WELDING Journal

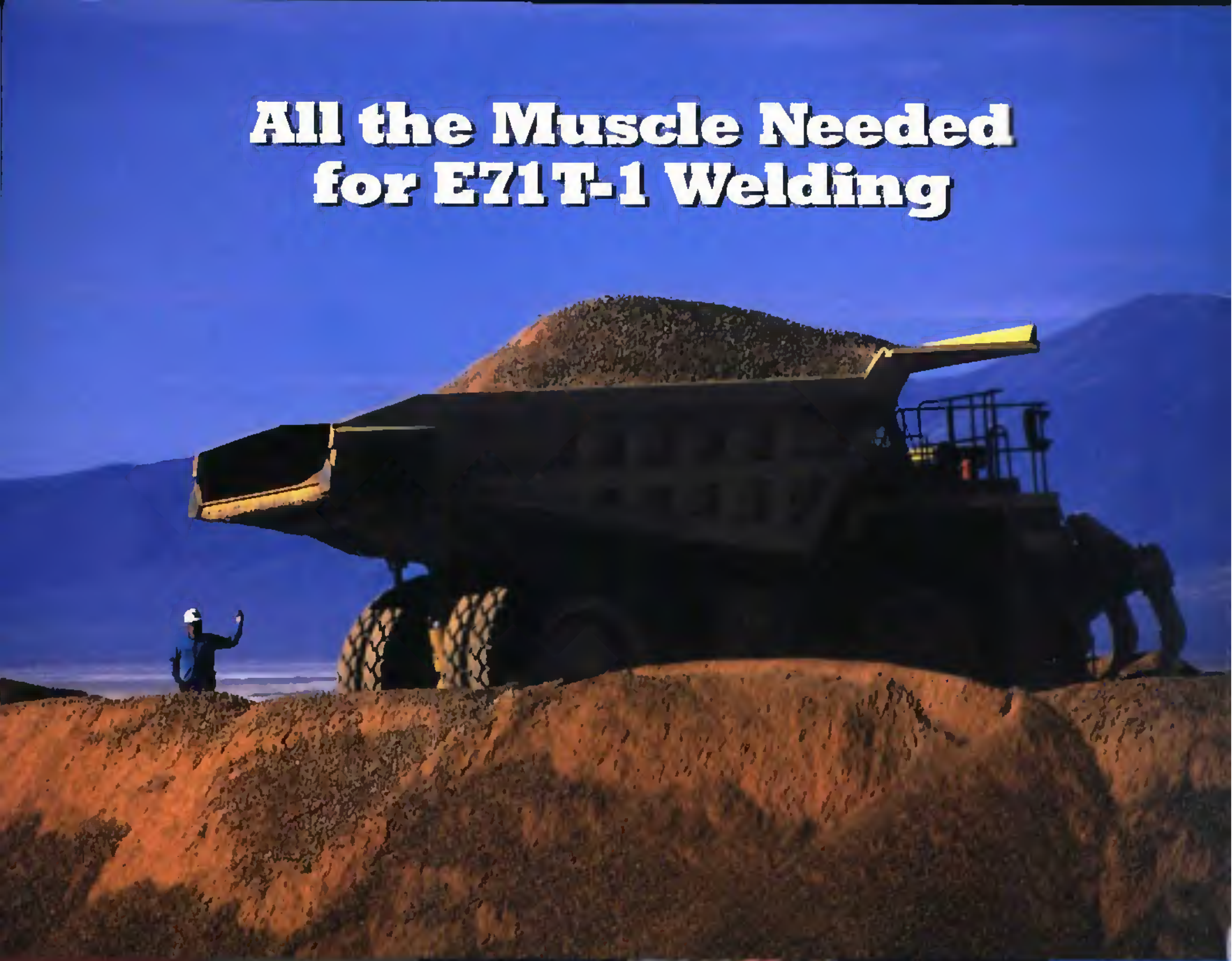
July 2004

SPECIAL EMPHASIS:

- Pipe and Tube Welding
  - Hollywood Bowl Gets a Make-over

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

All the Muscle Needed for E71T-1 Welding



Select-Arc, Inc. offers a complete line of E71T-1 flux cored, gas-shielded, carbon steel electrodes including the proven Select 710 and the innovative Select 727.

Since Select-Arc commenced tubular welding electrode production in 1994, Select 710 has served as the mainstay of the product line. That is because Select 710 is an excellent general purpose electrode with outstanding welder appeal. It features a smooth, stable arc transfer with low spatter emission and delivers better penetration than most "softer arc transfer" products.

Select 710 is a superb choice for general plate fabrication, structural steel welding and other applications where strength and toughness properties are primary requirements.

The new Select 727 is an exceptional all position, lower fume version of Select 710. Formulated to provide improved deposition rates and enhanced welder appeal, Select 727 offers significant reductions in fume emissions (40-50%) and spatter levels with superior bead geometry compared to conventional E71T-1 electrodes.

Select 727 is well-suited for situations where welding occurs indoors or in areas where reduced fumes are required. This electrode's strength and toughness make it ideal for applications such as structural steel, farm machinery, construction equipment, rail car fabrication and shipbuilding.

For more information on the time-tested Select 710 and the new Select 727 electrodes, call Select-Arc at 800-341-5215 or contact:

SELECT ARC INC.

P.O. Box 259
Fort Loramie, OH 45845-0259
Phone: (937) 295-5215
Fax: (937) 295-5217
www.select-arc.com

Circle No. 44 on Reader Info-Card

CL 400

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

USN 60

With its new High Power Square Wave Pulser, this high performance, single channel flaw detector gives you greater flexibility and penetration power than ever before in inspecting difficult materials like composites and forgings.

GE Inspection Technologies.

The name isn't the only thing that's new about these products.

USM 35

The patented color-coded display of legs helps you easily determine the position of the defect in the weld. This small, lightweight ultrasonic flaw detector provides 12 hours of inspection on a single battery charge.

USIP 40

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

PocketMIKE™

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

imagination at work

GE Inspection Technologies
50 Industrial Park Road, Lewistown PA 17044
(866) 243-2638
GEInspectionTechnologies.com

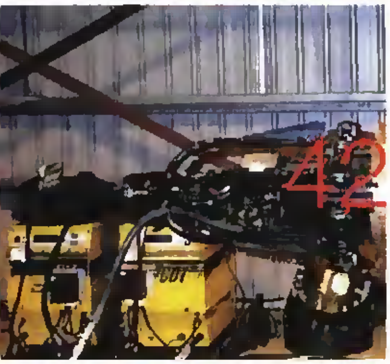
AGFA NDT | Krautkramer | SEIFERT

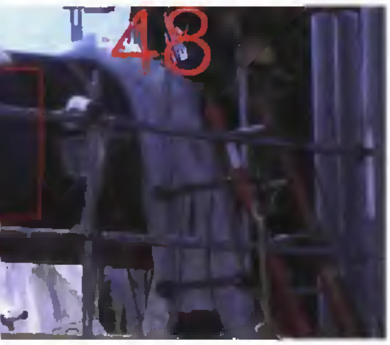
Circle No. 26 on Reader Info-Card

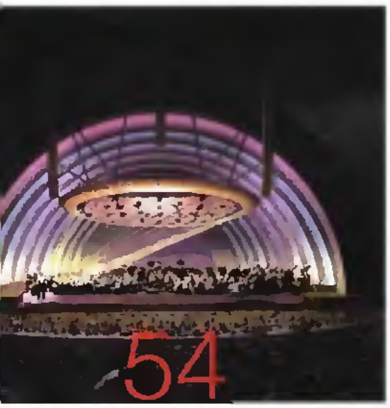

NexGen
By
JACKSON
EQC
NexGen

CONTENTS

July 2004 • Volume 83 • Number 7







♦Special Emphasis: Pipe and Tube Welding

Features

Welding Research Supplement

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

Departments

Welding Journal (ISSN 0043-2296) is published monthly by the American Welding Society for $90.00 per year in the United States and possessions, $130 per year in foreign countries: $6.00 per single issue for AWS members and $8.00 per single issue for nonmembers. American Welding Society is located at 550 NW LeJeune Rd., Miami, FL 33126-5671; telephone (305) 443-9353. Periodicals postage paid in Miami, Fla., and additional mailing offices. **POSTMASTER:** Send address changes to Welding Journal, 550 NW LeJeune Rd., Miami, FL 33126-5671.

Hoganas Sells Part of Powder Metal Operations

Swedish metal powder manufacturer Hoganas AB has sold part of the assets of the SCM Metal Products operation it acquired last year. The sale involves its U.S. copper-based powder product lines, which serve brazing, thermal spray, electrode, and flux applications, among others, as well as a manufacturing facility in Research Park, N.C. The purchaser was the Gibraltar Group of Buffalo, N.Y. The company's North American Hoganas High Alloys subsidiary will continue to produce noncopper powder products at its Johnstown, Pa., plant.

Alabama College Tries Free Welding Tuition

As a demonstration program, Bishop State Community College in Mobile, Ala., is training 40 welding students for free. Supported by a $250,000 grant from the state, the school's program aims to prove it can supply welders for three large local shipyards: Atlantic Marine, Austal USA, and Bender. The course is running eight hours a day, five days a week for eight weeks, and uses a facility that previously trained students for the aviation industry.

Factories Add and Subtract Jobs

A number of manufacturers have announced that they are adding jobs. Thomas Built Buses has opened a new $39.7 million school bus manufacturing plant in High Point, N.C., that will employ 192 workers and produce up to 22 buses per shift. The plant makes extensive use of robotics. Chrysler is investing $113 million in capital expenditures at its St. Louis South Assembly Plant in Fenton, Mo., to boost production of minivans with an innovative seat storage capability. Freightliner is adding a third shift and 593 new full-time jobs at its Cleveland, N.C., heavy-duty truck manufacturing plant. However, following the Army's cancellation of the $39 billion Comanche helicopter program, Sikorsky Aircraft is closing a large plant in Bridgeport, Conn., and has cut 175 workers.

Boom in LNG Terminals Seen

A study by Merrill Lynch reports that U.S. demand for natural gas has caught up with wellhead supply, as well as the storage and transportation infrastructure. Multibillion-dollar capital expenditures for storage, terminals, and pipelines are needed to keep natural gas supplies flowing over the next few years, the report concludes, or else the nation will have to rely on increased imports of liquified natural gas (LNG) carried aboard ships.

Hoping to avoid government permitting hassles, a Tulsa company has signed an agreement with the Sipayik Indian tribe to develop a one-billion-cubic-foot-capacity LNG terminal and storage facility on tribal land near the port of Eastport, Maine. Meanwhile, the Federal Energy Regulatory Commission has issued an environmental impact statement paving the way for development of an LNG terminal on the Texas Gulf coast, on Quintana Island near Freeport.

Harley-Davidson Hopes to Roar into China Market

Harley-Davidson has announced a relationship with China's Zongshen Motorcycle Group that the U.S. company hopes will pave the way for entry into the giant market. China has huge official and unofficial barriers against importing motorcycles, including a 50% import duty that, even if it drops to 30% next year as scheduled, Harley-Davidson considers onerous. The U.S. company will share technical and marketing knowledge with the Chinese firm, while gaining its own expertise in the new market. Unlike many companies with joint ventures in China, Harley-Davidson believes it can eventually export products made by American workers into China without manufacturing there.

'Rosie the Riveters' Convene

The National Rosie the Riveter Association's annual conference was held in Baltimore in June. Hundreds of "Rosies" with World War II home-front manufacturing experience attended. Lockheed Martin, which employed many women workers during the war, was the main sponsor.

WELDING Journal

Publisher *Andrew Cullison*

Editorial
Editor/Editorial Director *Andrew Cullison*
Senior Editor *Mary Ruth Johnsen*
News Editor *Ross Hancock*
Associate Editor *Howard M. Woodward*
Peer Review Coordinator *Doreen Kubish*

Publisher Emeritus *Jeff Weber*

Graphics and Production
Production Editor *Zaida Chavez*

Advertising
National Sales Director *Rob Saltzstein*
Advertising Sales Representative *Lea Garrigan*
Advertising Production *Frank Wilson*

Subscriptions
Leidy Brigman
leidy@aws.org

American Welding Society
550 NW LeJeune Rd., Miami, FL 33126
(305) 443-9353 or (800) 443-9353

EDITORIAL

Be an Active Member

On a recent Sunday afternoon, my wife Leslie hosted our church's annual Ladies' Spring Tea. This event resulted in approximately 50 women and girls of all ages — 4 to 84 — coming to our home for a traditional English tea complete with scones, and cucumber sandwiches. My role was to be available to assist those needing help on the stairs, but otherwise to keep a very low profile.

I confess to being a "people watcher." While waiting for flights in airports or sitting on the sometimes too few husband benches in shopping malls, I watch the people walk the aisles. Large people, little people (those under 10 years of age), slow moving people, and those in too much of a hurry, they help pass the time as I wait. Although somewhat different, it was much the same that Sunday afternoon. Although personally unique in many ways, the women had the common bond of not only being the same gender, but also belonging to the church community. This connection enhanced the conversations, the genuine interest shown toward each other, and their optimism regarding future events.

I found a direct correlation to my personal experiences in AWS. During my 30 plus years of membership, I have been fortunate enough to travel to many places and to meet many AWS members. I can report that the people making up the welding community are a widely diverse group, with many different interests, yet they each possess one key mutual interest: welding and joining technology. Notwithstanding the diversity of the human species, this common interest results in our membership sharing a prized character trait of being supportive and helpful toward one another.

I can speak through firsthand experience of how many AWS members have helped me to solve the numerous welding issues I have faced. Many times a phone call to a friend or an acquaintance is all I've needed to guide me to a technically sound resolution. Without this assistance and support, I would have spent many unnecessary hours researching potential solutions, employing a trial-and-error approach on test welds, or otherwise delaying the shipyard production trades as I sought an answer. Yes, it is possible to simply look up names in a directory and start calling people, but the success rate in getting those busy people to take the time to help a total stranger will be much less than if they were asked to help someone they know, even if they've only met that person one time.

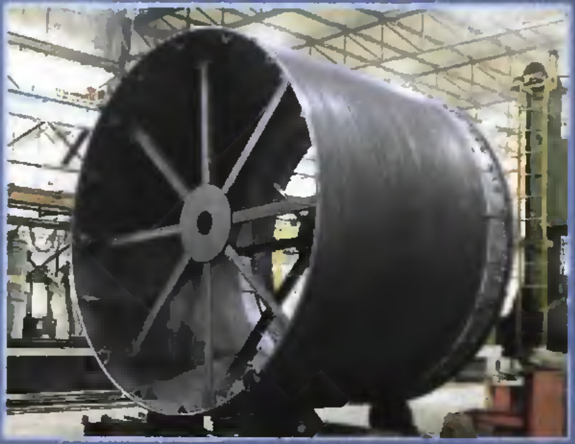
Our membership includes so many talented, brilliant, knowledgeable people that, taken collectively, no welding problem can go unsolved. For many of us in the industry, this is a priceless resource we can access. Unfortunately, however, many people may not be aware of the help their fellow AWS members can provide and are missing out on this valuable benefit of membership.

How can you tap into this talent pool? Participate in your Section activities, District conferences, committee meetings, and any of the many venues listed on the AWS calendar of events. By becoming an active, participating member, you can expand your personal base of contacts and networking opportunities. Only you can limit the advantages you have by being an AWS member. Don't shortchange yourself, become a more active member today.

Lee G. Kvidahl
AWS Past President (1993–1994)
and Chair, Membership Committee

Hodgson Custom Rolling Inc.

services a wide variety of industries in the ENERGY SECTORS of hydro, petro chemical, atomic, gas, oil, wind, etc. in addition to those in heavy manufacturing, steel, pulp & paper, mining, marine, forestry, etc. Hodgson's commitment to providing customers superior products and personalized professional service has earned itself a reputation for excellence, making the name HODGSON synonymous with "paramount quality and workmanship".



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

PLATE ROLLING & FLATTENING

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

PRESS BRAKE FORMING & HOT FORMING

Hodgson Custom Rolling's brake department processes all types of steel sections and plate up to 14" thick. Developed shapes such as cones, trapezoids, parabolas, reducers (round to round, square to round) etc.

STRUCTURAL SECTION ROLLING

Hodgson Custom Rolling has the expertise to roll curved structural sections into a wide range of shapes and sizes (angle, wide flange beam, I-beam, channel, bar, tee section, pipe, tubing, rail, etc.). We specialize in **Spiral Staircase Stringers**, flanges, support beams, gear blanks, etc.

FABRICATING

Hodgson Custom Rolling combines expertise in rolling, forming, assembly and welding to produce various fabrications including kiln sections, rock drums, heavy weldments, ladles, pressure vessel parts, multiple **Components for Heavy Equipment** applications etc.

Hodgson
Custom Rolling Inc.

ASME Certified
ISO 9001:2000

Circle No. 30 on Reader Info-Card

5580 Kalar Road
Niagara Falls
Ontario, Canada
L2H 3L1

Telephone: (905) 356-8132
Toll-free: (800) 263-2547
Fax: (905) 356-6025
E-mail: hodgson@hodgson.on.ca
Website: www.hodgsoncustomrolling.com

U.S. Address:
M.P.O. Box 1526
Niagara Falls, N.Y.
14302 - 1526

HODGSON CAN HELP SOLVE YOUR PROBLEMS

Lincoln Electric Names New CEO

Lincoln Electric Holdings, Inc., announced in early June that John M. Stropki, Jr., had been elected president and chief executive officer, succeeding Anthony A. Massaro, who held the position for eight years. Massaro had previously announced his intention to retire and will remain as chairman. Stropki, who began work in Lincoln Electric's Cleveland factory 35 years ago while attending college, is only the seventh CEO in the company's 109-year existence.

Robot Orders Jump in First Quarter

North American-based robotics manufacturers saw robot orders jump 17% in the first quarter of 2004 over the opening quarter of 2003, the best new order rate to start the year since the record-setting year of 1999. A total of 4101 robots valued at $226.5 million were ordered by North American manufacturing companies in the opening quarter. The revenue figure is 3% higher than in the first quarter of 2003. When sales to companies outside North America are added in, the totals are 4372 robots valued at $245.8 million, for gains of 20% in units and 6% in revenue. Among the applications posting the strongest gains in the first quarter were arc welding, material handling, and spot welding.

Industrial Gas Supplier Starts Distributor Council

Praxair, Inc., has formed a distributor council to advise the company in developing business strategies that benefit the company and its distributors with long-term, sustainable growth. The new council consists of representatives from Praxair's senior management and six independent distributors selected by the company.

NASA Project Leads to Portable Alloy Analysis Technology

Collaboration between NASA and KeyMaster Technologies of Kennewick, Wash., has resulted in development of a four-pound, handheld vacuum X-ray fluorescent analyzer that performs on-the-spot chemical analyses of alloys in materials such as welding electrodes — a task previously only possible in a chemical laboratory. The capability promises to be a boon to the aerospace industry, where NASA uses the device to verify the high-strength aluminum alloys used in the Space Shuttle propulsion system. The "chemistry lab in your hand" can detect elements such as silicon that can be detrimental to welding. It can also penetrate paint to detect corrosion.

Technical Standard Published for Welding Fabrics

Auburn Manufacturing, Mechanic Falls, Maine, is the first company to have its heat-resistant fabrics tested and approved to a new safety standard aimed at reducing fire risks during hot work such as welding. An insurance company, FM Global, developed the technical standard, called FM Global Approval Standard 4950, for heat-resistant fabrics used in protective blankets, pads, and industrial curtains.

Deepwater Oil Production on the Rise

In its latest report, "Deepwater Gulf of Mexico 2004: America's Expanding Frontier," the U.S. Minerals Management Service says deepwater oil production rose more than 840% and deepwater gas production increased about 1600% from 1992 to 2002. Of the 7800 active oil and gas leases in the Gulf, 54% are in deep water.

Miniature Embedded Electrodes Detect Corrosion in Real Time

Engineers at the Southwest Research Institute in San Antonio, Tex., have developed a technology for electronic embedded corrosion sensors that can be incorporated into welded materials, such as pipelines, aircraft, military equipment, and offshore structures. The electrodes are composed of material identical to the material making up the component being monitored, but are connected to each other with tiny resistors to form an electronic array. Intruments can be used to detect changes in current through the array to analyze the rate of corrosion over any period of time.

Panel Warns of Engineer Shortages

The National Science Board, a nongovernmental body that advises the president and Congress on scientific and engineering matters, warns that the country's preeminence in science and technology is in jeopardy because the country is facing a shortage of scientists and engineers. American students are losing interest in the sciences, the study states, and the United States can no longer rely on foreigners to fill the gap, due to various restrictions on guest workers, and international competition for their skills.

Steel Price Fluctuations Lead to New Index

Dow Jones Newswires has launched the first transactions-based, U.S. steel-price indexes: the Dow Jones Monthly Hot Rolled Coil and Cold Rolled Coil Indexes. The two indexes will be published on the fifth business day of every month, reflecting prices for steel obtained through spot trades or contracts, and shipped during the previous month. The launch of the indexes comes at a time of heightened volatility in world steel prices amidst a growing interest among steel producers and consumers in financial instruments capable of reducing exposure to price swings.

Engineers Held in High Esteem

In a survey conducted on behalf of the American Association of Engineering Societies, engineering received a higher rating from adults as a career choice for their children than either accounting or the ministry. When asked to use a scale of one through ten to represent extremely displeased to extremely pleased if their child were to enter a particular profession, engineering and science both received a nine. The survey found that the average American is personally acquainted with six engineers, but only a third of those polled felt well informed about engineering, and only 40% were interested in learning more.

LNG Terminal Project Gets EPA Approval

The U.S. Environmental Protection Agency (EPA) has issued permits for the construction by ChevronTexaco of a deepwater LNG terminal 37 miles off the coast of Louisiana. The offshore location helps ease fears of safety impacts from terror attacks. There are presently only four active LNG terminals in the United States, and analysts say these cannot meet future demand for natural gas. But communities have resisted new onshore LNG projects, because sabotage could prove catastrophic to a wide geographic area.

Organization Calls for Plan on Auto Production

The chairman of the National Association of Manufacturers called on the U.S. auto industry to adopt an "action plan" to meet the challenges posed by unprecedented global competition. Richard E. Dauch said external overhead costs associated with taxes, regulations, rising energy prices, health care, pensions, and runaway litigation conservatively add 22.4% to the price of domestic production, creating what he called "an uneven playing field."

Texas Welding Businesswoman Receives Recognition

Tracy Delce, a black woman who took over management of her brother's Tin Man Welding shop a few years ago, has grown the firm dramatically and received the annual Entrepreneur Award from the mayor of Ft. Worth, Tex. By getting help from the Small Business Administration, and concentrating on public works projects, the firm doubled its business in its first year, 2002, and has continued to rocket in growth since.

