion zone size than ID14, its average static strength is lower than that of ID14 because of its severe weld indentation and, therefore, the reduced effective sheet thickness $t$ (see Fig. 17).

Another interesting observation from Fig. 19 is that, for joint ID14-small-weld, the mean strength for the samples that failed in interfacial fracture mode is considerably lower than that of the samples.
that failed in nugget pullout mode. With increasing fusion zone sizes for ID14 and ID14-large-weld, the strength differences between the two failure modes decrease. Therefore, the observations we made earlier on the effects of failure modes on peak load and energy absorption for ID14 and ID15 cannot be generalized to welds with fusion zone size smaller than \( D_{\text{critical}} \). In addition, for the population ID14-large-weld, the samples that failed in interfacial fracture mode have a similar level of median strength, but a larger level of scatter than those that failed in nugget pullout mode.

It should also be noted that even though the analytical part of the study focuses on aluminum spot welds, a similar analysis procedure may also be used for spot welds of ultrahigh-strength steel because of the similar characteristics of the hardness traverse plots. For both of these materials, the weld nugget does not have significantly higher yield strength than the base metal and the heat-affected zone. Moreover, based on a similar microhardness argument, it can be shown that the traditional criterion for rejecting interfacial fracture welds works well in evaluating the quality of mild-steel spot welds.

**Conclusions**

Through experimental investigation, statistical study, and analytical study, the following conclusions can be derived from this research:

Theoretically, weld size, sheet thickness, and level of weld porosity are the main factors determining the cross-tension failure mode for the aluminum spot welds studied in this paper. For a given sheet thickness and porosity level, the larger the weld size in comparison with \( D_{\text{critical}} \), the more likely the weld will fail in nugget pullout mode under cross tension. It should be noted that this conclusion is quantitatively valid for situations where the weld metal and HAZ hardness/strength are similar to those of the base metal. If substantial strength disparities exist (e.g., when welding precipitation-hardening alloys in the T6 condition), the critical weld diameter for pullout failures could be significantly shifted according to Equations 3 and 4.

For the two populations of aluminum spot welds in ID14 and ID15, different failure modes under cross-tension and cup peel loading conditions do not significantly influence the static peak load and energy absorption levels of the samples. In a statistical sense, the pullout mode generates less than 10% higher peak load and total energy absorption compared with the interfacial fracture mode. However, this conclusion cannot be generalized to weld populations with fusion zone sizes smaller than \( D_{\text{critical}} \).

For the cross-tension samples that failed in nugget pullout mode in ID14 and ID15, larger weld diameter generates higher peak load and higher energy absorption.

Severe weld indentation reduces the static strength of cross-tension samples. In general, if we consider two samples from two different weld populations, the sample with larger weld size does not guarantee higher cross-tension strength even when both samples fail in nugget pullout mode. The degree of weld indentation should also be considered.

The cross-tension strength of aluminum welds can be reasonably estimated given the material's yield strength, sheet thickness, weld size, and the level of weld porosity.

The conclusions of this study seem to suggest that one would want to increase the weld size indefinitely to achieve a higher level of peak load and energy absorption. Practically, larger weld size is also associated with a higher energy requirement for the welding equipment, faster electrode wear, and possible weld indentation. Therefore, the optimized value of weld size should be selected based on practicality and fitness-for-service criteria.
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References


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