Student's Robot Does Paper-Folding Art

Devin Balkcom, a student at Carnegie Mellon University, was looking for a challenge when he decided to develop the world's

Circle No. 39 on Reader Info-Card


Graduate student's robot folds a paper art object.

first origami-folding robot as the subject of his doctoral thesis. The robot uses a tiny suction cup attached to the arm to pick up a piece of paper, rotate it, and place it over a narrow gutter in a worktable. Then a ruler descends and presses the paper into the gutter to create a crease. The robot can make paper hats and airplanes. "Once you build a robot that can duplicate human tasks," said Balkom, "you can learn more about human skills that we often take for granted."

College Changes Designation of Welding Curriculum

LeTourneau University, Longview, Tex., has renamed its welding degree concentrations to "Materials Joining" to reflect increased emphasis on joining of polymers, ceramics, and composites. The school expects that over five years, its emphasis on metals and welding vs. nonmetals and joining will change from a 90/10 mix to a 70/30 mix.

Study Says Worker Shortage a Bigger Threat to Manufacturing than Outsourcing

The Detroit Regional Chamber, a southeastern Michigan business organization, has released a study on offshore outsourcing and its impact on job loss in the state. The study found that only 12% of lost jobs were due to job displacement from imports and outsourcing, and that increased manufacturing productivity is having a much greater impact. The report warns that a substantial worker shortage in the state ultimately poses the greatest threat to the future of manufacturing competitiveness.

Welding Supply Shops See Jump in Lens Sales from Solar Event

Stargazers who wanted to witness the transit of the planet Venus over the face of the sun flooded some welding supply shops in early June to purchase safety lenses. Suppliers around the country ran short of No. 14 lens plates, a heavier grade than most welders use. Shops have time to stock up before the next transit of Venus in the year 2012.

Lincoln's Sponsored Car Wins at Indy

Buddy Rice raced an Indycar, partly sponsored by Lincoln Electric, to victory in the Indianapolis 500 on Memorial Day. The welding equipment manufacturer has been involved with the winning Rahal Letterman Racing team, co-owned by "Late Night" host David Letterman, for seven years as an equipment sponsor. This was the team's first victory.

Welding Companies Team Up to Help Hospital Ship

The *Caribbean Mercy*, one of the fleet of three Mercy ships that provide health care and disaster relief to some of the world's neediest people, was in drydock in Mobile, Ala., recently, when employees of Welding Equipment Supply Co. (WESCO), Pritchard, Ala., learned that the ship needed work on its operating room. The company contacted its colleagues at Air Products, Thermadyne, A-Welders & Medical Supply, and Western Enterprise, who all joined WESCO in donating products and labor to install and test an oxygen piping system. By working long hours, the project was finished in 3½ days, in time for the ship's departure for a mercy mission to Honduras.

China's Central Bank Warns that Its Metals Industries Are 'Overheated'

The People's Bank of China has published a monetary policy report warning that the country's steel and aluminum industries have been receiving too much investment. China is the world's largest manufacturer of steel, and curently consumes more steel than it produces. However, its steel production capacity will exceed demand by the end of 2005, the central bank predicts, leading to overcapacity. The report also predicts that China's aluminum manufacturing capacity will exceed its domestic demand by 50% by the end of 2005.

Industry Notes

- The National Equipment Museum in Bowling Green, Ohio, has broken ground on a library for the collection of manuals, photographs, and other archives relating to antique construction equipment dating back to the early 1800s.
- This month, the American Film Institute will hold a workshop for engineers on how to write screenplays for TV and movies. The workshop is funded by the U.S. Air Force.
- The National Park Service is developing a "Rosie the Riveter National Historical Park" in Richmond, Calif., and is seeking

anecdotes and artifacts from people who experienced factory life on the home front during WW II.

- Smith College, Northampton, Mass., has graduated its first class of engineering students, comprising 20 women.
- Northrop Grumman Newport News received a major contract to prepare for work on the next generation of aircraft carriers. Production will begin in 2007.
- The Volvo truck factory in Greensboro, N.C., has added 300 jobs and a second shift. The company is building a new plant in Maryland to build truck engines that are currently manufactured in Sweden.
- Airgas has arranged a product placement deal with the Discovery Channel's new series, called "BIG!," which features fabrications of giant popcorn machines and the like. The show will provide visibility for the firm's welding products.
- Nine welding students at the Penta Career Center in Toledo, Ohio, created welded lawn sculptures that they sold to raise money to help the families of ironworkers who were killed or injured when a crane collapsed at a bridge construction site earlier this year.
- The Army's Rock Island Arsenal, near Davenport, Iowa, has provided facilities and equipment for a 120-hour welding course offered through Black Hawk College, Moline, Ill. In return, the college will train arsenal workers along with its welding students.
- The production line for final assembly of the stealthy F-35 Joint Strike fighter jet is near completion at a Lockheed Martin facility in Ft. Worth. Inspection of the wing skins is carried out by a new laser/ultrasonic testing technology.
- A Russian plant has been built for the production of Hummer SUVs. The plant in Kalingrad expects to produce about 700 of the military vehicle's consumer version by October, under a license from GM that was signed last summer.
- Caterpillar has enhanced its military leave policy, which now makes up the difference between base military pay and the employee's normal Caterpillar wages. The policy applies to full-time workers in the National Guard and Reserves who have been called up for service.
- Ground has been broken for a $76 million nanotechnology center at Sandia National Laboratories in Albuquerque, N.Mex.
- By 2010, the earning power of a four-year degree will not be that much more than a two-year degree, according to projections by the Labor Dept. An associate's degree will be worth an average of $41,488 annually, while a bachelor's will yield $48,440.
- OSHA has announced an alliance with the Gulf Coast Maritime Safety Association to reduce hazards faced by Alabama shipbuilding workers.

International Briefs

- Boosted by manufacturing, Mexico's economy expanded during the first quarter at its fastest rate (3.7%) in three years, the country's finance ministry said.
- The Russian economic ministry reports that the country's GDP will have grown 7.5% in the first half of 2004. Russia is running a foreign trade surplus.
- A company in Vietnam is the first there to produce flux cored welding wire. It has a contract to supply $10 million worth of welding wire to the British Welding Alloys Group.
- According to a study by Deloitte Research, U.S. manufacturing firms have cut overseas investment for the third year in a row. The study warns that by outsourcing to foreign firms rather than owning their own foreign manufacturing capacity, U.S. firms may be paying to create their own future competitors. Direct foreign investment by U.S. manufacturers in 2003 was 32% less than in 2000.

STAINLESS Q&A

BY DAMIAN J. KOTECKI

Q: I have to weld a 410 clevis to the end of a 316L rod. Several hundred such weldments are to be made. The rod is actually a 3-in.-diameter pipe with ½-in. wall thickness. The clevis is essentially an end cap for the pipe. It was purchased already hardened and tempered to 30 Rockwell C to provide wear resistance against the clevis pin. The joint is to be full penetration and will be subject to fatigue loading and possibly impact, so I feel I need to perform a postweld heat treatment (PWHT) to temper the HAZ of the 410. In the September 2000 Stainless Q&A column about welding 410 to 304L, filler metal Alloys 312, 309L, and 308L were all considered to be suitable for that joint. But nothing was said about PWHT. There will be 316L filler metal on the jobsite for other joints involving the 316L parts of the assembly. Assuming that 312, 309L, and 308L would be suitable filler metals, would 316L also be a suitable filler metal? And what PWHT can I use without damaging the hardness of the 410 clevis?

Table 1 — Typical Compositions for 316L and 410 Base Metals and 316L Filler Metal, with Predicted FN from the WRC-1992 DiagramComponent

	C (%)	Mn (%)	Si (%)	Cr (%)	Ni (%)	Mo (%)	Cu (%)	N (%)
ASTM A240 Type 316L	0.03*	2.0*	1.0*	16.0–18.0	10.0–14.0	2.0–3.0	—	—
Typical 316L	0.02	1.5	0.4	17.0	12.0	2.2	0.2	0.03
ASTM A240 Type 410	0.15*	1.00*	1.00*	11.5–13.5	—	—	—	—
Typical Type 410	0.11	0.5	0.4	12.5	0.1	0.05	0.05	0.01
AWS A5.4 E316L-XX	0.04*	0.5–2.5	0.90*	17.0–20.0	11.0–14.0	2.0–3.0	0.75*	—
Typical E316L-XX	0.03	1.5	0.4	19.0	12.0	2.2	0.2	0.06
AWS A5.9 ER316L	0.03*	1.0–2.5	0.30–0.65	18.0–20.0	11.0–14.0	2.0–3.0	0.75*	—
Typical ER316L	0.02	1.5	0.4	19.0	12.0	2.2	0.2	0.06
AWS A5.22 E316LTX-X	0.04*	0.5–2.5	1.0*	17.0–20.0	11.0–14.0	2.0–3.0	0.75*	—
Typical E316LTX-X	0.02	1.5	0.4	19.0	12.0	2.2	0.2	0.06

** Maximum permitted by the specification*

Table 2 — Calculated Chromium and Nickel Equivalents and Predicted FN for the Root Pass of 316L and 410 Base Metals Welded with E316L-XX SMAW Electrodes

Alloy	WRC-1992 Cr$_{eq}$	WRC-1992 Ni$_{eq}$	Predicted FN
316L base metal	19.2	13.3	2.1
410 base metal	12.55	4.15	not applicable
Equal mix of base metals	15.88	8.73	not applicable
E316L-XX filler metal	21.2	14.25	6.0
Root pass	19.6	12.59	5.2

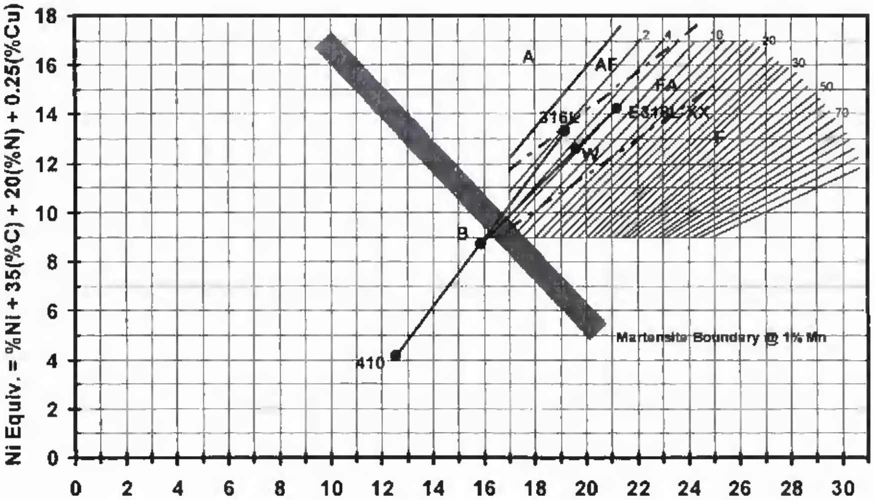


Figure 1 - Joining 410 and 316L with E316L-XX Electrodes

A: I agree that PWHT seems prudent for the sake of tempering the HAZ of the 410. There is a concern about whether there will be a little ferrite in the root pass. If there is ferrite in the root pass, subsequent passes should also contain ferrite and be crack resistant. However, when PWHT comes into the picture, there is a new consideration — the possibility of forming sigma phase in the weld metal. Let's work backward from the PWHT to the weld metal analysis, and then consider sigma phase.

Hardness of 30 Rockwell C indicates, from the tempering curves for 410 given in the ASM *Heat Treater's Guide*, that tempering was accomplished at about 1050°F (565°C). Any PWHT you might perform, so long as it is at no higher temperature than the original tempering temperature, will not appreciably soften the 410. However, it will soften the HAZ of the 410, which could be as hard as 45 Rockwell C in the as-welded condition. The *Heat Treater's Guide* recommends avoiding tempering in the range of 700° to 1050°F (370° to 565°C) for parts requiring high toughness. Tempering in the range of 1050° to 1125°F (565° to 605°C) is indicated for achieving 25 to 31 Rockwell C. Of course, the lower hardness would be achieved at the higher tempering temperature. So I would suggest that your PWHT be done at the low end of this latter temperature range — about 1050°F.

Since you would prefer to use 316L filler metal for your joint, the next thing to consider is whether 316L filler metal will provide some ferrite in the diluted root pass between 316L base metal and 410 base metal, so you won't need to worry about solidification cracking.

Table 1 provides typical compositions for 410 and 316L base metals, and for 316L

— *continued on page 19*


40% LARGER VIEWING AREA
than ANY other auto-darkening product

— *continued from page 15*

filler metals, so that prediction of root pass weld microstructure can be made using the WRC-1992 Diagram.

The 316L base metal is typically designed by the steel mill to solidify as primary ferrite, but, due to cost considerations, is generally relatively lean in composition. Since you didn't state which welding process you plan to use, Table 1 covers filler metals for all of the major welding processes. You will note that the filler metals tend to be richer in chromium content than the 316L base metal, so they tend to have higher ferrite content than the potential ferrite of the base metal.

You will also note that the typical compositions of the various forms of 316L filler metal are similar, even though there are differences in specific alloy limits for the different product forms. As a result, the various processes produce similar ferrite contents in the undiluted weld metal. So it is adequate to conduct the ferrite prediction using the SMAW E316L-XX composition, which generally tends to produce the lowest FN due to slightly higher carbon content than the other filler metals.

Table 2 lists the calculated chromium and nickel equivalents for the two base metals, the undiluted E316L-XX filler metal, and the typical 30% dilution root pass joining the two base metals. In calculating the root pass composition, the assumption is made that each base metal contributes equally to the dilution, i.e., 15% of the root pass composition comes from each base metal.

Figure 1 presents the ferrite prediction graphically. The synthetic base metal, composed of 50% 316L and 50% 410 lies at Point B on the diagram. The predicted weld metal composition, Point W at 5.1 FN, lies in the region of compositions that solidify as primary ferrite. Furthermore, if the dilution were to be significantly increased by using submerged arc welding, Fig. 1 indicates that more than 50% dilution would still provide about 4 FN and primary ferrite solidification. And even at higher dilution, the predicted root pass weld metal composition would lie in the region of primary ferrite solidification. Further, the root pass composition lies comfortably above the martensite boundary, so weld metal cold cracking will not be an issue. Of course, a preheat of about 300°F (150°C) is advisable to avoid cold cracking in the HAZ of the 410.

The last concern is the possibility of sigma phase transformation in the ferrite of the weld metal during PWHT at 1050°F (565°C). Experimental data for formation of sigma phase in 316L weld metal are shown in *Welding Metallurgy of Stainless Steels* by Erich Folkhard (published by Springer-Verlag). These data indicate that sigma phase formation is quite slow at 1050°F, showing little effect after ten hours at 600°C (1110°F). Even if it did form, there is not enough ferrite to transform to sigma to produce any significant embrittlement. So no difficulty with sigma phase is anticipated.

Accordingly, 316L filler metal is considered to be a quite satisfactory selection for your application. ◆

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 A5D 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.

AWS Foundation is proud to announce its 2004-2005 National Scholarship Recipients

Benjamin C. Woomer
The Ohio State University,
Welding Engineering
Howard E. Adkins
Memorial Scholarship

"I am truly grateful for this scholarship. Thank you for the financial support and national recognition. I am looking forward to making a difference in welding engineering."

Kurt G. Goodman
Ferris State University,
Welding Engineering Technology
Airgas – Jerry Baker
Scholarship

"It is truly an honor and a privilege to receive the Airgas – Jerry Baker Scholarship. Applying for and receiving this scholarship has been the highlight of my undergraduate studies. Your assistance and recognition are invaluable as I pursue a career in Welding Technology."

James R. Anderson II
Ferris State University,
Welding Engineering Technology
Airgas – Terry Jarvis
Memorial Scholarship

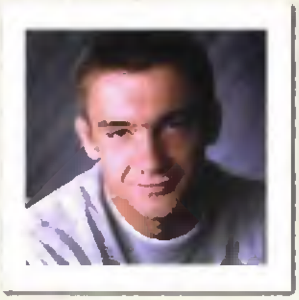
"I would like to thank the Airgas – Terry Jarvis Memorial Scholarship for its contribution to furthering my education in Welding Engineering Technology. I look forward to completing my bachelor's degree and becoming a productive member of society, as well as making a positive influence as a Welding Engineer."

Kenneth A. Ellis
Pennsylvania College
of Technology,
Welding & Fabrication
Engineering Technology
Arsham Amirikian
Engineering Scholarship

"It is an honor to receive the Arsham Amirikian Engineering Scholarship. I am thankful for the support of the AWS Foundation and the many AWS volunteers I have worked with. Volunteering for AWS activities has provided incalculable benefits for my welding career."

Nicholas Perry
Ferris State University,
Welding Engineering Technology
Edward J. Brady
Memorial Scholarship

"It is a great honor to receive the Edward J. Brady Memorial Scholarship. I am very grateful to the American Welding Society and the Edward J. Brady Scholarship Committee for their dedication. I would like to recognize my parents and Professor Andrew Burke. Thank you to everyone."



Ryan N. Kapustka
The Ohio State University,
Welding Engineering
William A. and Ann M. Brothers
Scholarship

"I am honored to be the recipient of the William A. and Ann M. Brothers Scholarship. This opportunity will be used to further my goal of becoming a Welding Engineer."

Clayton R. Owens
The Ohio State University,
Welding Engineering
Donald F. Hastings
Scholarship

"Receiving this scholarship has allowed me to worry less about paying for college and more about accomplishing great achievements in the field of welding engineering. Thanks a lot for making this happen."

Justin Nielson
LeTourneau University,
Welding & Mechanical
Engineering
Donald and Shirley Hastings
Scholarship

"Thank you for honoring me as the recipient of the Donald and Shirley Hastings Scholarship. The AWS Foundation's dedication to and support of education in the field of welding engineering is greatly appreciated. I look forward to contributing to the field of welding engineering. Thank you for investing in my future."

Kirk D. Webb
Ferris State University,
Welding Engineering Technology
William B. Howell
Memorial Scholarship

"It is an honor to be eligible for an AWS National scholarship, and even more of an honor to receive this scholarship. This scholarship will allow me to become more fully engrossed in my studies without having to worry about how my education will be paid for. It is not only an investment in me but an investment in the joining sciences."

Andrew C. Martin
University of South Florida,
Master of Science in
Engineering Management
Hypertherm-International
HyTech Leadership Scholarship

"I would like to thank the AWS Foundation for its generosity and support. I am honored to receive this scholarship. It will be an enormous help towards my pursuit of a Master of Science degree in Engineering Management."

Jason Reinhold
Ferris State University,
Welding Engineering Technology
ITW Welding Companies
Scholarship

"I feel honored to be one of the first recipients of the ITW National Scholarship. This goes to show that the AWS Foundation is always striving to find more ways to help out the welding industry."

David J. Jedele
Ferris State University,
Welding Engineering Technology
ITW Welding Companies
Scholarship

"I am very grateful that this organization has the eagerness to help out future Welding Engineers. Without its generosity and organization, this award would not have been possible."

Kelly S. Feenstra
Ferris State University,
Welding Engineering Technology
John C. Lincoln
Memorial Scholarship

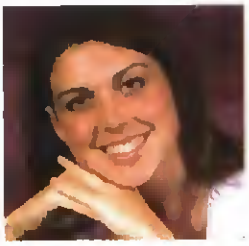
"Being selected as the recipient of the John C. Lincoln Memorial Scholarship is an honor and a privilege. The scholarship money will be a great asset towards my tuition in my senior year at Ferris. I greatly appreciate the help from the AWS Foundation and the Lincoln National Scholarship Selection Committee."

James R. Cuhel
Ferris State University,
Welding Engineering Technology
Matsuo Bridge Company Ltd.
of Japan Scholarship

"I am very thankful to the American Welding Society for selecting me for a national scholarship. This scholarship is a great aid to my future career."

James A. Thomas
The Ohio State University,
Welding Engineering
Praxair
International Scholarship

"I am privileged to receive this scholarship and want to extend my gratitude to Praxair, the AWS Foundation, and all individuals who are helping me pursue my degree."



Linda Nicole Dutruch
University of Mobile,
Business Administration
James A. Turner, Jr.,
Memorial Scholarship

"I thank the AWS Foundation for the chance to continue my education. I work at Welding Engineering Supply Company, where I have been employed for the past five years. I am blessed to be involved with the welding industry, which offers so many opportunities to young people with the help and support of the American Welding Society."

Each year, the American Welding Society Foundation provides scholarship funds to help hundreds of students who otherwise would be unable to afford a welding education. We are the only industry foundation with the specific mission of helping to fund the education of welding students. In so doing, we create the careers that sustain and grow our industry.

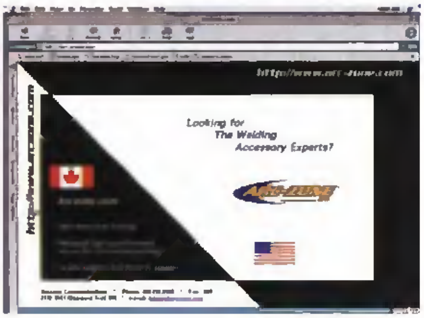
We get these funds from your contributions. The more you contribute, the more students we can help to educate.

To make a scholarship contribution – or even set up your own Section Named Scholarship – contact your Section or Vicki Pinsky at the AWS Foundation. Call 800-443-9353, ext. 212, or e-mail *vpinsky@aws.org*

Thank you for your continuing support.

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

Arc-Zone.com Available through Canadian Site



Arc-Zone.com (*www.arc-zone.com*) has contracted with Arczone.com of Canada (*www.arczone.com*) to share its front page. The move was made because the company's customers often left out the hyphen when typing the Web address and ended up at a Web site in Canada, said Arc-Zone.com president Jim Watson.

Terry Trainor, the company's director of Internet Services, worked out arrangements to share the front page with the Canadians, who weren't actually using it at that time. Trainor designed a page that includes the Arc-Zone.com logo alongside the contact information for the Canadian company; therefore, customers who leave out the hyphen will still be able to locate the company's gas metal arc, gas tungsten arc, and plasma arc welding and cutting products.

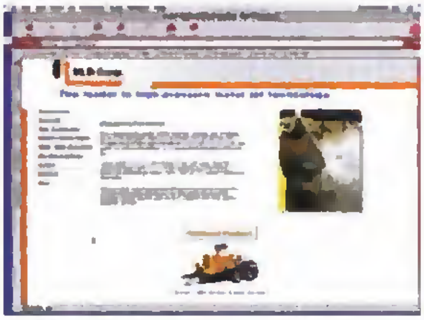
PMA Introduces Advocacy Web Site

The Precision Metalforming Association (PMA) recently developed a Web site dedicated to government advocacy in an effort to make it convenient for manufacturers to become involved with the association's grassroots efforts. The site, *www.metalformingadvocacy.com*, allows visitors to follow current legislation that impacts the metalforming industry and send e-mails to members of Congress, the White House, and major executive departments, as well as view voting records for members of Congress.

The Precision Metalforming Association is the trade organization that represents the industry that creates precision metal products using stamping, fabricating, and other processes. It represents nearly 1300 member companies.

The site includes news items relevant to the industry, information about candidates in the 2004 elections, and allows users to register to vote. It also provides a media library in which metalformers can search for media outlets. Results will contain contact information for each media outlet, including lists of staff members, their positions, and e-mail addresses.

Downloadable Videos Show Water Jet Cutting Tools in Action



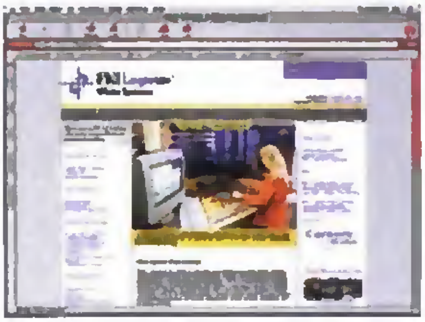
NLB Corp. If you've never seen a water jet cutting system in operation, you now can through this Web site. A five-minute aluminum cutting video is among the application videos that can be downloaded. The site also features an extensive "Applications" section that describes the most common uses of water jetting, offers product information, and provides downloadable application literature.

In addition, visitors interested in water jet pumps can scroll through diesel, electric, or convertible units. They can also enter their own specifications to see which unit best matches their needs and request a quotation. The site also provides information about renting the company's equipment, as well as descriptions and specifications for hundreds of accessories. A credit application is also included.

www.nlbcorp.com

Materials Handling Products Highlighted

FKI Logistex® White Systems. This site details the company's automated material storage and retrieval systems. The company recently redesigned the site for easier navigation and to give visitors quick access to information. A menu system on the left side of every page guides visitors to where they want to go.



Besides a large amount of product information, the site includes an extensive library of videos that show the systems in action and details regarding customer service. High- and low-resolution versions of company literature can be downloaded. Also, a set of case studies is shown that can be searched by company, industry, or product.

www.whitesystems.com

ASI Expands Automation Component Offerings

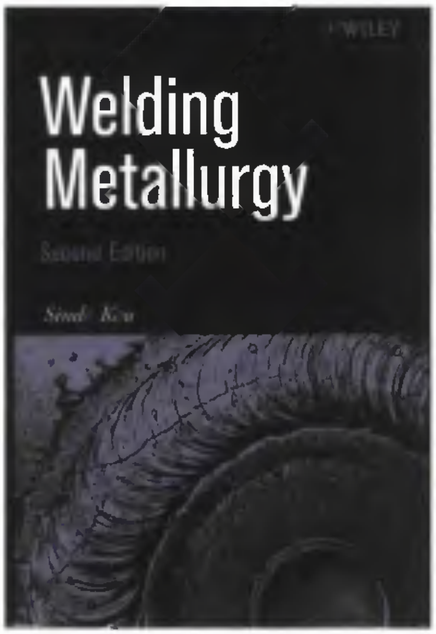
Automation Systems Interconnect, Inc. The company has expanded the number of interconnect and interface products designed for industrial control equipment and systems available through its Web site. The updated site includes IEC terminal blocks, compact din-rail mounted power supplies, interface modules, sensors and sensor accessories, circuit breakers, industrial control relays, signal conditioners, marking systems, wire markers, labels, tools, and ferrules. Listings include specifications, availability, pricing, and ordering information. Visitors can request that literature be mailed to them or view them online. Included are catalogs, brochures, and demonstration videos.

www.asi-ez.com


Pro-Plus 400MST
Pro-Wave 185TSW
THERMAL ARC

BOOK REVIEW

BY R. DAVID THOMAS, JR.



Welding Metallurgy, by Sindo Kou. Hardbound, 8 × 10 in., 480 pages, second edition. Published 2002 by John Wiley & Sons, Inc., 111 River St., Hoboken, NJ 07030; (201) 748-6000; *www.wiley.com/WileyCDA/*; ISBN 0-471-43491-4. $132.00.

This latest edition of Dr. Kou's textbook was obviously written as a supplement to a lecture course for his students in welding technology. Kou is a respected professor and chair of the Department of Materials Science and Engineering at the University of Wisconsin. This is a well-organized volume for basic instruction for students who are pursuing training that leads to a professional career in welding technology. In the preface, the author describes how this new edition revises his initial work published in 1987, and incorporates new understanding from recent research and greatly improved graphics.

The table of contents is well arranged into four major sections, each divided into logical chapters. The first, titled "Introduction," consists of five chapters on the fundamentals of welding, the fusion processes (primarily arc welding), heat flow, chemical reactions, fluid flow in both the vapor and molten regions, and the mechanical stresses resulting from the heating and cooling effects of the joining processes. The author then proceeds to describe in six chapters of Part II, called "The Fusion Zone," by reference to thermodynamic phase diagrams and micro and macro photos, the various morphologies found as welds solidify and subsequent microstructural changes during solid phase transformation. This section then describes sources of alloy segregation and various inhomogeneities encountered, including alloy segregation often associated with defects such as cracking or porosity. In a fascinating Part III, Kou describes the complicated structures found in what is termed "The Partially Melted Zone," the region between the fusion and the unfused workpiece. Finally, Part IV deals with "The Heat-Affected Zone," where the thermal effects of the welding process alter the microstructure of the workpiece, often with some sacrifice to the mechanical or other properties of the welded joint. For alloys where some of the problems are more frequently encountered, entire chapters are devoted to aluminum alloys, nickel-based alloys, low-alloy steels, and stainless steels.

Throughout the book many illustrations are provided, including schematic sketches, phase diagrams, and macro- and microstructures, allowing one to imagine attending the author's lectures. Moreover, one cannot avoid the student's possible dread for examinations of the course, as at the end of each chapter are listed problems to solve with no hints as to the answers, except by a more careful review of the principles. These make valuable class discussion topics, not only for college-level students, but in any postprofessional training seminars. Each chapter also provides a list of references cited, as well as a selected list, marked "Further Reading."

In less than 500 pages, Kou has compressed knowledge found in the multivolume AWS *Welding Handbook*, and Volume 6 on welding in the ASM *Handbook*, and even the almost 1000-page classic AWS Fourth Edition of George E. Linnert's *Welding Metallurgy*. Of even greater importance, he has incorporated references to recent sophisticated research in current problem areas; this makes it a valuable addition to any professional in welding technology. One should emphasize that this book is for a professional or would-be professional, for it deals with mathematical models and physical chemical concepts that might discourage those who may lack basic training in this field of engineering.

The index allows the reader to seek the sections that specifically address topics of interest. I turned to the topic "submerged arc welding," and was directed to Chapter 1, where the welding processes were described, and to a figure illustrating the grain structure with and without the titanium carbide inoculation of a submerged arc weld. I was disappointed not to have found references to pages 83 to 92 where flux basicity is covered. I suggest that these valuable pages would not have been overlooked if the index searches had included the abbreviation SAW as well as submerged arc welding.

While on the subject of indexing, if I were an instructor in a welding course and were making use of this textbook, I would love to be referred by way of the index to the "Problems" that deal with specific subjects. For example, if I were to search the index for the valuable list of questions relating to stainless steels, I would have been directed to page 432 containing Table 18.1 giving references to several sections of the book where specific problems are detailed. However, none would have directed me to stainless steel questions that occur frequently at the end of many chapters, not only to the end of Chapter 18 on stainless steel. If Kou undertakes another revision, my suggestion for the index would include searching for the topics among the end of each chapter's problems. As I mentioned before, I found these questions and problems one of its more important features, one not found in most reference volumes.◆

R. DAVID THOMAS, JR., is a Fellow of the American Welding Society, Miami, Fla.

Dear Readers:

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

Change of Address? Moving?

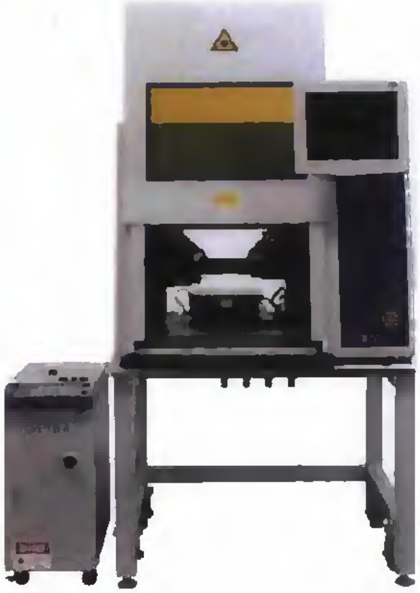
Make sure delivery of your *Welding Journal* is not interrupted. Contact the Membership Department with your new address information — (800) 443-9353, ext. 480; *jleon@aws.org*.

SAW Wire Provides Consistent Mechanical Properties

Available as ⅛-in.-diameter submerged arc wire, Thermaclad® 104TJ is packaged on a 60-lb coil or in a 750-lb drum. It requires neutral flux and is suited for downhole tool joints that require consistent mechanical properties in order to meet the environmental requirements of deep well drilling.

Thermadyne Industries, Inc. 100
101 S. Hanley Rd., Ste. 300, St. Louis, MO 63105-3406

Laser Beam Welding Workstations Provide Class I Environment



Utilizing a pulsed Nd:YAG laser beam welding system, Delta Series Workstations feature a steel chassis, Class I CDRH compliant work envelope, safety viewing window, safety interlocks, and fume extraction ports. Choices in multiaxis CNC motion stages, control hardware, and Windows® software are available. Additional features include vibration isolation footings, modular control panels, e-stop and fire command buttons, and laser emission indicators.

Unitek Miyachi Corp. 101
1820 S Myrtle Ave., P.O. Box 5033, Monrovia, CA 91017-7133

Brazing Machine Features Automatic Operation

CB Lite II™, suited for small production runs and job shops, is equipped with repeatable programmable logic control (PLC) setup to control heat, air, and water cycle times. Able to be retooled and retorched for quick application changeover, the movable machine is designed for use with rings or preforms. The unit will os-

cillate torches across a joint or rotate a part for uniform heating. The operator loads the part and pushes a button. All timing is preset in PLC, and the part is consistently brazed.

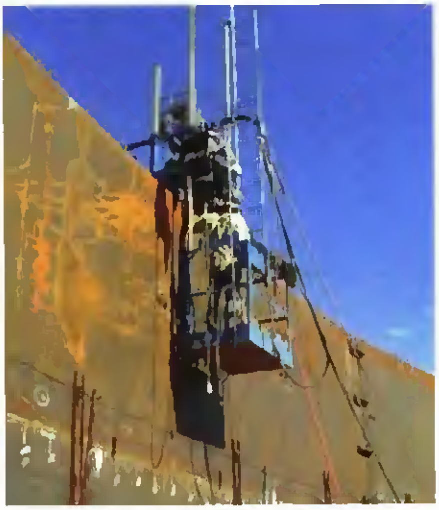
Precision Engineered Systems 102
225 Fentress Blvd., Daytona Beach, FL 32114

GTAW Machine Delivers 200 A of Welding Power

Pulling 25 A of power, the Invertig 201 AC/DC GTA welding machine allows users to vary AC frequency from 20 to 200 Hz while maintaining a square wave throughout its complete range for control over the arc. Pulsing, with frequency from 0.4 to 300 Hz, is standard, and balance is adjustable from 10 to 90%. The unit weighs 65 lb and fits in a cabinet measuring 20 × 9½ × 19¾ in. It comes with a 25-ft SR-17 air-cooled torch, foot pedal with a 15-ft cable, and a gas regulator.

HTP America, Inc. 103
3200 Nordic Rd., Arlington Heights, IL 60005-4729

Nickel Wire Facilitates Out-of-Position Welds



Stoody® 625, 182, 82, and A grades of flux cored nickel wires achieve welds in the uphill position. Available in both 0.045- and 1/16-in. diameters, wires are packaged on 33-lb wire baskets. Welders can choose between running 75% argon/25% CO_2 or straight CO_2.

Stoudy Co. 104
5557 Nashville Rd., P.O. Box 90032, Bowling Green, KY 42102

Welding Robots Eliminate Cable Interference

Operated via an NX100 robot controller, Expert Arc robot models EA1400N and EA1900N feature an internal cabling design that allows them to work in tight spaces or on workpieces positioned close to the manipulator arm. The T-axis can rotate a torch ±200 deg without cable interference. With repeatability of 0.003 in., the 6-axis EA1400N has 54.7-in. horizontal and 95.6-in. vertical reach, while the EA1900N features 75-in. horizontal and 134.6-in. vertical reach.

Motoman, Inc. 105
805 Liberty Ln., West Carrollton, OH 45449-2158

Electrodes Are Suited for Welding Various Alloys

Blue Max® stainless steel consumables can be used for welding high-alloy, duplex, or super duplex stainless and nickel-based alloys. Products include SMAW, GTAW, GMAW, and SAW consumables. Electrodes are lot-controlled with certificates of conformance available. Packaging options include hermetically sealed Sahara-Packs™.

The Lincoln Electric Co. 106
22801 St. Clair Ave., Cleveland, OH 44117

Backing Tape Produces Flat Welds, Reduces Slag

The company's weld backing tape offers heat resistance, provides close-fitting surface under the weld, and suits applications where use of purge gas is impractical. The metallic adhesive tape has a 25-mm-wide glass fiber strip, which is held up against the weld preparation area and maintains the weld in the same plane as the plates or tubes being joined. Two versions, one for weld applications up to 80 A, and a heavy-duty version for applications up to 160 A, are available.

Huntingdon Fusion Techniques 107
Stukeley Meadow, Carms, UK SA16 0BU

Welding Torch Kits Include In-Head Flash Arrestor

Dual Guard™ cutting, welding, and heating outfits are available in heavy-duty and medium-duty kits. Their heavy wall, hammer-style head minimizes heat warping and helps maintain a positive seat with the cutting tip. A flash arrestor module consists of a stainless steel filter that absorbs heat energy away from flashback and prevents it from going farther into the

equipment. Reverse-flow check valves with replaceable filters stop debris from entering the torch.

Smith Equipment 108
2601 Lockheed Ave., Watertown, SD 57201-5636

Safety Curtain Offers Automatic Operation

The Guardian™ Barrier Curtain protects personnel from weld flash and flying debris. Its Category 4 safety interlock switch detects any upward movement of the curtain, and stops robotic operation of the automated welding process. This switch enables Guardian to be used without a redundant light curtain or a pressure-sensitive mat. Its standard Soft-Bottom Edge™ helps protect personnel and property from impact damage.

Frummelt Products Corp. 109
P.O. Box 245020, Milwaukee, WI 53224-9520

Welding Helmet Provides Large Viewing Area

The Vision Guardian Model I400383H autodarkening helmet incorporates ADF optics that provide a usable 9.12 in.^{2} of view. It features an external control pod

that allows dark shading adjustment 9–13; an ADF safety test button and confirmation to warn of a dead ADF; and a battery drawer that keeps lithium replaceable batteries moisture-free. Hot graphic themes are available for personalization.

High Test Industries 110
P.O. Box 218, Walled Lake, MI 48390

Industrial Shoes Require No Break-in

The company's line of industrial footwear includes 13 flexible models that do not need to be broken in, providing instant comfort and less foot fatigue. A lightweight series employs sneaker-like construction for flexibility and reduced weight. Another series features a heel protection system that provides extra support and stability for reduced foot fatigue and increased safety. A third series incorporates air-cushioning chambers for increased shock absorption and air-circulation chambers for increased breathability.

DeWalt Industrial Footwear 111
701 E. Joppa Rd., Baltimore, MD 21286

Compact Robots Save Floor Space

The six-axis ARC Mate 100iBe and ARC Mate 120iBe robots are simplified versions of the ARC Mate 100i and ARC Mate 120i models, utilizing existing mechanical arms with optimized servomotor, amplifier, and controller features. Both new robots are compact, and offer maximum reach in confined areas, allowing manufacturers to install multiple robots in close proximity. The R-J3i B Mate Controller and ArcTool software are standard with the ARC Mate series.

Fanuc Robotics 112
3900 W. Hamlin Rd., Rochester Hills, MI 48309-3253

Anchor Point Attaches to Roof Rafter

The company's Claw Permanent Roof Anchor provides a permanent anchorage point when attached to a wood rafter or truss member (upright or inverted) during construction. The stainless steel claw anchor accommodates any 2-in.-wide wood rafter and includes a special UV-resistant Santoprene flashing and protective vinyl cap for use when the claw anchor is not in use. The anchor is designed for use by a single user of up to 310 lb.

Miller Fall Protection 113
1345 15 St., Franklin, PA 16323

— *continued on page 93*

Welding in the Defense Industry

breakthrough welding information from leading defense industry experts

July 13–14

Orlando's Grosvenor Resort

Leading defense industry experts to share results on overcoming weldability obstacles of aluminum, titanium, and stainless steels on an array of applications.

Engineers wanting to use aluminum, titanium, and/or stainless steels because of their excellent mechanical properties, but who are struggling to achieve the cost economy of high volume production, need to attend this conference.

With new available alloys and ingenious use of existing welding processes — including friction stir welding, electron beam welding, laser beam welding, and new hybrid processes such as flux-assisted gas tungsten arc welding — engineers from Top 100 defense contractors will share the results of weldability development on applications that can be transferred quickly to commercial manufacturing and fabrication.

To review the program and presenters, go to *www.aws.org/conferences/defense.*

Friction Stir Welding

too good to be true?

August 10–11

Orlando's Grosvenor Resort

Discover the ability to join materials that are difficult to fusion weld.

No consumables. No fumes. Low distortion, even in long welds. Excellent mechanical properties as proven by fatigue, tensile, and bend tests. No porosity. No spatter. Low shrinkage. Can operate in all positions. Energy efficient.

Sound too good to be true? There are a few challenges with friction stir welding. Over two intense days, find out how these final stumbling blocks are being resolved.

To review the program and presenters, go to *www.aws.org/conferences/frictionstir.*

Weld Cracking

16 experts on one serious subject

February 15–16, 2005

New Orleans' Hotel Monteleone

Brought back by popular demand, the Fifth Weld Cracking Conference will once again provide useful information to keep the welding engineer out of trouble, specifically cracking trouble. The old and the new will be presented. The old represents all the things you should know about weld cracking and were afraid to ask, while the new represents some of the newer technologies that can be used to keep the problem at arm's length. The elements of hot and cold cracking, weld repair, lamellar tearing, and stress corrosion cracking will all be covered. Toughness testing and heat treating will also be discussed. As in past conferences, there will be time for questions from the audience and knowledgeable speakers will be on hand to provide the answers. Be prepared to take many notes.

AWS D1.1 Code Week

September 20–24, San Francisco, Calif.
October 11–15, Philadelphia, Pa.
November 8–12, Atlanta, Ga.

The AWS D1.1 Code Week is designed to provide an in-depth look at AWS D1.1/D1.1M: 2004, *Structural Welding Code — Steel.*

◆ Day 1 — D1.1 Road Map
◆ Day 2 — Design of Welded Connections
◆ Day 3 — Qualifications
◆ Day 4 — Fabrication
◆ Day 5 — Inspection

Register for the full week and receive your complimentary copy of AWS D1.1/D1.1M: 2004, *Structural Welding Code — Steel.* For more information, contact the AWS Conferences and Seminars Business Unit at (800) 443-9353 ext. 223, or visit our Web site at *www.aws.org/w/s/conferences/d1.*

For further information, contact Conferences, American Welding Society, 550 NW LeJeune Rd., Miami, FL 33126. Telephone: (800) 443-9353 ext. 449 or (305) 443-9353 ext. 449; FAX: (305) 648-1655. Visit the Conference Department home page, *www.aws.org/w/s/conferences/*, for upcoming conferences and registration information.

Creating a New Force in Hardsurface Welding...

ISO 9001
SELECT-ARC
CERTIFIED

Jeff Schnabel and Select-Arc.

When Jeff Schnabel joined the Select-Arc team of welding specialists, he envisioned adding a new dimension to the company's highly regarded flux cored and metal cored product lines. Today, the union of Jeff's extensive hardsurfacing electrode knowledge and Select-Arc's exceptional manufacturing expertise has revolutionized the welding industry.

How?

With the introduction of a comprehensive group of hardsurfacing electrodes, specifically developed to improve your welding productivity, enhance performance and extend the life of components and machinery. Jeff incorporated his years of hardsurfacing experience with Select-Arc's dedicated research professionals to produce the innovative Select Wear hardsurfacing electrode products. These new wires are designed to meet and exceed your most demanding hardsurfacing electrode requirements.

The many customers who have depended on Select-Arc's quality electrode products, superior service and most value-added can now enjoy the significant benefits of specifying Select-Arc hardsurfacing electrodes. For more information on Select Wear electrodes, call Jeff at 1-800-341-5215 or visit our website at **www.select-arc.com.**

SELECT ARC INC.

600 Enterprise Drive
P.O. Box 259
Fort Loramie, OH 45845-0259
Phone: (937) 295-5215
Fax: (937) 295-5217
www.select-arc.com

Circle No. 45 on Reader Info-Card

American Welding Society

Friends and Colleagues:

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

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

Sincerely,

Dr. Alexander Lesnewich
Chairman, AWS Fellows Selection Committee

(please type or print in black ink)

CLASS OF 2006

FELLOW NOMINATION FORM

DATE__________ NAME OF CANDIDATE__________

AWS MEMBER NO.__________ YEARS OF AWS MEMBERSHIP__________

HOME ADDRESS__________

CITY__________ STATE_____ ZIP CODE_____ PHONE__________

PRESENT COMPANY/INSTITUTION AFFILIATION__________

TITLE/POSITION__________

BUSINESS ADDRESS__________

CITY__________ STATE_____ ZIP CODE_____ PHONE__________

ACADEMIC BACKGROUND, AS APPLICABLE:

INSTITUTION__________

MAJOR & MINOR__________

DEGREES OR CERTIFICATES/YEAR__________

LICENSED PROFESSIONAL ENGINEER: YES_____ NO_____ STATE__________

SIGNIFICANT WORK EXPERIENCE:

COMPANY/CITY/STATE__________

POSITION__________ YEARS_____

COMPANY/CITY/STATE__________

POSITION__________ YEARS_____

SUMMARIZE MAJOR CONTRIBUTIONS IN THESE POSITIONS:

____

____

____

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

SEE GUIDELINES ON REVERSE SIDE

SUBMITTED BY: PROPOSER__________ AWS Member No.__________
Print Name__________

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

NOMINATING MEMBER:__________
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.

<u>Return completed Fellow nomination package to:</u>

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

Everything is **bigger** in Texas

And the AWS Welding Show 2005 is the biggest of them all!

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:

- ★ Gas Products
- ★ Oilfield and Pipeline Equipment
- ★ Cutting and Grinding Products
- ★ Brazing and Soldering
- ★ Resistance Welding
- ★ Laser Welding and Cutting
- ★ Nondestructive Testing and Inspection

AWS WELDING SHOW 2005

April 26-28, Dallas, Texas
DALLAS CONVENTION CENTER

Circle No. 8 on Reader Info-Card

© American Welding Society 2004 CON-1070

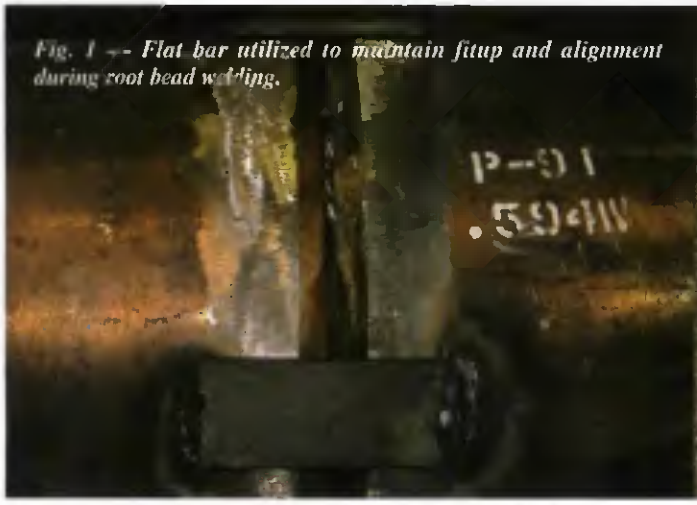


Fig. 1 — Flat bar utilized to maintain fitup and alignment during root bead welding.

Fig. 2 — Completed root bead shown with induction heating coil and blankets installed and flat bars removed.

Welding Root Beads in P91

Radiograph-quality root beads can be deposited in P91 using shielded metal arc welding

BY
CHARLES PATRICK,
TONY FERGUSON, AND
JOHNNY MAITLEN

CHARLES PATRICK, TONY FERGUSON, and JOHNNY MAITLEN are with Fluor Corp., Sugarlund, Tex.

The use of P91 (9Cr-1Mo-V) chromium-molybdenum steel pipe has continued to increase since its introduction into power plant construction. With conventional single-V-groove pipe welds, the root bead for P91 material is deposited with the gas tungsten arc welding (GTAW) process with an inert gas purge (e.g., argon) in the pipe to prevent contamination of the root bead (i.e., formation of oxides or "sugaring"), improve wetting, and augment general bead appearance. The purging process can be extremely expensive and labor intensive for field-fabricated pipe since a minimum of five to six volume changes of gas are typically required to reduce the oxygen content inside the pipe to an acceptable level (usually 2% or less oxygen). A variety of techniques (e.g., soluble dams, collapsible disc dams, inflatable bladder dams, etc.) provide a reduction in the purge volume, which in turn, decreases the required volume of gas, resulting in reduced costs. However, in many instances, these techniques are not viable options, thus necessitating a purge of the entire piping system.

Fluor Corporation recently qualified and successfully completed the first production welds in North America using Böhler Thyssen's newly developed Thyssen Chromo T 91 E9018-B9-H4 electrode with the shielded metal arc welding (SMAW) process. According to the manufacturer, this low-hydrogen electrode was developed for uphill welding using either alternating current (AC) or direct current (DC), direct current electrode negative (DCEP) or direct current electrode positive (DCEP) polarity, and for depositing root beads using DC with excellent weldability.

Decision

Samples of the electrodes in 3/32 in. (2.4 mm) and 1/8 in. (3.2 mm) diameter were obtained and subsequently implemented in the welding of sample welds. The decision to proceed to procedural qualification was determined by the following criteria: visual appearance of the root bead's interior surface, the short training time required, weldability, and the elimination of purge gas.

Procedure Qualification Data

Two pieces of SA-335:Grade P91, UNS Number K91560, ASME Section IX, P-Number 5B, Group 2, Schedule 80 (0.594-

Fig. 3A — Welder qualification plate in position; B — welder training.

in. [15.1-mm] wall thickness), 10 in. (254 mm) diameter were combined to form the test coupon. The specified weld parameters are presented in Table 1.

Table 1 — Welding Parameters

	Joint	
Bevel Angle	37$\frac{1}{2}$ deg	
Root Face (land)	$\frac{3}{32}$ in. (2.4 mm)	
Root Opening	$\frac{1}{8}$ in. (3.2 mm)	
	Filler Metal	
Root Bead	$\frac{1}{8}$ in. (3.2 mm)	
Balance	$\frac{3}{32}$ & $\frac{1}{8}$ in. (2.4 & 3.2 mm)	
	Position	
Position of Joint	5G (rolled)	
Weld Progression	Uphill	
	Preheat	
Minimum Preheat Temperature	430°F (221°C)	
Maximum Interpass Temperature	476°F (247°C)	
Preheat Maintenance	Yes	
	Electrical Characteristics	
	Root	Balance
Current	Direct	Direct
Polarity	Straight	Reverse
Amperage	72	81–103
Voltage	19.6	20.8–25.3
Heat Input	35.3 kJ/in. (1.4 kJ/mm)	62.5 kJ/in. (2.5 kJ/mm)
	Technique	
	Root	Balance
Travel Speed	2.4 in./min (1.0 mm/s)	2.4–3.5 in./min (1.0–1.5 mm/s)
Bead Type	Stringer	Stringer & Weave

Weld joint fitup (i.e., root opening and internal alignment) was maintained by tack welding three carbon-steel flat bars equally spaced around the circumference of the pipe (Fig. 1), thus eliminating the need to place tack welds into the weld groove and avoiding potential defects associated with tie-ins at the tacks. Localized areas were preheated to 430°F (221°C) using a rose bud prior to welding the flat bars into place.

Following the welding of the flat bars and verification of the correct fitup and alignment, the complete weld joint was preheated and maintained at a minimum of 430°F (221°C) utilizing Miller's Induction Heating System. The completed root bead, after grinding, is shown in Fig. 2 with blankets and induction heating coil in place and the flat bars removed.

Metallurgical Testing for Procedure Qualification

The completed weld was transported to an independent metallurgical laboratory for testing in accordance with ASME Section IX and B31.1, along with additional requirements specified by Fluor. The performed tests and their corresponding results are listed in Table 2.

Welder Training and Qualification

Welder training was initiated using a $\frac{3}{8}$-in.- (9.5-mm-) thick plate possessing a 30-deg bevel angle, $\frac{1}{8}$-in. (3.2-mm) root face, $\frac{3}{32}$-in. (2.4-mm) (loose) root opening positioned at a 45-deg angle, $\frac{1}{8}$-in. electrodes, and 75 A current — Fig. 3.

Once the welder demonstrated proficiency at welding the plate in the 45-deg angle position, the plate was replaced with a 6-in.- (152-mm-) diameter schedule 160 pipe coupon. The joint fitup tolerances and parameters previously noted were maintained during the remainder of the training. An additional six to eight hours of training using pipe coupons were typically required before the welder obtained proficiency to proceed to the welder qualification test. The qualification tests were performed on identical pipe coupons, joint tolerances, and parameters as used in training. All qualification tests successfully passed both a root and final visual inspection as well as a radiographic examination in accordance with ASME Section IX. In order to support the project's schedule, a total of six welders were trained and qualified as noted above.

Production Welding

On a cold February morning with the temperatures hovering in the single digits and a brisk wind blowing, preparations were quickly underway to fit up the first production P91 weld joint to be welded in North America with an electrode specifically designed for shielded metal arc root bead welding. The weld joint selected was a 12-in.- (305-mm-) diameter pipe welded

Table 2 — Metallurgical Tests

Postweld Heat Treatment (PWHT) per ASME B31.1

Heating Rate (°F/h)	Holding Temperature (°F)	Time at Temperature (h)	Cooling Rate (°F/h)
400 (204°C)	1400 (760°C)	2	500 (260°C)

Tensile Test per ASME Section IX

Dimensions (in.)	Area (in.^{2})	GL (in.)	0.20%YS (psi)	UTS (psi)	%El	Fracture Location/Type
0.7590 × 0.5500 (19.3 × 14 mm)	0.4175 (269.4 mm^2)	2.00 (50.8 mm)	64,000 (441 MPa)	90,800 (626 MPa)	26.5	Weld/Ductile
0.7510 × 0.5520 (19.1 × 14 mm)	0.4146 (267.5 mm^2)	2.00 (50.8 mm)	69,900 (482 MPa)	97,400 (672 MPa)	29.0	Base/Ductile

Bend Test Per ASME Section IX

Side Bends	Dimensions (in.)	Bend Angle (deg)	Former Diameter (in.)	Results
4	0.375 (9.5 mm)	180	1.5 (38.1 mm)	Acceptable

Additional Bend Test in Accordance with ASME Section IX

Root Bends	Dimensions (in.)	Bend Angle (deg)	Former Diameter (in.)	Results
2	1.5 (38.1 mm)	180	2.4 (61 mm)	Acceptable

Charpy Test per ASTM E 23

Location	Dimensions (mm)	Test Temp. (°F)	Energy Absorbed (ft lb)	% Shear	Mils Lateral Expansion
Weld	10 × 10 × 2V (0.394 × 0.394 × 0.079 in.)	68 (20°C)	80 (109 J)	75	67
Weld	10 × 10 × 2V (0.394 × 0.394 × 0.079 in.)	68 (20°C)	72 (98 J)	70	62
Weld	10 × 10 × 2V (0.394 × 0.394 × 0.079 in.)	68 (20°C)	54 (73 J)	60	55
HAZ	10 × 10 × 2V (0.394 × 0.394 × 0.079 in.)	68 (20°C)	101 (137 J)	90	70
HAZ	10 × 10 × 2V (0.394 × 0.394 × 0.079 in.)	68 (20°C)	176 (239 J)	100	79
HAZ	10 × 10 × 2V (0.394 × 0.394 × 0.079 in.)	68 (20°C)	121 (164 J)	100	77

Hardness Survey per ASTM E 384

Method	Load (kg-ft)	Depth (in.)	Number of Traverses	Maximum Hardness
Vickers	500.0	0.063 (1.6 mm)	9	238

Vickers Microhardness Survey

1.	207	10.	184	19.	189	28.	195	37.	219
2.	179	11.	196	20.	228	29.	210	38.	225
3.	203	12.	215	21.	238	30.	219	39.	234
4.	195	13.	228	22.	167	31.	224	40.	224
5.	196	14.	217	23.	204	32.	224	41.	204
6.	200	15.	219	24.	223	33.	229	42.	227
7.	228	16.	204	25.	219	34.	188	43.	220
8.	205	17.	198	26.	203	35.	234	44.	206
9.	194	18.	211	27.	180	36.	219		

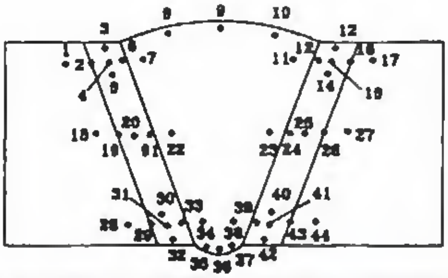


Fig. 4 — Fitup and alignment were maintained by using a section of P91 pipe with a carbon-steel handle.

Fig. 5 — Chris Pucci deposits the first SMAW P91 root bead in North America.

to an 18-in.- (457-mm-) × 12-in. weld-o-let with a wall thickness at the weld joint of 1.312 in. (33.3 mm). The joint fitup tolerances and parameters previously noted for training were utilized for this and subsequent weld joints. In order to eliminate tacks in the weld groove, four short sections of P91 pipe were equally spaced around the circumference of the weld joint and welded into place to maintain fitup and alignment tolerances. Each short section was fitted with a carbon steel handle to assist in holding them during installation and protect the pipefitter from the heat being radiated from the 430°F (221°C) preheat — Fig. 4.

Chris Pucci is shown in Fig. 5 depositing the root bead with techniques and skills acquired through the training described herein. The root bead was deposited in opposite quarter sections with each start and stop ground to a taper to assist in a complete tie-in and smooth bead transition into the next section. A technique was employed that allowed the amperage to be increased by approximately 10 A via a remote control, thus further augmenting successful tie-ins and transitions. This was accomplished by visually monitoring the progression of the root bead during welding through the root opening and subsequent "window" (short section of root bead approximately 2 in. [51 mm] long that was not welded), allowing the amperage to be increased at the appropriate time. Immediately following the tie-in location, the amperage was returned to the original setting. Following the deposition of the root bead, except for the window, the welder changed to an E9015-B9 electrode and deposited the second bead (hot pass). The ends of this bead were cascaded approximately ¾ in. (19 mm) from the ends of the root bead on each side of the window. Visual examination through the window revealed that the heat from the hot pass resulted in approximately 95% of the slag on the interior of the root pass being detached. Following the visual examination, the welder changed electrodes and completed the remainder of the root bead using the techniques previously noted. Once the root bead was completed, the welder again changed electrodes and completed the "hot pass" and the remainder of the weld.

A total of 28 large-bore P91 welds with an average pipe diameter of 18 in. and an average wall thickness of 1.781 in. (45.2 mm) using Thyssen Chromo T 91 E9018-B9-H4 electrodes for the root bead followed by E9015-B9 filler metal were completed at the project. Each weld was radiographed in accordance with ASME/ANSI B31.1, which resulted in one weld being rejected for a root bead discontinuity (incomplete joint penetration at a window closure tie-in). A respectable project weld reject rate of 3% for field production welding using this welding technique was duly noted.

Cost Savings

Cost savings are difficult to approximate in field applications due to the project environment and the uniqueness of each weld. However, cost savings directly related to the 28 welds, after deducting costs associated with training and qualifications, were estimated at $56,560. The largest single cost savings was the elimination of work hours required to clean and install the purge dams inside the pipe. Other significant cost savings included the elimination of work hours waiting for the oxygen content of the purge to reach 2% as required by specification, cost of argon for both shielding and purge gas, and elimination of the time-consuming gas tungsten arc welding process.

Conclusion

Böhler Thyssen's newly developed Thyssen Chromo T 91 E9018-B9-H4 electrode with the SMAW process has demonstrated that it is a viable option for welding radiograph-quality root beads in P91 during initial construction. This combination certainly has a future in operations and maintenance applications as well. ◆

Acknowledgments

The authors gratefully acknowledge Böhler Thyssen for donating the filler metal for trial and PQR development, and Russel Fuchs, senior technical manager and welding engineer for Böhler Thyssen Welding USA, Inc., for his technical support. The authors thank Miller Electric Mfg. Co. for providing the Induction Heating System, and Gerald Miller, account manager for Miller Electric, for his technical support.

Weld Metal Properties of Reeled Pipelines

Construction method of offshore pipelines determines the characteristics of the welded joints

BY J. R. STILL

Fig. 1 — Onshore pipe-to-pipe welding using pulse gas metal arc welding.

Methods for laying pipe offshore involve conventional lay barges, reel ships, and towing of pipe bundles. All of these methods rely on welding to join the pipes, either onshore or offshore. Pipe laying using a reel ship is an attractive option, as all pipe joints, with the exception of the offshore tie-ins, are welded onshore. This technique is considered to be one of the most reliable methods for laying a pipeline offshore. Welding trials are an essential part of the approval process where the weld joint properties must meet the requirements of the national standard, i.e., BS 4515-1 (Ref. 1), API 1104 (Ref. 2), plus any additional requirements requested by the client. This article describes the onshore production facilities, welding processes, and the properties achieved during welding procedure trials that include strain-aged Charpy impacts.

Construction of Pipelines for Reeling

The onshore fabrication of pipelines for reeling involves having a purpose-built workshop, laid out in such a way to ensure that the welding of pipe material and butt joints is carried out with the minimum of disruption. Also, contained within these facilities will be a radiographic and coating unit. Fabricated pipeline sections up to 1000 m

Fig. 2 — An internal clamp with backing shoes is used for the root run.

J. R. STILL is a consultant welding and materials engineer, Aberdeen, Scotland.

(3280 ft) in length, referred to as pipe stalks, are transferred from the fabrication shop to an open holding area. Within the holding area, all weld repairs, tie-ins between pipe stalks, and coating and coating repairs are carried out, which are inspected on completion to ensure that the quality meets the client's requirements.

The pipe stalks are eventually coiled onto the vessel reel. This can involve several pipe stalks joined by butt joint welding.

On location offshore, the reeled pipe is uncoiled and laid on the seabed. Depending on the length of the pipeline being laid, it may be necessary to tie-in the laid pipe with a section of the reeled pipe by butt joint welding. This operation is carried out on the reel vessel and, on completion of welding, nondestructive examination (NDE), and coating, pipe laying continues.

Pipeline Welding

A 16-in. (406.4-mm) -diameter, API 5L X60 (Ref. 3) pipeline, manufactured through a quenched and tempered route, was recently laid in the U.K. sector of the North Sea. Chemical composition and mechanical properties are outlined in Tables 1 and 2.

Construction of the 16-in. (406.4-mm) -diameter pipeline involved the following welding procedures:

Pipe-to-Pipe Mainline Onshore. The method used for the mainline butt joint welds consisted of an automatic pulsed gas metal arc welding (GMAW-P), an example of which is illustrated in Fig. 1. Details of the welding procedure, which was carried out in the 5G position, is outlined in Table 3. Weld preparation consisted of a narrow gap bevel with zero gap between root faces. An internal clamp with copper backing shoes (Fig. 2) is used for the root run and hot pass. Preheat temperature was 100°C with interpass temperature controlled at 300°C maximum.

Complete Penetration Repair to Mainline Weld Onshore. Repairs to the mainline welds are carried out in the pipe stalks' holding area, and welding is carried out in an all-weather habitat. The process used for repairing original mainline welds consists of shielded metal arc welding (SMAW). Details of the weld procedure carried out in the 5G position are outlined in Table 4. Welding in this instance is carried out in the uphill position using a preheat temperature of 150°C and an interpass temperature controlled at 300°C maximum.

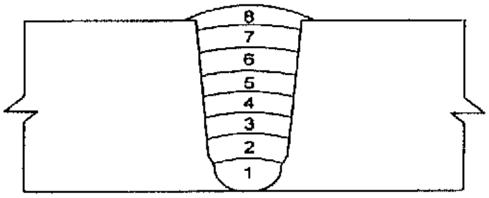
Table 1 — Pipe Metal Chemical Analysis

C	Si	S	P	Mn	Ni	Cr	Mo
0.11	0.25	0.003	0.12	1.10	0.11	0.08	0.11
V	Cu	Al	Nb	N	B	Ca	Ti
0.05	0.14	0.025	0.022	0.0082	0.002	0.0017	0.003
Carbon Equivalent		0.36	Steel Making Process			Electric Arc	

Table 2 — Pipe Metal Mechanical Properties

		Tensile Tests	
		Tensile Strength N/mm^2	Elongation (%)
		567	24
		Test Temperature	Impact Properties Joules
		Charpy Impact Tests –40°C	252, 252, 258, Av 254
		Inside	180, 179, 177, Av 178
Hardness	HV 10	Mid wall	184, 182, 179, Av 181
Results		Outside	196, 194, 199, Av 196

Table 3 — Pipe-to-Pipe Mainline Weld Procedure



16-in. Pipe-to-Pipe Mainline Onshore — Metal API 5L X60

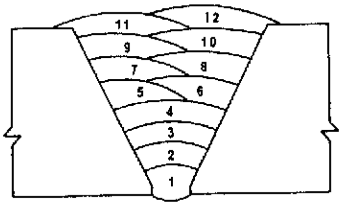
Welding Position 5G — Diameter 406.4 mm — Thickness 23.8 mm

Pass No.	Process	Filler Size (mm)	Amps	Volts	R.O.L. (mm)	Time (s)	Speed (mm/s)	Heat Input (kJ/mm)
1	GMAW-P	0.9	213–231	21–25	630–670	42–46	14.6/15	0.3
2	GMAW-P	0.9	208–225	21–25	660–670	96–100	6.6/7	0.7/0.8
Fill	GMAW-P	0.9	201–228	21–25	660–670	93–98	6.7/7.1	0.7/0.8
Last 2	GMAW-P	0.9	195–219	21–25	100	12–20	5.0/8.3	0.6/1.0
Cap	GMAW-P	0.9	159–178	21–15	100	19–26	3.8/5.3	0.8/1.1

Filler Metal Specification		Flux/Shielding Gas	
Classification	A5.28 ER80S-G	Type	Ar/CO_2
		Classification	85% Ar/15% CO_2
Electrical Characteristics	DC + VE	Flow Rate	20–27 L/min.
Preheat °C	100	Tungsten Electrode	NA
Interpass Temp °C	255		

Note: GMAW-P (Pulsed gas metal arc welding)

Table 4 — Repair to Mainline



Complete Penetration Repair to Mainline Onshore

Metal API 5L X60

Welding Position 5G

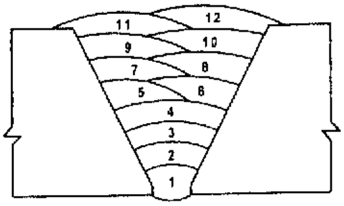
Diameter 406.4 mm

Thickness 23.8 mm

Pass No	Process	Filler Size (mm)	Amps	Volts	R.O.L. (mm)	Time (s)	Speed (mm/s)	Heat Input (kJ/mm)
1	GTAW	2.4	90–160	8–11	65–90	35–88	1.0–2.0	0.6–1.2
2	GTAW	2.4	160–240	8–11	70–90	27–58	1.6–2.6	0.8–1.1
Fill	SMAW	3.2	90–140	20–24	80–150	45–60	1.4–2.6	1.0–1.8
Cap	SMAW	3.2	90–130	20–24	60–110	43–63	1.4–2.0	1.2–1.8

Filler Metal Specification		Flux/Shielding Gas	
Classification	A5.28 ER80S-G A5.28 ER90S-G A5.5 E9018-G	Type Classification	High-Purity Argon 99.995% Argon
Pass No.	1. ER80S-G 2. ER90S-G Fill and Cap E9018-G		
Electrical Characteristics	DC – VE DC – VE DC + VE	Flow Rate	12–20 L/min
Preheat °C	150	Tungsten Electrode	2.4 mm, 2% Thoriated
Interpass Temp °C	300		

Table 5 — Pipe-to-Pipe Cut-out/Tie-in Onshore



16-in. Pipe-to-Pipe Mainline Cut-Out/Onshore Tie-in

Metal API 5L X60

Welding Position 5G

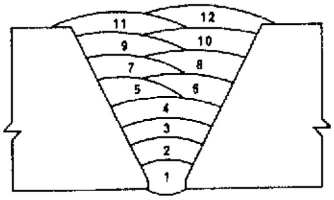
Diameter 406.4 mm

Thickness 23.8 mm

Pass No.	Process	Filler Size (mm)	Amps	Volts	R.O.L. (mm)	Time (s)	Speed (mm/s)	Heat Input (kJ/mm)
1	GTAW	2.4	90–200	8–11	90–235	60–160	1.0–2.1	0.7–1.1
2	GTAW	2.4	150–280	8–11	100–330	51–120	1.6–2.8	0.8–1.0
Fill	FCAW-G	1.2	140–220	24–26	90–320	32–141	2.0–4.0	1.1–2.4
Cap	FCAW-G	1.2	140–215	24–26	100–380	32–86	2.8–4.4	1.0–1.5

Filler Metal Specification		Flux/Shielding Gas	
Classification	A5.28 ER80S-G A5.28 ER90S-G A5.29 E80T-K2	Type Classification	High-Purity Argon Argon 25 99.995% Argon
Pass No.	1. ER80S-G 2. ER80S-G Fill and Cap E80T-K2		75% Ar/25% CO_2
Electrical Characteristics	DC – VE DC – VE DC + VE	Flow Rate	GTAW 12–20 L/min FCAW-G 15–25 L/min
Preheat °C	100	Tungsten Electrode	2.4 mm, 2% Thoriated
Interpass Temp °C	300		

Table 6 — Pipe-to-Pipe Offshore Tie-in



Pipe-to-Pipe Offshore Tie-in — Metal API 5L X60

Welding Position 6G — Diameter 406.4 mm — Thickness 23.8 mm

Pass No.	Process	Filler Size (mm)	Amps	Volts	R.O.L (mm)	Time (s)	Speed (mm/s)	Heat Input (kJ/mm)
1	GTAW	2.4	90–200	8–11	90–235	60–160	1.0–2.1	0.7–1.1
2	GTAW	2.4	150–280	8–11	100–330	51–120	1.6–2.8	0.8–1.0
Fill	FCAW-G	1.2	140–220	24–26.5	90–320	32–141	2.0–4.0	1.1–2.4
Cap	FCAW-G	1.2	140–215	24–26.5	100–380	32–86	2.8–4.4	1.0–1.5

Filler Metal Specification		Flux/Shielding Gas	
Classification	A5.28 ER80S-G A5.28 ER90S–G A5.29 E80T-K2	Type Classification	High-Purity Argon Argon 25 99.995% Argon
Pass No.	1. ER80S–G 2. ER90S-G Fill and Cap E80T–K2		75% Argon/25% CO_2
Electrical Characteristics	DC – VE DC – VE DC + VE	Flow Rate	GTAW 12–20 L/min FCAW-G 15–25 L/min
Preheat °C	100	Tungsten Electrode	2.4 mm. 2% Thoriated
Interpass Temp °C	300		

Table 7 — Weld Metal Chemical Analysis

Weld Procedure	C	Si	S	P	Mn	Cr	Mo	Ni
Pipe-to-Pipe Mainline	0.10	0.52	0.008	0.01	1.24	0.04	0.02	0.03
Repair to Mainline	0.10	0.52	0.008	0.01	1.17	0.05	0.07	0.62
Pipe-to-Pipe Cut Out and Pipe-to-Pipe Onshore Tie-in	0.10	0.55	0.007	0.01	1.28	0.04	0.09	0.65
Pipe-to-Pipe Offshore Tie-in	0.10	0.44	0.008	0.01	1.17	0.04	0.14	0.68

Table 8 — Cross-Weld Tensile Tests

Weld Procedure	Ultimate Tensile Strength (N/mm²)	Fracture Location
Pipe-to-Pipe (Mainline)	609, 617	Base Break
Pipe-to-Pipe (Cut Out)	628	Base Break
Repair to Mainline	589, 590	Base Break
Pipe-to-Pipe Offshore Tie-in	621, 628	Base Break

Pipe-to-Pipe Mainline Cut Out/Tie-In Onshore. The weld procedure is used for welding butt joints between pipes, which can consist of mainline butt joint weld cutouts and butt joint welding of pipe stalks to pipe stalks, or pipe stalks to reeled pipe. Weld preparation consists of a 50 to 60-deg bevel where the root run is deposited using gas tungsten arc welding (GTAW) and filled with SMAW. Bridge tacks are used to maintain the root opening, which are removed and repositioned to prevent the opening from shrinking and restricting access. Details of the welding procedure 5G position are illustrated in Table 5. Preheat and interpass temperatures are identical to that applied for the mainline butt joint welds.

Pipe-to-Pipe Tie-In Offshore. The weld procedure used for offshore tie-ins is similar to that used for pipe-to-pipe tie-ins onshore, with the exception that the welding procedure is qualified in the 6G position. Details of the weld procedure are outlined in Table 6.

Weld Metal Properties

Chemical Analyses

Chemical analyses for the above weld procedures are outlined in Table 7. With the exception of the GMAW-P weld procedure, the weld metal compositions for the remaining procedures are similar and contain 1% nickel.

Mechanical and Metallurgical Properties

Weld procedure mechanical testing was carried out in accordance with BS4515-1 (Ref. 1), plus additional requirements specified by the client.

Table 9 — Weld Metal Hardness Survey

	Pipe-to-Pipe (Mainline)			Pipe-to-Pipe Cut Out			Repair to Mainline			Pipe-to-Pipe Offshore Tie-in		
Location	Top	Middle	Bottom	Top	Middle	Bottom	Top	Middle	Bottom	Top	Middle	Bottom
Base Metal	188	189	207	188	178	203	201	195	203	183	183	215
HAZ	212	194	219	230	183	205	203	198	201	222	182	215
Weld	197	219	247	202	188	232	220	213	222	209	215	247
HAZ	216	192	220	206	188	193	203	192	201	206	197	207
Base Metal	185	183	203	174	178	195	199	189	206	183	180	206
Specification		Weld Metal			Root and Mid-Thickness		250	HAZ		Root and Mid-Thickness		250
					Cap		275			Cap		275

Table 10 — Strain-Aged Weld Metal and Heat-Affected Zone Charpy Impact Results at –30°C

	Pipe-to-Pipe Mainline		Repair to Mainline		Pipe-to-Pipe Cut Out and Pipe-to-Pipe Onshore		Pipe-to-Pipe Offshore	
Location	Position	Joules	Position	Joules	Position	Joules	Position	Joules
Weld Cap	0 deg	73, 74, 72, Av 73	Repair	64, 56, 70, Av 63	0 deg	62, 67, 97, Av 97	0 deg	131, 136 137 Av 135
Weld Cap	180 deg	83, 77, 75, Av 78			180 deg	119, 85, 98, Av 101	90 deg	133, 137, 135 Av 135
HAZ Cap	0 deg	94, 172, 184, Av 150	Repair	270, 230, 248, Av 249	0 deg	53, 75, 116, Av 81	0 deg	188,242. 237 Av 222
HAZ Cap	180 deg	40, 111, 162, Av 104			180 deg	179, 234,228, Av 214	90 deg	201, 190, 220 Av 204
Weld Root	0 deg	81, 80, 80, Av 80	Repair	48, 64, 50, Av 50	0 deg	83, 39, 82, Av 68	0 deg	115. 119, 95 Av 110
Weld Root	180 deg	79, 87, 79, Av 82			180 deg	57, 60, 48, Av 55	90 deg	126, 119, 108 Av 118
HAZ Root	0 deg	88, 129, 168, Av 128	Repair	210, 190, 250, Av 217	0 deg	227, 254, 247, Av 243	0 deg	163, 184, 242 Av 196
HAZ Root	180 deg	220, 116, 76, Av 137			180 deg	194, 224, 202, Av 207	90 deg	228, 168, 222 Av 206

Charpy Impact Dimensions 10 × 10 ×2 V Charpy Impact Test Temperature –30 °C All Charpy Impacts Heat-Treated at 100 °C for 1 hour after 2.4% Strain

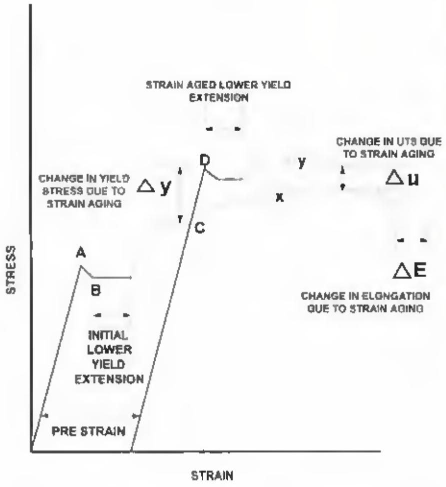


Fig. 3 — Stress/strain curve shows relationship between strain and yield strength.

Tensile Tests

Tensile tests consisting of cross-weld tensile specimens were carried out on all weld procedures. Tensile results varied from 589 to 628 N/mm², depending on the weld procedure, which were well above the minimum pipe tensile result of 567 N/mm². Details of the results obtained are outlined in Table 8. The tensile specimens all fractured in the base metal.

Fig. 4 — Microstructure of the API 5L X60 seamless pipe metal, austenitized at 920°C, water quenched, and tempered at 690°C.

Hardness Survey

Weld joint hardness surveys were carried out at three locations: on the top, middle, and bottom of each macro using a 10-kg load. The results recorded are outlined in Table 9. Hardness results varied from 174 to 222 HV, with the exception of the following isolated values:

- Pipe-to-pipe recorded a weld metal root hardness value of 247 HV.
- Pipe-to-pipe cut-out recorded a heat-affected zone (HAZ) value from the top hardness value of 230 HV, and a weld metal value of 232 from the root.
- Pipe-to-pipe offshore recorded a weld metal value of 247 HV from the root.

The high weld metal root hardness values recorded are difficult to explain, since one would have expected that the root area would have experienced the effect of depositing the hot pass (and subsequent passes) and where the previously deposited microstructure would have been refined. It would appear that the HAZ hardness value recorded from the top survey may be due to a reduction of the preheat temperature.

Strain-Aged Charpy Impacts

Weld metal Charpy impact tests are carried out in the strain-aged condition to simulate the effect that reeling on and off the vessel has on the mechanical properties of the weld metal. Charpy impact specimens were removed from the 0-deg and 180-deg positions and tested at –30°C in the strain-aged condition. To obtain strain-aged Charpy specimens involves removing a section of the pipe weld from the longitudinal direction of the pipe and applying a 2.4% strain and aging at 100°C for one hour. Toughness requirements specified were 40 joules minimum average and 30 joules minimum individual value. Details of the Charpy impact test results in the strain-aged condition are illustrated in Table 10.

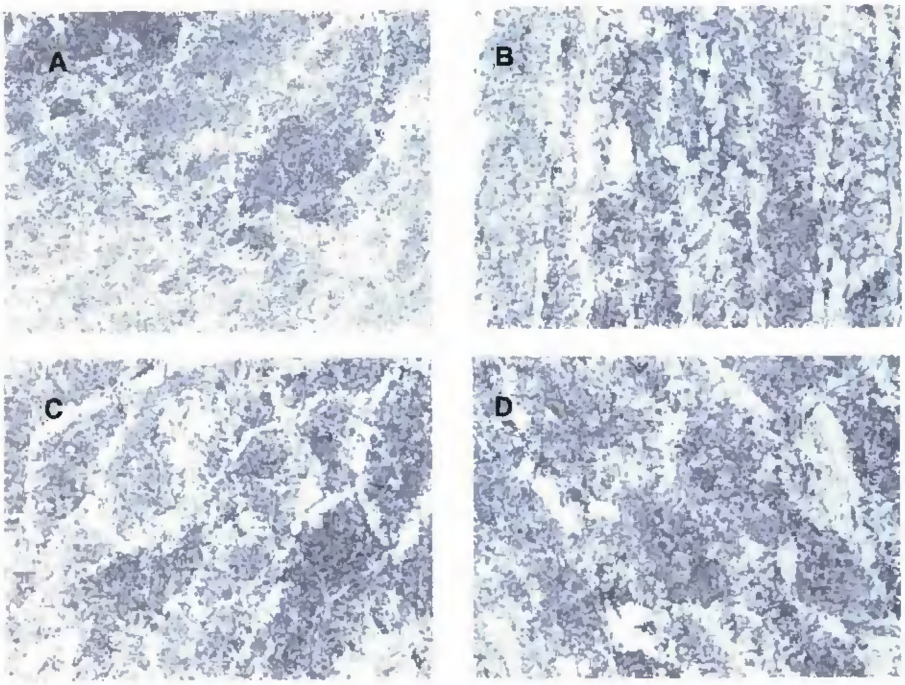


Fig. 5 — Microstructures of the weld metals (all position 5G). A — Thyssen K Nova, A5.28 ER80S-G; B — Bohler-BVD 90, A5.5 E9018-G, SMAW; C — Filarc 98S, A5.5 E9018G, SMAW; D — Lincoln Outershield, A5.29 E80T, FCAW-G.

Strain Aging

Strain aging is the result of atoms of carbon and nitrogen dissolved in ferrite, which segregate to dislocations and lock their movement (Ref. 3). This increases the strength and hardness of a steel but reduces its ductility. The rate of segregation is controlled by the following essential variables:

- Dislocation density
- Temperature
- Concentration of carbon and nitrogen atoms.

In order to provide a brief description of strain aging, the stress/strain curve illustrated in Fig. 3 (Ref. 4) illustrates the effect that straining has on the yield strength. When the weld specimens are strained, yielding takes place at point "A" upper yield point and drops dramatically to point "B" lower yield point. The horizontal section after point B is known as the "Initial Lower Yield Strength" (Ref. 4). Straining of the weld specimen is allowed to continue to point "C" on the stress/strain curve "x. " At this point, the tensile specimen is unloaded and aged at 100°C for 1 hour. When the strain is reapplied to the weld specimen, yielding returns and continues to point "D" on the stress/strain curve "y." The horizontal portion after the yield point is referred to as the "strain-aged lower yield extension." This increase in yield strength Δy is an indication that strain aging has occurred.

However, other factors such as interstitial atoms of carbon and nitrogen play significant roles in the strain aging process. Weld metal dislocation is effectively immobilized during cold working by interstitial atoms of carbon and nitrogen along the cores of the dislocation (Point B–C). Further cold work results in the unlocking of new dislocation, resulting in blocking at point "D." Yielding continues until no further dislocation movement is available. However, if the strain is continued fracture would result.

Strain-aged tests are carried out on all weld procedures where the strain rate and aging temperature can vary depending on the diameter and thickness.

In addition to the above, the steel supplier carries out strain-aged tests on pipe material where test specimens are strained at 5% and aged at 250°C.

Weld Metal Microstructures

Figures 4 and 5 illustrate the pipe material and weld metal microstructures respectively. The pipe material was processed through a quenched and tempered route, producing a microstructure consisting of tempered martensite. Although weld metals were deposited by different consumables and processes, their the weld metal compositions were similar, with the exception of the GMAW-P. The microstructure consists essentially of veins of polygonal ferrite with an acicular ferrite matrix.

Summary

Pipe reeling is considered one of the most reliable methods for laying a pipeline offshore. All welding, with the exception of the offshore tie-ins, is carried out onshore. This practice allows better control over materials, welding, repairs, and weld coatings.

In order to reduce the effect of strain aging on reeled pipe welds, steelmakers are now making additions of niobium, vanadium, molybdenum, or titanium to bind the interstitial carbon and nitrogen atoms to form stable carbides, and aluminium to form nitrides. It has been reported that strain-aged trials carried out on pipeline steels modified with the above elements showed no significant degradation of properties (Ref. 5). ◆

Acknowledgments

The author would like to thank David Baillie for commenting on the preparation of this paper, and Dr. K. Prosser for the useful discussion on strain aging.

References

1. *BS 4515-1 2000, Specification for Welding of Steel Pipelines on Land and Offshore, Part 1: Carbon and Carbon Manganese Steel Pipelines.* London: British Standards.
2. *API 1104, Standard for Welding Pipelines and Related Facilities.* Washington, D.C.: American Petroleum Institute.
3. Blickwede, D. J. 1969. Strain aging and its effect. *Metal Progress* July: 91–94.
4. Baird, J. D. 1963. Strain aging of steel – a critical review, part 1: practical aspects. *Iron and Steel* May: 186–192.
5. EEMUA. 1999. *Guidelines for Materials Selection and Corrosion Control for Subsea Oil and Gas Equipment.* Publication 194. London: The Engineering Equipment and Materials Users Association.

Maintenance Welding on the Trans-Alaska Pipeline

Welding repair procedures were updated to adjust for reduced oil flow rates

BY WILLIAM A. BRUCE AND ALAN S. BECKETT

Fig. 1 — Setup for small-scale laboratory trials.

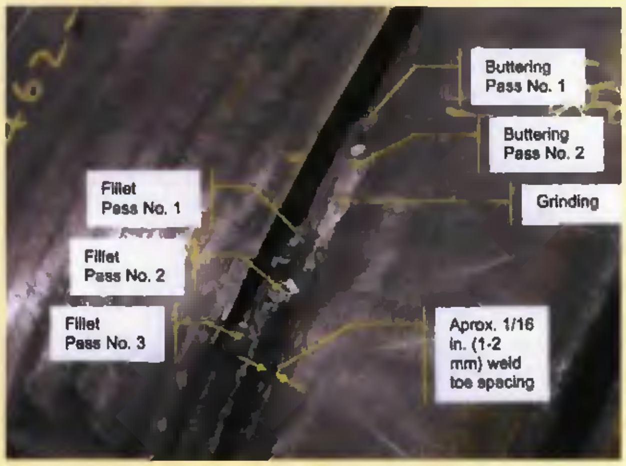


Fig. 2 — Demonstration weld showing temper bead sequence.

Fig. 3 — Setup used for procedure qualification trial welds in Fairbanks.

The existing welding practices and procedures used in conjunction with maintenance and tie-in welding on the Trans-Alaska Pipeline System (TAPS) have not been significantly revised since they were prepared shortly after original construction in the mid-1970s. The originally qualified procedures have served the operator, Alyeska Pipeline Service Co., well to date, and there is no evidence that the procedures are unsound. However, operating conditions on the pipeline have changed over time, while some new developments have occurred in in-service welding technology that may be appropriate for Alyeska to consider adopting. The objective of a recently completed project at Edison Welding Institute (EWI) was to review early work for Alyeska and existing Alyeska procedures and practices. The purpose of this project was to examine alternative procedure options for avoiding hydrogen cracking during in-service welding on TAPS, and to recommend and assist in the requalification of new procedures, if required.

Background

TAPS transports crude oil from the North Slope of Alaska to the marine terminal in the ice-free port of Valdez, Alaska. The pipeline is 48 in. (1219 mm) diameter and 800 miles (1287 km) in length. Construction began on March 27, 1975, and was completed on May 31, 1977. The United States depends on TAPS to deliver 17% of its domestic oil production.

When welding onto an in-service pipeline, to facilitate a repair or to install a branch connection using the "hot tapping" technique, there is a risk of hydrogen cracking from the fast cooling rates that tend to be produced by the flowing contents removing heat from the pipe wall. To prevent hydrogen cracking, at least one of the three conditions necessary for its occurrence must be eliminated. Beyond the use of low-hydrogen electrodes to minimize hydrogen levels, many companies

---

Adapted from a paper presented March 2003 at the International Conference on Pipeline Repair and In-Service Welding, Welding Technology Institute of Australia, Wollongong, Australia.

WILLIAM A. BRUCE is a Principal Engineer in the Materials Section at Edison Welding Institute, Columbus, Ohio. ALAN S. BECKETT is Alyeska Welding Program Steward at Alyeska Pipeline Service Co., in Anchorage, Alaska.

Fig. 4 — Alyeska's Miller Electric induction heating system.

Fig. 5 — Example of completed procedure qualification trial weld.

have developed procedures that minimize the formation of crack-susceptible microstructures. Procedure options for minimizing the formation of crack-susceptible microstructures for welds made onto in-service pipeline include the use of a sufficiently high heat input level, the use of preheating, the use of a temper bead deposition sequence, or some combination of these.

The existing procedures used by Alyeska for in-service welding use low-hydrogen electrodes and rely on achieving a preheat temperature of at least 125°F (52°C). Preheating has the dual benefit of reducing weld cooling rates somewhat, which can reduce hardness levels, and allow time for hydrogen diffusion. The operating temperature of TAPS has decreased over the years as the volume of crude oil flowing through the system has decreased. The average operating temperature at the present flow rate of approximately 1.0 million barrels per day is approximately 68°F (20°C) compared to 116°F (47°C) at 1.85 million barrels peak production. This lower operating temperature results in difficulty achieving the 125°F minimum-required preheat temperature. It was therefore desirable to examine alternative procedure options for avoiding hydrogen cracking during in-service welding on TAPS.

Extensive testing was carried out at Cranfield Institute of Technology (now Cranfield University) for Alyeska in 1977 and 1979 (Refs. 1, 2). The purpose of this work was to investigate variables affecting weld quality and to develop a welding procedure for attaching repair fittings to TAPS with regard to both hydrogen cracking risk and the risk of lamellar tearing (decohesion of sulfide inclusions). This work resulted in the establishment of a minimum-required preheat temperature and recommendations for fillet weld size.

Review of Alyeska Maintenance Welding Procedures

The existing welding procedure specifications (WPSs) and supporting procedure qualification records (PQRs) were reviewed with regard to good welding practice in general, and for compliance to API RP 1107 and API Specification 1104, Appendix B requirements. The adequacy of the existing procedure was also evaluated using the results of a recently completed group-sponsored project (GSP) at EWI (Ref. 3), where procedures for in-service welding that are resistant to hydrogen cracking over a wide range of conditions were developed and qualified to the requirements of a variety of industry codes.

With very few exceptions, the Alyeska procedures were found to be in compliance with ASME Section IX and API 1107. API 1107 has been superseded by Appendix B of API 1104 (19th Edition), however. Comparison of the Alyeska procedures with the results of the recently completed GSP at EWI indicates that several procedure options exist for current operating conditions of TAPS.

Laboratory Trials to Determine Adequacy of Existing Procedures

Small-scale welding trials were carried out to demonstrate that a range of parameters could be used to produce sound crack-free welds without the use of preheat. Two pipe materials, a 0.462-in. (11.7-mm) -thick X65 and a 0.562-in. (14.3-mm) -thick X70 (Table 1), were supplied by Alyeska.

Trial welds approximately 12 in. (300 mm) in length were made using hydrogen-controlled electrodes and candidate parameters under simulated in-service conditions. These conditions included simulating the ability of the flowing contents to remove heat from the pipe wall by circulating water across the inside surface of the pipe material while the welds were made. Restraining welds were also used to produce realistic levels of residual stress — Fig. 1. Multipass fillet welds were made over a wide range of heat inputs (25 and 40 kJ/in. [1.0 and 1.6 kJ/mm]) and using a temper bead deposition sequence — Fig. 2. Metallographic specimens were extracted for examination and the resulting HAZ hardness was measured and compared with previously established limits for in-service welds (Ref. 4). In addition, mechanical test specimens were extracted and tested so that any hydrogen cracks would be revealed.

Table 1 — Chemical Analysis Results for Laboratory Trial Materials

	Chemical Composition (wt-%)	
Element	0.462 in.	0.562 in.
C	0.093	0.091
Mn	1.33	1.37
P	0.015	0.010
S	0.012	0.004
Si	0.29	0.25
Cu	0.03	0.02
Sn	—	—
Ni	0.01	0.01
Cr	0.01	0.01
Mo	<0.01	<0.01
Al	0.02	0.03
V	0.05	0.07
Nb	<0.005	0.04
Zr	<0.005	<0.005
Ti	<0.005	<0.005
B	<0.0005	<0.0005
Ca	—	—
Co	—	—
CE_{IIW}	0.33	0.34

The results of these trials indicate that all of the candidate parameters (25 and 40 kJ/in. minimum-required heat input, and temper bead deposition sequence) produced sound crack-free welds without

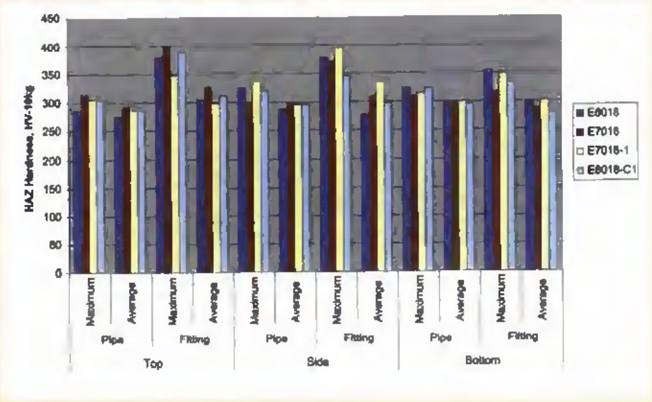


Fig. 6 — Summary of HAZ hardness testing results from Round 1.

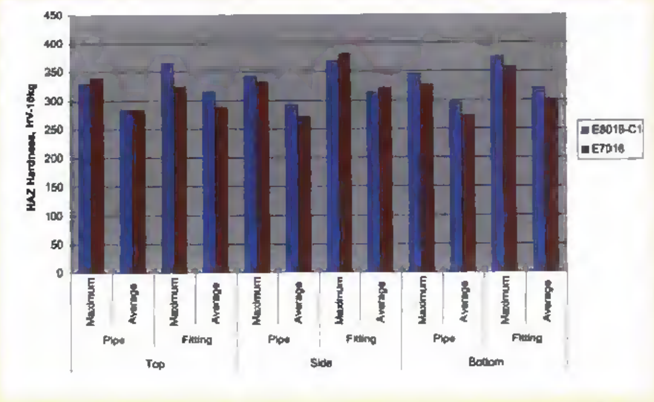


Fig. 7 — Summary of HAZ hardness testing results from Round 2.

Table 2 — Chemical Analysis Results for Procedure Qualification Trial Materials

	Chemical Composition (wt-%)		
Element	Round 1 Pipe	Round 2 Pipe	Fitting
C	0.10	0.16	0.12
Mn	1.34	1.09	1.42
P	0.021	0.014	0.007
S	0.004	0.002	0.004
Si	0.23	0.19	0.38
Ni	0.03	0.07	0.10
Cr	0.01	0.11	0.10
Mo	0.00	0.01	0.03
Cu	0.01	0.28	0.28
V	0.060	0.004	0.003
Al	0.02	0.02	0.04
Ti	0.00	0.00	0.00
Nb	0.026	0.001	0.040
Zr	0.000	0.000	0.000
W	0.01	0.00	0.00
Pb	0.01	0.00	0.00
B	0.0002	0.0000	0.0000
CE_{IIW}	0.34	0.39	0.41

the use of preheat. The ease with which the HAZ hardness limits were met is due in large part to the chemical composition of the two materials that were provided for this task. The chemical composition of these two materials is quite "lean" (i.e., relatively low carbon content and CE_{IIW}) and higher carbon-equivalent materials may be encountered in practice. The pipe material supplied for TAPS generally has a carbon content in the 0.08 to 0.16% range and a CE (based on %C + %Mn/6) generally in the 0.30 to 0.39% range. The GSP results described above indicate that a 25 kJ/in. procedure without preheat may be inadequate for these higher carbon-equivalent materials.

Recommendation for Maintenance Procedure Requalification

Although the procedure development work done at Cranfield was carried out under simulated in-service conditions, the subsequent qualifications carried out by Alyeska of procedures in use until now were not. Also, the guidance in API 1104 Appendix B was not in existence when the procedure qualifications were carried out by Alyeska. Therefore, it was recommended that Alyeska's procedures for maintenance welding be requalified.

Based on the review of Alyeska's maintenance welding procedures and the results of the laboratory trials, it was recommended that further procedure qualification effort without preheat concentrate on procedures that rely on 40 kJ/in. minimum-required heat input and/or a temper bead deposition sequence.

Monitoring of Maintenance Procedure Requalification Activities

Procedure requalification trials were carried out in Fairbanks at an Alyeska facility using contract welders selected by Alyeska. The setup for these trials involved lengths of 48-in.-diameter pipe material to which end plates and legs were welded. The ability of the flowing contents to remove heat from the pipe wall was simulated using ambient-temperature tap water as before — Fig. 3. Segments of procedure qualification welds were made between the pipe material and sections of fitting material on the top, side, and bottom of the pipe. Two rounds of procedure qualification trials were carried out.

In the first round, four different welding consumables were evaluated using target welding parameters that would result in a heat input level of at least 40 kJ/in. without the use of preheating. The pipe surface temperature was 58°F (14°C). During the first round, some difficulty was experienced maintaining a heat input level of at least 40 kJ/in. The GSP results also indicate that a procedure that relies on 25 kJ/in. minimum-required heat input with preheating (200°F [93°C]) is adequate for materials with carbon content greater than 0.10% and CE_{IIW} up to 0.42%. In the second round, target parameters that would result in a heat input level of less than 40 kJ/in. with a reduced level of preheating (86°F [30°C]) were investigated as an alternative to a heat input level of at least 40 kJ/in. Two consumables used in the first round were selected for use in the second round. Preheating was achieved using Alyeska's Miller Electric induction heating system — Fig. 4.

An example of a completed weld is shown in Fig. 5. Following each round, metallographic and mechanical testing specimens were extracted and tested in accordance with the requirements of API 1104 Appendix B.

Materials

It was not possible to locate pipe material with a CE_{IIW} of 0.39 (i.e., the highest of the pipe material delivered for TAPS), so for the first round, a length of pipe 0.562-in. (14.3-mm) -thick X70 with a CE_{IIW} of 0.34 was made to suffice. For the second round, a length of pipe was fab-

Fig. 8 — Fitting material welded to pipe material adjacent to RGV prior to removal.

Fig. 9 — Completed procedure confirmation weld — side A (no preheat).

ricated from 0.625-in. (15.9-mm) -thick ASTM A516 Grade 70 plate material with a CE_{IIW} of 0.39. The fitting material consisted of sections of A537 Class 1 plate, taken from the center of an actual T. D. Williamson Stopple® fitting, which had a CE_{IIW} of 0.41. The edges of the fitting material were beveled to resemble the edge of a Stopple fitting. Chemical analysis results for the pipe and fitting material are shown in Table 2.

Four different consumables were used during the procedure qualification trials. The first was an E8018-C1, which has been the standard consumable used by Alyeska for maintenance welding. Since overmatching strength is not necessarily desirable for in-service sleeve fillet welds (higher residual stresses tend to develop), two lower-strength consumables were also evaluated. These were E7018-1 and E6018. The latter electrode was developed specifically for applications where hydrogen cracking is a concern, as the low-strength weld metal allows shrinkage strains to accumulate in the weld metal as opposed to the crack-susceptible HAZ. The fourth electrode was an E7016, which is similar to an E7018-1 except that the iron powder content in the coating is lower. These electrodes produce relatively small weld beads and are useful for applications where a high level of heat input is required and/or tempering from subsequent passes is desired.

Round 1 Results (40 kJ/in. without Preheat)

Two sections for metallographic examination and hardness testing were removed from each weld. The 12 hardness measurements, six in the pipe material HAZ and six in the fitting material HAZ, were made using a Vickers indenter with a 10-kg load. A summary of the HAZ hardness testing results for the first round of procedure qualification trials is shown in Fig. 6. The results indicate that no one electrode type produced HAZ hardness levels that are substantially lower than another. The E7016 seemed to be the most variable; while it produced some of the lowest maximum hardness values, it also produced some of the highest.

In terms of absolute numbers, the results were encouraging. The maximum measured HAZ hardness in the pipe material is 337 HV, which is well below the maximum allowable value. For the chemical composition of the fitting material, the previously developed acceptance criterion allows HAZ hardness of up to 400 HV for welds made using good low-hydrogen practice. Several of the HAZ hardness measurements in the fitting material approach 400 HV, but none are above.

Round 2 Results (Reduced Heat Input with Preheat)

As before, two sections for metallographic examination and hardness testing were removed from each weld. A summary of the HAZ hardness testing results for the second round of procedure qualification trials is shown in Fig. 7. The results were again encouraging. All of the measured HAZ hardness values in the pipe material were less than 350 HV. The maximum measured value in the pipe material is 346 HV. Some of the measured HAZ hardness values in the fitting material exceeded 350 HV, but as indicated above, the acceptance criterion allows HAZ hardness of up to 400 HV for welds made using good low-hydrogen practice for the chemical composition of the fitting material (up to 0.42 CE_{IIW}).

In general, the E7016 seems to have produced lower HAZ hardness values than the E8018-C1, although the E7016 produced the highest measured value (381 HV measured on the fitting-side HAZ of one section).

Table 3 — Chemical Analysis Results for Confirmation Weld Analysis

	Composition (wt-%)	
Element	Pipe Material	Fitting Material
C	0.15	0.12
Mn	1.33	1.38
P	0.017	0.011
S	0.006	0.003
Si	0.17	0.36
Ni	0.01	0.10
Cr	0.23	0.11
Mo	<0.01	0.03
Cu	0.09	0.28
V	0.040	<0.005
Al	0.03	0.03
Ti	<0.005	<0.005
Nb	0.020	0.030
Zr	<0.005	<0.005
W	<0.01	<0.01
Pb	<0.01	<0.01
B	<0.0005	<0.0005
CE_{IIW}	0.43	0.40

Resulting Welding Procedure Specification

The data from both rounds of the procedure qualification exercise were incorporated into a single WPS by Alyeska. This WPS specifies preheating the pipe material to 86°F (30°C), with a higher preheat temperature required for the fitting material, but allows reduced preheat provided that the heat input is 40 kJ/in. or greater.

Verification of Procedure Suitability

During the course of this project, an

Fig. 10 — Metallographic section CW1A-M1 (no preheat).

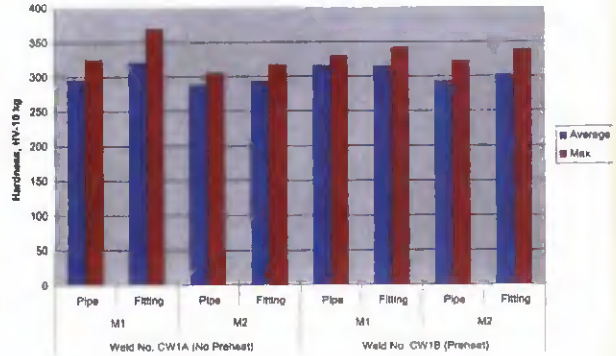


Fig. 11 — Summary of HAZ hardness testing results for procedure confirmation welds.

opportunity arose to verify the suitability of the resulting WPS during a previously scheduled remote gate valve (RGV) replacement operation. This was accomplished using the confirmation weld scheme. The confirmation weld scheme involves making a weld using the qualified procedure onto the portion of the pipeline that will be removed; in this case, the pipe material adjacent to the RGV. A section of T. D. Williamson Stopple fitting material approximately 6 in. (150 mm) wide and 18 in. (450 mm) in length, with the edges beveled to resemble the edge of a Stopple fitting, was welded to the TAPS main line under actual in-service conditions — Fig. 8.

The TAPS main line in this area consists of 0.562-in. (14.3-mm) -thick X70 material. One side was welded without preheat while maintaining a heat input of at least 40 kJ/in. and the other side was welded with preheat without heat input control. An example of a completed weld is shown in Fig. 9. Following replacement of the RGV, the pipe material adjacent to the RGV containing the confirmation weld was sent to EWI for analysis.

Upon arrival at EWI, two metallographic sections were removed from each weld. Analysis consisted of metallographic examination, hardness testing, and chemical analysis. A macrograph of a typical weld is shown in Fig. 10. Chemical analysis results for the pipe and fitting material are shown in Table 3.

A summary of the HAZ hardness testing results for the procedure confirmation exercise is shown in Fig. 11. The results of the analysis indicate that both procedure variations produced sound crack-free welds with acceptable hardness levels. This is the case in spite of pipe material having a rather rich chemical composition (0.15% C and a CE_{IIW} of 0.43). The robustness of the two procedure variations is demonstrated by their ability to produce acceptably low hardness levels in spite of the pipe material being relatively rich.

Summary

The procedure requalification exercise that was carried out allowed the suitability of procedures to be demonstrated for the current and projected future operating conditions for TAPS using current industry-based guidance. The initial procedure that was qualified involves no preheating and a minimum required heat input of 40 kJ/in. The acceptability of these parameters under these conditions for material with a CE_{IIW} up to 0.42 is based on GSP results. Because of anticipated difficulty to reliably achieve a heat input of 40 kJ/in. in the field, a second procedure was qualified that involves a reduced level of preheating (from the level in the existing procedure) and a reduced level of heat input. The acceptability of these parameters under these conditions for material with a CE_{IIW} up to 0.39 is based on the results of the procedure qualification testing that was performed. The data from the procedure qualification exercise were incorporated into a single WPS by Alyeska. Analysis of confirmation welds taken in conjunction with an RGV replacement operation indicates that both procedure variations are suitable under actual in-service conditions for material with a CE_{IIW} up to 0.43.

Acknowledgments

The authors would like to thank Alyeska Pipeline Service Co. for sponsoring this project and for allowing the results to be published, and Frank Caito for his helpful assistance. The contribution of Mike Rosenfeld from Kiefner & Associates is also gratefully acknowledged.

References

1. Jubb, J. E. M., Apps, R. L., Dos Santos, A., Chambers, W. F., and Rothwell, A. 1977. *Welded Attachments to the Alyeska Pipeline.* Cranfield Institute of Technology (Sept.).

2. Apps, R. L., Chambers, W. F., Jubb, J. E. M., Nelson, K. A., and Rothwell, A. 1979. Cranfield Institute of Technology (June).

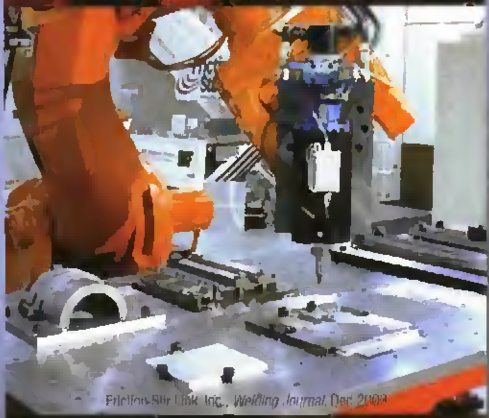
3. Bruce, W. A. 2001. *Selecting an Appropriate Procedure for Welding onto In-Service Pipelines.* International Conference Pipeline Repairs, Welding Technology Institute of Australia, Wollongong, Australia (March).

4. Bruce, W. A. 2002. *Qualification of Procedures for Welding onto In-Service Pipelines.* IPC 2002 — 4th International Pipeline Conference, Calgary, Alberta, Canada (Sept.).

No consumables. No fumes. No porosity. No spatter.

Sound too good to be true?

[illegible] *Welding Journal*, May [illegible]



Friction Stir Link, Inc., *Welding Journal*, Dec 2003

Concurrent Technologies Corp., *Welding Journal*, Mar 2003

GET THE LATEST DEVELOPMENTS IN FRICTION STIR WELDING AT THE AWS FRICTION STIR WELDING CONFERENCE, AUGUST 10-11, 2004, IN ORLANDO, FLORIDA.

Welding with no consumables, no fumes, and low distortion even in long welds. Excellent mechanical properties, proven by fatigue, tensile, and bend tests. No porosity. No spatter. Low shrinkage. Energy-efficient. Operates in all positions. These are the characteristics of friction stir welding (FSW), a versatile solid-state bonding process.

At this two-day conference, you will:

- Learn how to join materials that are difficult to weld with conventional fusion processes
- Understand how to specify the material properties you want, including those of titanium, aluminum, steels, and nickel-base alloys
- Discover how robotic FSW can reduce operating costs and enhance flexibility, supplanting traditional welding processes in many applications
- Learn what's the most cost-effective fixturing
- Compare the FSW system to conventional machines
- Find out why FSW can move mainstream today

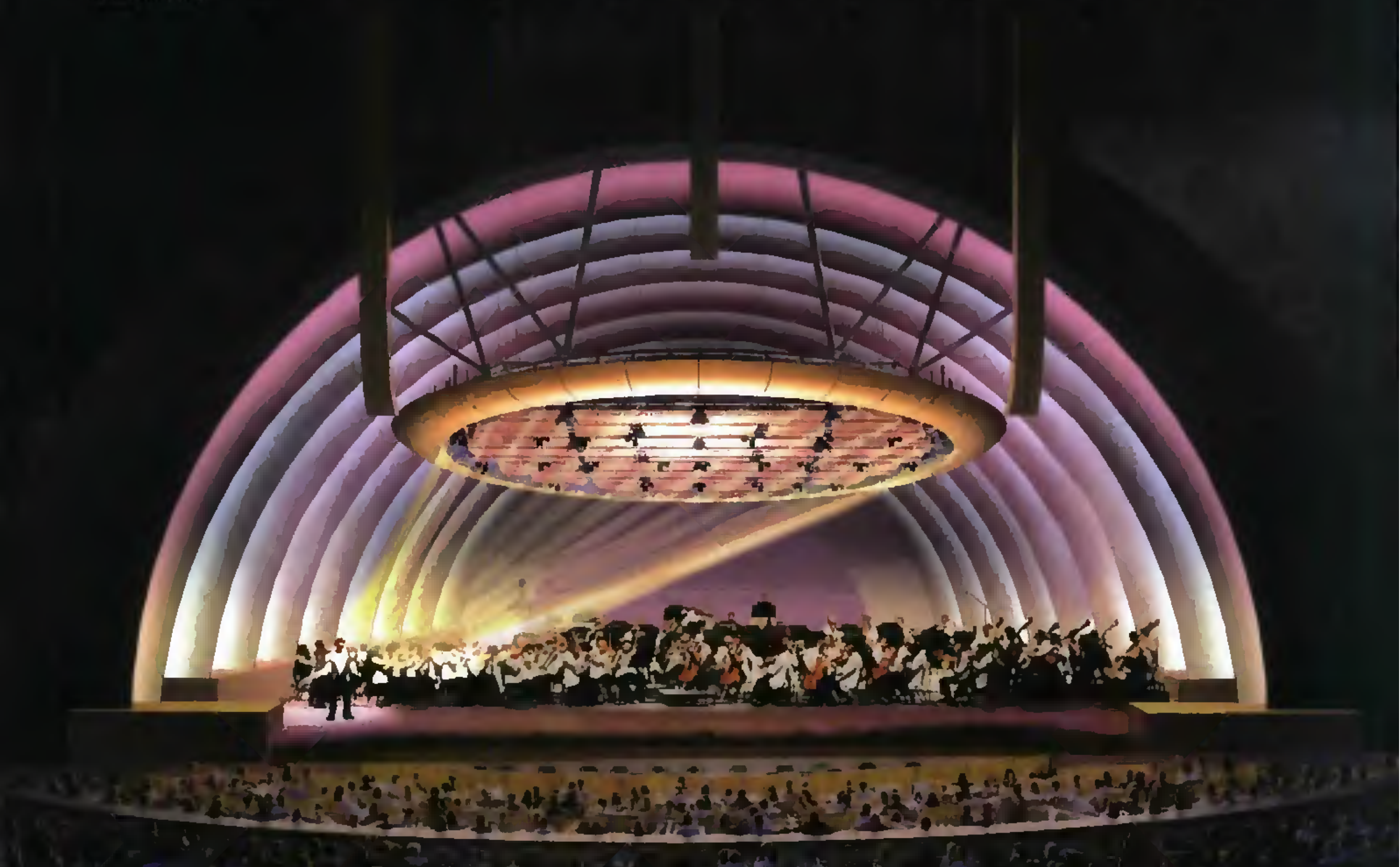
For more information, call 1-800-443-9353, Ext. 449, or go online to: *http://www.aws.org*, click on "Services" then "Conferences".

American Welding Society

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

To become an AWS member, call 1-800-443-9353, ext. 480, or visit our website at *http://www.aws.org*

Circle No. 5 on Reader Info Card



An artist's rendering of a night view of the new Hollywood Bowl stage. (Rendering by Hodgetts+Fung, courtesy of the Los Angeles Philharmonic Association.)

A New Tune for the Hollywood Bowl

The new Hollywood Bowl relies on ten tubular steel trusses to support its impressive shell

BY RYAN ADAY

Since its beginning in 1922, the Hollywood Bowl has had four shells. The original 1922 shell was constructed out of wood and canvas. The Bowl was rebuilt three times over the next seven years, the last time taking place in 1929. That shell, which became one of the world's most recognized outdoor music venues, was constructed out of a steel frame overlaid with wood. The Bowl remained a Los Angeles landmark for more than 74 years, and served as the summer home of the Los Angeles Philharmonic. Hundreds of thousands of visitors have enjoyed performances and admired the beauty of this outdoor marvel over the years.

As impressive as it was, the Bowl was plagued with acoustic problems. Several attempts were made throughout the years to solve those problems, but they met with little success. A second problem with the bowl was its size; the amphitheater could not accommodate the entire Los Angeles Philharmonic. One-third of the orchestra's members had to perform outside of the shell. In 2000 it was recognized that there was only one thing that would solve these problems: tear down the aging landmark and reconstruct a

---

RYAN ADAY (ryana@milcoconstructors.com) is a Field Engineer with Milco Constructors, Inc., Long Beach, Calif.

new state-of-the-art amphitheater (see lead photo). The Los Angeles-based architectural firm of Hodgetts + Fung Design Associates undertook the challenge of designing a bigger structure with better acoustics, while still retaining the charm and trademark look of the 1929 Hollywood Bowl. After three years of design and preparation work, the ground was broken and construction of the new Hollywood Bowl was under way in 2003.

The Hollywood Bowl shell project, according to the Los Angeles Philharmonic Association, "creates a new shell that preserves the iconic Moderne curve of the previous shell, while improving acoustics for performers on stage and enhancing the musical experience for concertgoers with new lighting, sound, and theatrical elements."

Building the New Bowl

The general contractor, Matt Construction of Santa Fe Springs, Calif., was responsible for coordinating all of the contractors taking part in the project and to make sure the Hollywood Bowl was ready

Fig. 1 — Fabrication of the trusses was on a fast track in order to meet the philharmonic's summer concert schedule.

Fig. 2 — Much of the field welding took place at heights 42 ft or more from the ground.

Fig. 3 — A member of Ironworkers Local 433 works on a truss prior to its being lifted into place.

for the June 19th start of the 2004 summer concert series.

The new Bowl is an impressive work of art partially due to the more than 350 tons of structural steel that make up its massive shell. Milco Constructors, located in Long Beach, Calif., erected the steel with the help of members of Ironworkers Local 433. Milco mobilized in late October 2003 and the last truss was set in late December — Fig. 1. Ten massive trusses make up the backbone of the shell. The largest truss is 62 ft tall and 130 ft wide and weighs 25,000 lb. Milco had S&S Steel Fabrication, Hurricane, Utah, fabricate the steel at its shop, then ship the pieces by truck to Los Angeles. Milco Constructors fit it together and welded it on site.

The goal at S&S was to do approximately 95% of the steel fabrication in its shop so that field erection could proceed quickly and smoothly. Each of the trusses was shipped in three to five sections, which

A Brief History of the Hollywood Bowl

A recent photo of the 1929 Bowl at dusk. The Hollywood Bowl sits in the largest natural amphitheater in the United States. (Photo courtesy of the Los Angeles Philharmonic Association.)

The following facts about the Hollywood Bowl were provided by the Los Angeles Philharmonic Association.

■ The Hollywood Bowl is the largest natural amphitheater in the United States and is a Los Angeles County Park (see photo).

■ It can seat nearly 18,000 concertgoers.

■ The Bowl's first stage, built in 1922, consisted of a simple wooden platform with a canvas top. Patrons sat on movable benches.

■ A cooperative society of 33 Los Angeles architects built the Bowl's first arched proscenium in 1926. The curved wooden frame consisted of a low elliptical arch in the background with a circular arch inside, framing the musicians. It was torn down at the end of that season because of acoustical problems.

■ Lloyd Wright, eldest son of Frank Lloyd Wright, designed two shells for the Hollywood Bowl. The first shell was intended only as a temporary structure and was used for one season. Wright used wood from the dismantled set of *Robin Hood* to build a pyramid-shaped structure intended to enhance the Bowl's acoustics and complement the rustic setting.

■ Wright's second commission included the specific instruction to design a circular music shell. The 1928 shell consisted of nine concentric, segmental arches that could be "tuned" panel by panel. For reasons that remain unclear, it was left standing through the winter of 1928 and began to deteriorate. It was declared unsafe and was demolished in 1929.

■ The shell constructed in 1929 preserved the visual essence of Lloyd Wright's 1928 design, but substituted a semicircle for Wright's elliptical form. Made of transite panels covering a steel frame, the 55-ton shell was designed on a track system. The shell could be moved off the stage area to allow for theatrical staging to be built for a specific purpose. From the beginning, the curved shape caused serious acoustic problems, including focused sound randomly returning to the stage.

■ Numerous attempts were made to improve the 1929 shell's acoustics. In 1970, architect Frank Gehry and acoustician Christopher Jaffe devised an inexpensive, temporary solution by creating "sonotubes," manufactured cardboard forms that looked like concrete columns. Their arrangement inside the shell and extending along the outer wings enhanced the sound but disguised the Bowl's famous curved shape. The sonotubes remained in place until 1980.

■ Development in the area also disturbed the natural amphitheater's acoustics. The addition of the Hollywood Freeway in 1952, the grading of hillsides, home building, and other factors began to surround the once tranquil grounds with ambient noise.

■ In 1980, Gehry-designed hollow fiberglass spheres were hung inside the shell in a carefully calculated arrangement. While helpful, the spheres did not solve the Bowl's acoustical problems.

■ The new shell project was funded by voters through the passage of Proposition A. The project also includes new backstage areas. Specifically, the shell project preserves the recognizable, 1920s Moderne concentric ring look of the 1929 shell, dramatically improves the shell's acoustics, creates 30% more stage space to accommodate a full orchestra inside the shell, and allows lighting and sound technology to be integrated into the design, restoring the shell's clean, uncluttered look.

Fig. 4 — A truss being lifted into place by the 360-ton crawler crane.

Milco then had to fit up and weld together to form the completed shell.

The project was constructed with A36 steel. The lower sections of the trusses are 10 × 10 × ⅝-in. tube steel. The upper sections were either back-to-back 6 × 4 × ½-in. angle iron or 6 × 6 × ⅝-in. tube steel. Field welding utilized both shielded metal arc welding with 7018 electrodes and flux cored arc welding with self-shielded E-71T-8 wire. The truss field splices were complete joint penetration welds, with fillet welds making up the rest of the welds. The deputy inspector of the city of Los Angeles performed visual inspections on all the fillet welds; the tube steel complete penetration welds underwent ultrasonic testing.

The primary difficulty in constructing the Bowl was that each truss was a different height and radius. The front truss was 62 ft high with a 54-ft, 3-in. radius and the back truss was 42 ft high with a 35-ft, 11-in. radius. Each piece of steel fit at a compound angle. Workers had to spend a lot of time and pay close attention to detail in the fabrication of the trusses because x, y, and z coordinates all had to be taken into consideration. The angles had to be right the first time, because once welded together the trusses could not be refitted and rechecked due to their size. One of the main challenges for the welders was that nearly all field welding took place above ground using a Zoom Boom telescoping handler — Fig. 2.

Final positioning of the preassembled trusses required a 360-ton crawler crane. Positioning required a 160-ft lift radius, because of an underground parking structure that was in the way. When the trusses were ready to erect, the 360-ton crawler lifted the pieces into position and the ironworkers set them in place — Figs. 3, 4. Because of the quality of fabrication, there were almost no alignment problems.

Fig. 5 — A full view of the acoustical canopy. (Rendering by Hodgetts + Fung, courtesy of the Los Angeles Philharmonic Association.)

Improving the Sound

The shell is designed to be load bearing so in addition to the trusses, bracing has been added to help support the weight of all the high-tech sound and lighting equipment. The Bowl's design features an acoustical ring that will allow sound engineers to fine-tune the quality of the sound — Fig. 5. This should eliminate the acoustical problems of the past. The acoustical ring is mounted on a pulley system and can be raised and lowered as needed.

The stage area of the new Hollywood Bowl is 30% larger than the 1929 structure. Not only is the stage floor larger, but the entire structure is significantly bigger to the point that the old shell could have easily fit inside the new one. The new Hollywood Bowl incorporates modern technology while retaining the beauty and tranquility of its surroundings. Now that it is complete, the Hollywood Bowl should continue as a Los Angeles landmark for at least another 70 years. ◆

Welding the World's Strongest Linepipe in Arctic Conditions

Girth welding was accomplished by pendant-controlled welding "bugs." (Photos courtesy of CRC-Evans.)

X120 pipe is 50% stronger than standard gas transmission pipe, but needs special welding procedures

BY ROSS HANCOCK

To field test its experimental X120 steel linepipe, ExxonMobil wanted to prove the pipe's compatibility with standard construction practices for natural gas transmission.

"They wanted to use a normal contractor using normal welders," said Brian Laing, president of CRC-Evans, Houston, Tex., the company that helped develop welding procedures for the new pipe.

But its hard to believe there's anything

ROSS HANCOCK (rhancock@aws.org) is News Editor of the **Welding Journal.**

normal about the welders from Louisbourg Contractors of Mississauga, Ontario, who spent late January and early February near the top of the world, in northern Alberta, joining a mile of the new pipe. These extraordinary workers successfully established that a new generation of ultrastrong pipe can be put into use in the most challenging of environments.

The X120 steel, with a yield strength of 120 ksi, making it the world's strongest commercialized pipeline material by a margin of 50%, was jointly developed by ExxonMobil, Nippon Steel Corp., and Mitsui & Co. Current gas transmission pipelines are made from X60, X70, or X80 steel, with yield strengths of 60, 70, or 80, respectively.

Stronger pipe steel means more gas can be delivered through a pipeline at higher pressure. Reduced pipe wall thickness adds to the increased throughput.

Prior to last winter's field test, the X120 steel was subjected to extensive testing at CRC-Evans to prove its mettle and to develop girth welding procedures that could match the base metal's strength. Welds were burst-tested at –40°C. Welds were made in pipes that were intentionally misaligned. Surface-breaking, fatigue pre-cracked defects were introduced into the root sides of the welds, and the joined pipes were loaded to the point of failure.

In all the tests, the welds had enough fracture toughness and defect tolerance to hold up to stresses approaching the tensile strength of the pipe material.

The team developed and tested new welding consumables for the high-strength pipe. Laing recalls that it was the 29th candidate welding wire that finally delivered the required performance. The special composition of the weld metal creates a unique "dual phase" microstructure that ExxonMobil engineers call "AFIM" (acicular ferrite interspersed in martensite), which provides a uniform dispersion of a soft phase (acicular ferrite) in a matrix of harder constituents (mostly lath martensite and degenerate upper bainite).

Laing said the welding procedures utilize the "next level of technology in welding equipment." In the Canadian wilderness, this high-tech equipment was placed on sleds and pulled by tractors alongside the mile of preplaced pipes. Mobile welding sheds were lowered over the joints by cranes. After pipe-facing, a root pass would be made with an internal welding machine (which incorporates alignment machinery) using a short circuiting transfer gas metal arc welding process. The hot pass, fill passes, and cap pass were made using CRC-Evans' microprocessor-controlled automatic welding machines, which can be operated by a remote pendant. The machines can be equipped with a joint-tracking technology that sees through the arc to follow the bevel.

Pipeline owner TransCanada Pipelines Ltd., Calgary, Alberta, reports that the mile of X120 pipeline, the strongest gas transmission line in the world, was installed with lower-than-normal weld defect rates, and is operating successfully as part of a longer pipeline-looping operation, delivering natural gas from northwestern Canada to markets all over North America. ◆

Welders work in near-arctic conditions on a section of a TransCanada gas pipeline using X120 linepipe.

Internal welding equipment for the root pass included pipe-alignment mechanisms.

Welding equipment sleds (right) were pulled by tractors. Welding sheds (left) were lowered over pipe ends by cranes.

Aerial view of the X120 pipe laying operation, showing the array of heavy equipment needed.

Nickel Alloy Filler Metal Review

Frequently used for piping and pressure vessel applications, nickel-based filler metals are abundant and versatile

BY HARRY W. EBERT

When discussing Ni-based alloy filler metals frequently used for piping and pressure vessels by refineries, chemical plants, and power plants, one must start with dissimilar joints such as welding 300 Series austenitic stainless steels to carbon and low-alloy steels and also consider weld cladding operations.

For Dissimilar Welds, E310 Is a Poor Choice and E309 Has Limited Applications

Initially, Type E310 (~25%Cr-20%Ni) electrodes were used for such applications. They were easy to use, had welder appeal, and the amount of dilution was not very critical. However, many such welds failed in service since the inherent microfissuring of these fully austenitic deposits propagated into cracks when subjected to thermal stresses caused by the large differences in coefficients of thermal expansion (CTE). By replacing the E310 with E309 (~23%Cr-13%Ni), a stainless steel with some ferrite, the micro-fissuring problem was reduced or even eliminated, but these joints are more dilution sensitive. However, since they retain the large differences in CTE, users were concerned with high stresses and possible thermal fatigue along the ferritic-to-austenitic steel weld interface when the weld was subjected to a heat treating operation and/or to high temperature (>320°C /600°F) service.

The 600 Series Comes on the Scene

The 600 Series Ni-alloy filler metals (~72%Ni, 15%Cr, 8%Fe), which are also known as INCONEL®, have a CTE about halfway between ferritic and austenitic steels. This reduces the thermal stresses by dividing them between two weld interfaces. They are also less sensitive to dilution problems and microfissuring. In the discussion of these Ni-alloys, trade name designations and AWS/ASME classifications are used. When the latter start with an "E" they refer to coated electrodes for the SMAW process; when they start with "ER", they refer to rods and bare wire used for gas metal arc, gas tungsten arc, and submerged arc welding processes.

The use of NiCrFe filler metals started with INCO-WELD-A® (ENiCrFe-2) and INCO-ROD-A® now called Filler Metal 92 or INCONEL® 92 (ERNiCrFe-6). While both of these materials fulfilled their intended objective, both presented some new problems. The coated electrode had little welder appeal since its weld pool was not very easy to control; this has since been improved by a modification of the secondary chemicals and by the introduction of Filler Metal (INCONEL®) 182 (ENiCrFe-3). The composition of the Filler Metal (INCONEL®) 92 bare wire made the deposit subject to age hardening when exposed to heat treatment or service temperatures >700°C/1300°F, which increased strength but decreased ductility. For most applications, this wire has been replaced by Filler Metal (INCONEL®) 82 (ERNiCr-3), which does not age harden.

Corrosion and Temperature Sensitivity

Weld deposits containing high Ni-to-Cr ratios are more susceptible to sulfur corrosion when subjected to temperatures >370°C/700°F. This ratio and the risk of sulfur corrosion have been lowered by selecting alloys that contain more Cr and/or some Mo, such as Alloy 671 with ~44% Cr (ERNiCr-4) and Alloy 625 with ~22%Cr and 9%Mo (ENiCrMo-3 and ERNiCrMo-3). However, at the present time, Alloy 671 has only been AWS/ASME classified as a bare wire filler metal and Alloy 625 filler metals should not be used for service at temperatures >540°C/1000°F, since the deposits tend to embrittle with time. For applications up to 1000°C/1830°F, Type 617 alloy coated and bare wire filler metals with Co additions (ENiCrCoMo-1 and ERNiCrCoMo-1) have been developed.

Two Other Nickel Alloys

In addition to some of the 600 Series al-

HARRY W. EBERT, P.E., is a consulting welding engineer, Madison, N.J., and an AWS Fellow.

Table 1 —Typical or Nominal Chemical Compositions of Filler Metals

AWS Class Filler Metals	Common Name	Ni%	Cr%	Mo%	Other %
E and ER309	309	13	23	-	-
E and ER310	310	20	25	-	-
ENiCrFe-2	A	65	15	-	Mn 2
ERNiCrFe-6	92	65	15	-	Ti 3
ENiCrFe-3	182	65	15	-	Mn 7
ERNiCr-3	82	65	20	-	-
ERNiCr-4	671	55	44	-	-
E and ERNiCrMo-3	625	65	22	9	-
E and ERNiCrCoMo-1	617	50	23	9	Co 12
E and ERNiCu-7	140	65	-	-	Cu 30
E and ERCuNi	187	30	-	-	Cu 70

loys, two other groups of Ni-alloy filler metals are of primary interest when dealing with refineries, chemical plants, and utilities. The 800 Series Nialloys, also known as INCOLOY® (~33%Ni, 21%Cr, and Fe) have a number of base metal applications. Since AWS/ASME has not classified a matching filler metal, these alloys are usually welded with some of the 600 Series NiCrFe filler metals (INCONEL®), which are quite compatible. However, in Europe a number of near matching Alloy 800 type filler metals have been developed and are accredited by some regulatory agencies.

The 400 Series Ni-alloys, also known as MONEL® (~65%Ni and 30%Cu), are provided with matching filler metals. After years of development, we are now using the 7th composition (ENiCu-7 and ERNiCu-7) to weld Alloy 400 to itself, to different steels, and to other nickel alloys. However, here we must provide a word of caution. One supplier uses the term MONEL® for two quite different alloys. In addition to the Ni-Cu alloy mentioned above, one supplier also uses this term for a copper-nickel alloy (~70%Cu and 30%Ni), which AWS/ASME classifies as ECuNi and ERCuNi. To prevent mix-ups, it is suggested that people use the applicable AWS/ASME classification or that suppliers rename the filler metals "NiCu-Monel" and "CuNi-Monel."

Versatility of Ni-alloy Filler Metals

More than 60 Ni-alloy filler metals have been classified by AWS/ASME, and more are pending. Many are designed to meet specific or special requirements that do not usually apply to piping and pressure vessels. However, the versatility of Ni-alloy filler metals continues to make them valuable for a variety of industrial applications. ◆

Acknowledgments

The author wishes to thank Ni-alloy filler metal experts Mr. R. Fuchs, Mr. S. Kiser, and Dr. F. Winsor for their constructive review of this paper.

Backup Purging of Root Welds

For certain alloys or for high-purity applications, exposure to air at the back side of the weldment can contaminate the weld when making the root pass. To avoid this problem, the air must be purged from this region. Argon, helium, and nitrogen are commonly used gases for backup purging. Gas flow requirements for the purge may range from 0.5 to 42 L/min (1 to 90 ft^3/h) based on the volume of air to be purged. As a general rule, a relatively inert atmosphere can be obtained by flushing the area with four times the volume to be purged. After purging is completed, the flow of backup gas during welding should be reduced until only a slight positive pressure exists in the purged area. After the root and first filler passes are completed, the backup purge may be discontinued, depending on quality requirements.

Several devices are available to contain shielding gas on the back side of plate and piping weldments. One of those devices is shown in Fig. 1. When purging piping systems, provisions for an adequate vent or exhaust with baffles to contain the purge gas are important to prevent excessive pressure buildup during welding. The dimensions of the vents through which the backup gas is exhausted to the atmosphere should be at least equal to the dimensions of the opening through which the gas is admitted to the system. Care must be taken to ensure the backup purge pressure is not excessive when welding the last inch or two of the root pass to prevent weld pool concavity or blowout.

When using argon or nitrogen the backup gas should enter the system at a low point to displace the atmosphere upward and should be vented at points beyond the joint to be welded. In piping systems with several joints, all joints except the one being welded should be taped to prevent gas loss.

Manual welding of reactive metals can be facilitated if the entire weldment is placed in a controlled-atmosphere chamber. Purging is started after the assembly is placed in the chamber. Readings are taken from instruments that analyze oxygen, nitrogen, and water vapor to ensure contaminants are at a low level before welding is started.

For some metals a trailing shield is necessary if chambers or other shielding techniques are not available or practical. A trailing shield (Fig. 2) is a device that directs the flow of shielding gas so that it provides inert gas coverage over the weld area until the molten weld metal has cooled to the point that it will not react with the atmosphere. Fixed barriers (Fig. 3) also aid in containing shielding gas within the area immediately surrounding the electrode.

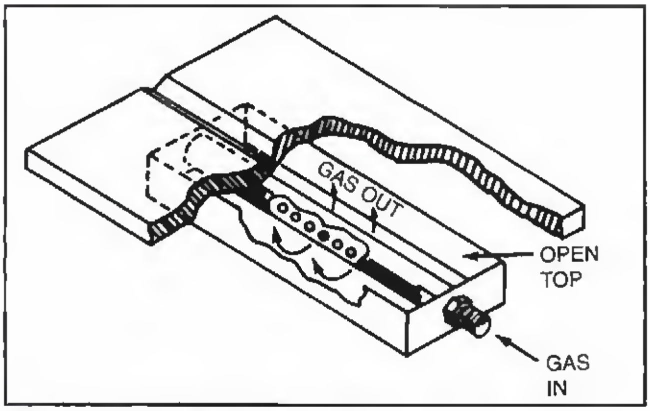


Fig. 1 — Backup purge gas channel.

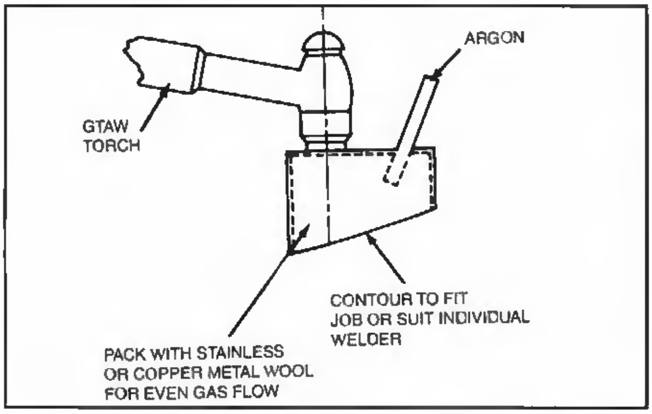


Fig. 2 — Trailing shield for a manual gas tungsten arc torch.

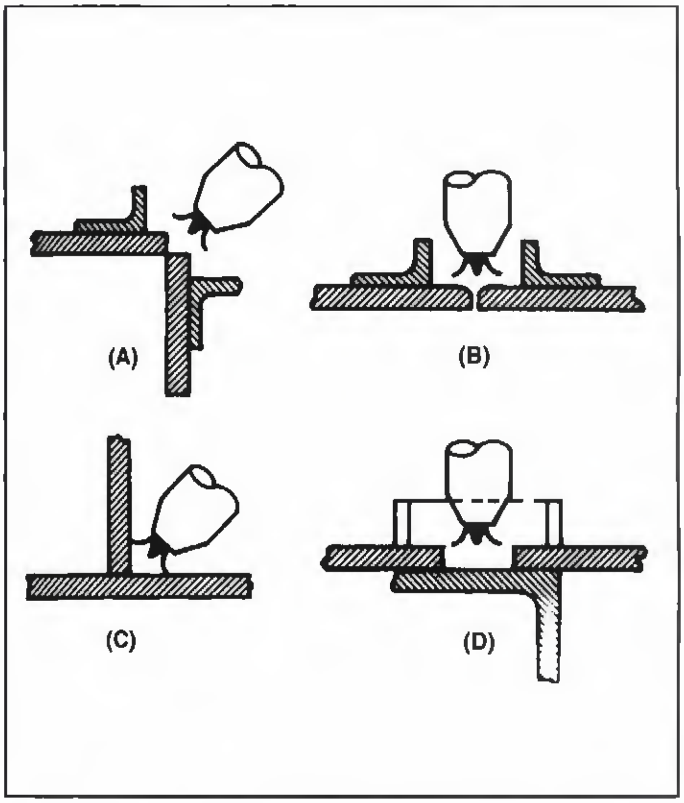


Fig. 3 — Examples of barriers used to contain the shielding gas near the joint.

Excerpted from the *Welding Handbook*, Vol. 2, part 1, ninth edition.

NJC Completes Adhesive Bonding Project for Primary Aircraft Structures

Fig. 1 — Cost savings of 60% are being realized in the adhesive assembly of these JSF F-35 composite inlet duct structures.

The Navy Joining Center (NJC) completed a Navy MANTECH project with the Air Force and Composite Affordability Initiative (CAI) to characterize manufacturing variables that affect adhesive bonding for composite joints used in the fabrication of primary aircraft structures. The project developed adhesive joint mechanical property data that quantify the effects of manufacturing variability in adhesive bonded systems to meet Navy aircraft service requirements for bonding composite structures. This project was accomplished by several airframe manufacturers and Edison Welding Institute (EWI).

The use of adhesive bonding for primary aircraft structures has the potential to save significant weight and cost over conventionally riveted or bolted joint designs. New bonded joint designs have been developed that minimize peel stresses and provide a more robust joint as part of the Core Technology Plan for the CAI program. The joint, commonly referred to as Pi (π) or tongue-and-groove joint, includes male and female sections bonded with an adhesive. This type of joint is more tolerant to damage and flaws than other composite joint designs. The joints are lighter and less expensive to fabricate than conventional mechanically fastened joints.

The target applications for this joint include skin-to-ribbed box composite subassemblies requiring both structural and closeout connections. Even though the Pi-joint configuration has the potential to improve the performance of adhesively bonded joints, fabrication issues were addressed in the project to ensure that the bonded joints can be reliably manufactured for primary structures.

This project complemented earlier CAI activity by addressing manufacture "scale-up" and testing of adhesive-bonded joints under operational conditions. Large Pi-joint fabrication test elements were manufactured using a range of process variables. Test specimens were produced from the large Pi-joint test elements in sufficient numbers to provide data on shear loading, combined-angle loading, and fatigue performance.

A number of manufacturing variables were identified by the airframe manufacturers and tests were performed quantifying their effects on adhesive-bonded joints.

The manufacturing variables investigated for adhesive bonding included surface preparation, bond line thickness, offset web, porosity, and impact damage. These results have been released to the Navy, Air Force, and the CAI community.

Some data developed early in the project were used by designers for bonding of composite structures in the Joint Strike Fighter (JSF) program. Figure 1 shows the application of bonding technology on the JSF inlet duct assembly. Flight testing continues for other applications for advanced aircraft structures.

The results of this project support the Navy and Air Force requirements for future adhesive-bonded aircraft structures for enhanced performance and reduced operation costs.

Cost savings of 60–70% are being realized in assembly operations in bonded structures. In addition, the CAI has been provided with data to support certification efforts, design specifications, and manufacturing processes to aid in maturing the technology.

The CAI analysis tools have benefited from new bonding data that enable improved accuracy with reductions in testing and analysis time.

As the reliability of adhesive bonding is confirmed, both the Navy and the airframe manufacturers will encourage the use of this joining technology for primary structures.

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

Dr. Suhas Vaze Named Project Manager

Edison Welding Institute's Government Programs Office and the Navy Joining Center have appointed Dr. Suhas Vaze as project manager in charge of planning and control of NJC technology development projects.

Vaze holds a Ph.D. in mechanical engineering from the University of Notre Dame. He has more than eight years of experience in finite element analysis, manufacturing, and materials processing.

Previously, Vaze worked for Concurrent Technologies Corp. as manager, Materials Processing Department, where he managed several project teams in various U.S. Army and Navy MANTEC development projects centered in materials processing technology. This work led to improved fabrication techniques for manufacturing advanced military gas turbine engines for combat vehicles utilizing friction stir welding and flowform forging.

Vaze has received several awards for his technical presentations at national and international conferences. He also has published many articles for materials and mechanical science periodicals.

Operated by

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

COMING EVENTS

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

Japan International Welding Show. July 14–17, Intex, Osaka International Trade Fair Ground, Osaka, Japan. Organized by the Japan Welding Engineering Society and Sanpo Publications, Inc. For details visit *www.sanpo-pub.co.jp.*

37th Annual International Metallographic Society Convention. August 1–5, Savannah, Ga. Contact: ASM International, *www.asminternational.org/events.*

3rd Annual International Surface Engineering Congress. Aug. 2–4, Orlando, Fla. Contact: ASM International, *www.asminternational.org/events.*

SME Manufacturing Technology Summit, Aug. 10–11, University of Michigan, Dearborn Fairlane Center, Dearborn, Mich. Sponsored by the Society of Manufacturing Engineers. Contact SME at (800) 733-4763; *www.sme.org/techsummit.*

American Ceramics Society Meetings. Aug. 23–27, Conference on Ferrites, San Francisco, Calif.; Sept. 12–16, Pacific Coast Regional and Basic Science Division meeting, Seattle, Wash.; Sept. 12–16, International Conference on High-Temperature Ceramic Matrix Composites, Seattle Wash.; Nov. 7–11, Glass and Optical Materials Division fall meeting, Cocoa Beach, Fla. Contact: *customersrvc@acers.org;* or *www.ceramics. org.*

ASM Materials and Processes for Medical Devices. Aug. 25–27. St. Paul, Minn. Contact: ASM International, *www.asminternational.org/events.*

6th Pacific/Asia Offshore Mechanics Symposium. Sept. 12–16, Vladivostok, Russia. Sponsored by the International Society of Offshore and Polar Engineers. For more information, contact *www.isope.org; or meetings@isope.org.*

♦ **Overcoming the Problems of Dissimilar Metal Joining Conference.** September 14-15, New Orleans, La. Considered will be laser beam, friction stir, magnetic pulse, and inertia welding, as well as transition joints to join aluminum to steel, and diffusion and adhesive bonding as alternatives. Contact: AWS Conference Department, (305) 443-9353, ext. 449 or e-mail *conf@aws.org.*

Materials Solutions 2004 Conference and Exposition. Oct. 18–21, Greater Columbus Convention Center, Columbus, Ohio. Contact: ASM International, *www.asminternational.org/materialssolutions.*

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

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

Tube China 2004. Oct. 25–28, Shanghai New International Expo Center, Shanghai, China. Contact: Messe Düsseldorf North

America, 150 N. Michigan Ave., Ste. 2920, Chicago, IL 60601; (312) 781-5180; *info@mdna.com, or www.mdna.com.*

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

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

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

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

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

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

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

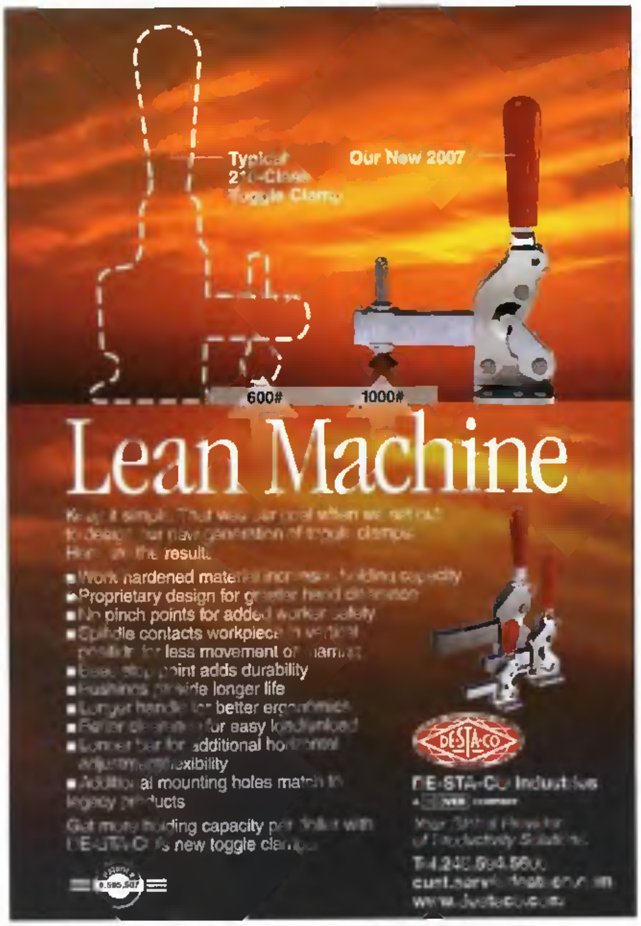
Educational Opportunities

Welding Technology Workshop. July 1, Ball State University, Muncie, Ind. For everyone interested in welding. Fee $25. Contact Ed Wyatt at *wyatt.w@worldnet.att.net*, (317) 576-6420, ext. 303.

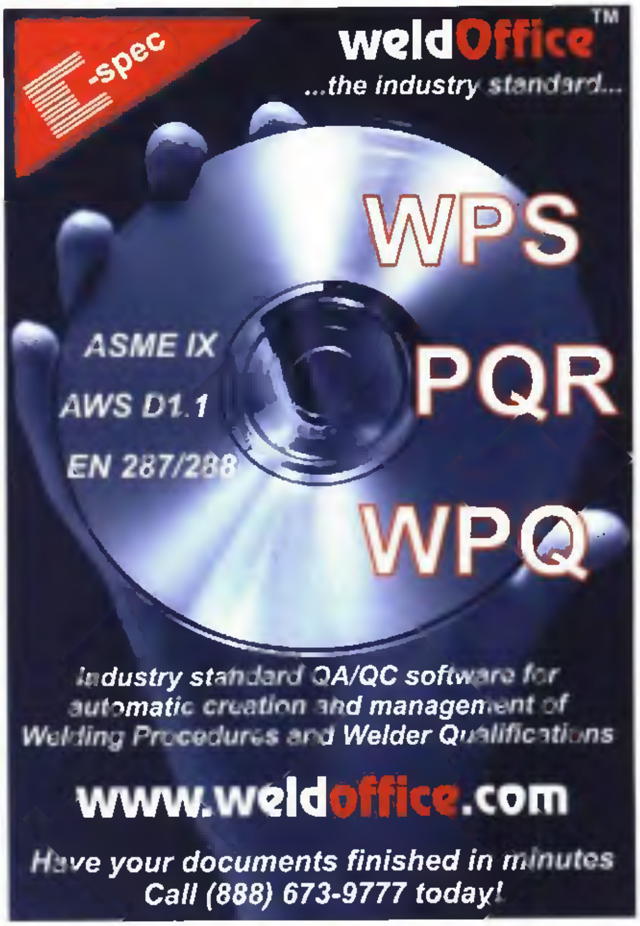
Fundamentals of Visual Inspection. July 7, Sept. 8. Classes held at Hobart Institute of Welding Technology, Troy, Ohio. For further information and 2004 schedules, call (800) 332-9448 or e-mail *hiwt@welding.org; www.welding.org.*

Pipeline Process Solutions Seminars. July 13–15, repeated Nov. 2–4, The Lincoln Electric Co., Cleveland, Ohio. For pipeline contractors and manufacturers. There is no charge for this seminar. For more information or to register, call (216) 383-4718, *www.lincolnelectric.com.*

Basic Motorsports Welding School. August 2–6, September 13–17, Sept. 27–Oct. 1, Oct. 11–15, Nov. 1–5, Dec. 13–17. Includes GTAW, GMAW and PAC for steel, chrome-moly, stainless steels and aluminum. Advanced Welding School, Nov. 8–12.



Circle No. 21 on Reader Info-Card



Circle No. 20 on Reader Info-Card

TRIANGLE ENGINEERING, INC.

Services for the Welding Industry

- Weld engineering and consulting – WPS, PQR
- Welder training and qualification coupons
- Destructive test equipment
- Full testing services

AWS Sustaining Member

P.O. Box 1205, 6 Industrial Way
West Hanover, MA 02339
(781)878-1500 • (781)878-1374 • Fax(781)878-2547
www.trieng.com

Circle No. 49 on Reader Info-Card

Contact: The Lincoln Electric Co., (216) 383-2461; *www.lincolnelectric.com.*

Blacksmithing Indiana State Fair. Aug. 11–22, Indianapolis, Ind., McKenzie Career Center, Robert Dalrymple Blacksmithing Shop. Contact Ed Wyatt at *wyatt.w@worldnet.att.net*; (317) 576-6420, ext. 303.

Welding for the Non-Welder, Aug. 16, Oct. 11. Classes held at Hobart Institute of Welding Technology, Troy, Ohio. For further information and 2004 schedules, call (800) 332-9448 or e-mail *hiwt@welding.org; www.welding.org.*

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

Cold Spray 2004 Technology Workshop. Sept. 27–28, Hilton Hotel, Akron (Fairlawn), Ohio. Emphasis on aerospace, defense, gas turbines, and automotive. Sponsored by ASM International. For reservations or more information, contact Joanne Miller (800) 336-5152, ext. 6; *Jimiller@asminternational.org*; or visit *www.asminternational.org/events.*

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

Has the lack of a *CWI* become an *obstacle* to your *success?*

The Hobart Institute of Welding Technology can provide the professional training you need to pass the Certified Welding Inspector and Educator exams. While nearly all of our students pass with flying colors, those who don't the first time can return within six months free of charge.* We're that confident!

HOBART INSTITUTE OF WELDING TECHNOLOGY

Visual Inspection
July 7-9 • September 8-10

Arc Welding Inspection & Quality Control
August 9-13 • November 8-12

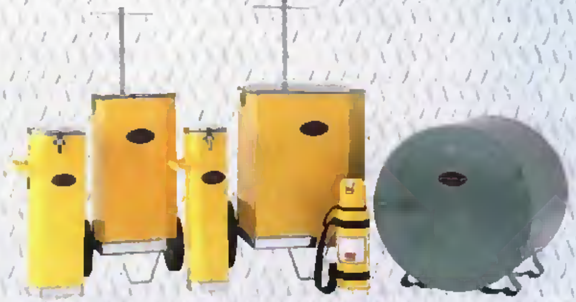
Prep for AWS Welding Inspector/Educator Exam
July 19-30 • September 13-24 • October 25-November 5

These and other comprehensive Technical Training courses are offered throughout the year–
Call Today! 1-800-332-9448

or visit us at www.welding.org for more information. Some restrictions apply; please contact us for details. © 2004 Hobart Institute of Welding Technology, Troy, OH. St. of Ohio Reg. No. 70-12-0064HT

Circle No. 29 on Reader Info-Card

Original **DryRod**®, dryWIRE® & Safetube® Brand
Let Phoenix show you how to protect your welding profits!



- Portable oven line offers four capacities: 10lbs (5kg), 20lbs (10kg), 50lbs (25kg) and 150lbs (70kg)
- Bench ovens available in 350lbs (160kg) and 1100lbs (500kg)
- Variety of Flux ovens and High-Temperature rebaking ovens
- dryWIRE® oven is a large capacity oven designed to store flux cored wire, or for use as a general purpose oven.
- Safetube®,welding rod holder, is a water tight storage system
- Proudly made in the USA

PHOENIX International®

Available through your welding supply distributor; or contact us for more information:
Phoenix International, Inc. • 8711 West Port Avenue • Milwaukee, WI 53224 USA
Tel: 414.973.3400 • Fax: 414.973.3210 • www.phx-international.com

Circle No. 42 on Reader Info-Card

Educational Opportunities

AWS 2004 Schedule CWI/CWE Prep Courses and Exams

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

City	Exam Prep Course	CWI/CWE Exam
Albuquerque, N.Mex.	Aug. 1–6 (API 1104 Clinic also offered)	Aug. 7
Anchorage, Alaska	Sept. 12–17 (API 1104 Clinic also offered)	Sept. 18
Atlanta, Ga.	Oct. 24–29 (API 1104 Clinic also offered)	Oct. 30
Baltimore, Md.	Oct. 31–Nov. 5 (API 1104 Clinic also offered)	Nov. 6
Baton Rouge, La.	July 18–23 (API 1104 Clinic also offered)	July 24
Beaumont, Tex.	Nov. 7–12 (API 1104 Clinic also offered)	Nov. 13
Charlotte, N.C.	Aug. 22–27 (API 1104 Clinic also offered)	Aug. 28
Chicago, Ill.	July 25–30 (API 1104 Clinic also offered)	July 31
Chicago, Ill.	Oct. 24–29 (API 1104 Clinic also offered)	Oct. 30
Columbus, Ohio	Aug. 2–6 (API 1104 Clinic also offered)	Aug. 7
Columbus, Ohio	Nov. 1–5 (API 1104 Clinic also offered)	Nov. 6
Corpus Christi, Tex.	EXAM ONLY	July 24
Corpus Christi, Tex.	EXAM ONLY	Sept. 18
Dallas, Tex.	Sept. 26–Oct. 1 (API 1104 Clinic also offered)	Oct. 2
Denver, Colo.	July 11–16 (API 1104 Clinic also offered)	July 17
Denver, Colo.	Oct. 3–8 (API 1104 Clinic also offered)	Oct. 9
Detroit, Mich.	Sept. 26–Oct. 1 (API 1104 Clinic also offered)	Oct. 2
Houston, Tex.	Aug. 2–7 9-Year Recert Course	No Test
Houston, Tex.	Aug. 15–20 (API 1104 Clinic also offered)	Aug. 21
Indianapolis, Ind.	Aug. 15–20 (API 1104 Clinic also offered)	Aug. 21
Kansas City, Mo.	July 25–30 (API 1104 Clinic also offered)	July 31
Long Beach, Calif.	Nov. 7–12 (API 1104 Clinic also offered)	Nov. 13
Los Angeles, Calif.	July 19–24 9-Year Recert Course	No Test
Louisville, Ky.	Nov. 14–19 (API 1104 Clinic also offered)	Nov. 20
Memphis, Tenn.	Aug. 8–13 (API 1104 Clinic also offered)	Aug. 14
Miami, Fla.	EXAM ONLY	July 15
Miami, Fla.	EXAM ONLY	Aug. 19
Miami, Fla.	EXAM ONLY	Sept. 16
Miami, Fla.	EXAM ONLY	Oct. 14
Miami, Fla.	Dec. 5–10 (API 1104 Clinic also offered)	Dec. 11
Milwaukee, Wis.	Sept. 26–Oct. 1 (API 1104 Clinic also offered)	Oct. 2
Minneapolis, Minn.	Sept. 19–24 (API 1104 Clinic also offered)	Sept. 25
New Orleans, La.	Sept. 12–17 (API 1104 Clinic also offered)	Sept. 18
New Orleans, La.	Sept. 13–18 9-Year Recert Course	No Test
Orlando, Fla.	July 11–16 (API 1104 Clinic also offered)	July 17
Orlando, Fla.	Nov. 15–20 9-Year Recert Course	No Test
Philadelphia, Pa.	July 11–16 (API 1104 Clinic also offered)	July 17
Philadelphia, Pa.	Aug. 9–14 9-Year Recert Course	No Test
Phoenix, Ariz.	Oct. 3–8 (API 1104 Clinic also offered)	Oct. 9
Pittsburgh, Pa.	Oct. 17–22 (API 1104 Clinic also offered)	Oct. 23
Portland, Maine	July 25–30 (API 1104 Clinic also offered)	July 31
Portland, Oreg.	Nov. 7–12 (API 1104 Clinic also offered)	Nov. 13
Reno, Nev.	Oct. 31–Nov. 5 (API 1104 Clinic also offered)	Nov. 6
Rochester, N.Y.	EXAM ONLY	Aug. 21
Sacramento, Calif.	Aug. 8–13 (API 1104 Clinic also offered)	Aug. 14
Sacramento, Calif.	Oct. 4–9 9-Year-Recert Course	No Test
St. Louis, Mo.	EXAM ONLY	Dec. 4
Salt Lake City, Utah	July 18–23 (API 1104 Clinic also offered)	July 24
San Antonio, Tex.	Oct. 17–22 (API 1104 Clinic also offered)	Oct. 23
San Diego, Calif.	Sept. 19–24 (API 1104 Clinic also offered)	Sept. 25
San Juan, P.R.	Dec. 5–10 (API 1104 Clinic also offered)	Dec. 11
Seattle, Wash.	Sept. 19–24 (API 1104 Clinic also offered)	Sept. 25
Sioux Falls, S.Dak.	Nov. 14–19 (API 1104 Clinic also offered)	Nov. 20
Tulsa, Okla.	Oct. 17–22 (API 1104 Clinic also offered)	Oct. 23

An Important Event on Its Way?

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

American Welding Society

Friends and Colleagues:

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

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

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

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

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

Sincerely,

H. E. Cable
Chairman, Counselor Selection Committee

(please type or print in black ink)

CLASS OF 2006

COUNSELOR NOMINATION FORM

DATE__________ NAME OF CANDIDATE____________________

AWS MEMBER NO.__________ YEARS OF AWS MEMBERSHIP__________

HOME ADDRESS____________________

CITY__________ STATE_____ ZIP CODE_____ PHONE__________

PRESENT COMPANY/INSTITUTION AFFILIATION____________________

TITLE/POSITION____________________

BUSINESS ADDRESS____________________

CITY__________ STATE_____ ZIP CODE_____ PHONE__________

ACADEMIC BACKGROUND, AS APPLICABLE:

INSTITUTION____________________

MAJOR & MINOR____________________

DEGREES OR CERTIFICATES/YEAR____________________

LICENSED PROFESSIONAL ENGINEER: YES_____ NO_____ STATE__________

SIGNIFICANT WORK EXPERIENCE:

COMPANY/CITY/STATE____________________

POSITION____________________ YEARS__________

COMPANY/CITY/STATE____________________

POSITION____________________ YEARS__________

SUMMARIZE MAJOR CONTRIBUTIONS IN THESE POSITIONS:

____

____

____

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

****MOST IMPORTANT****

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

SUBMITTED BY:
PROPOSER____________________ Print Name____________________
AWS Member No.__________

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

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

SUBMISSION DEADLINE FEBRUARY 1, 2005

American Welding Society

Nomination of AWS Counselor

I. HISTORY AND BACKGROUND

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

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

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

II. RULES

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

III. NUMBER OF COUNSELORS TO BE SELECTED

Maximum of 10 Counselors selected each year.

<u>Return completed Counselor nomination package to:</u>

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

Telephone: 800-443-9353, extension 293

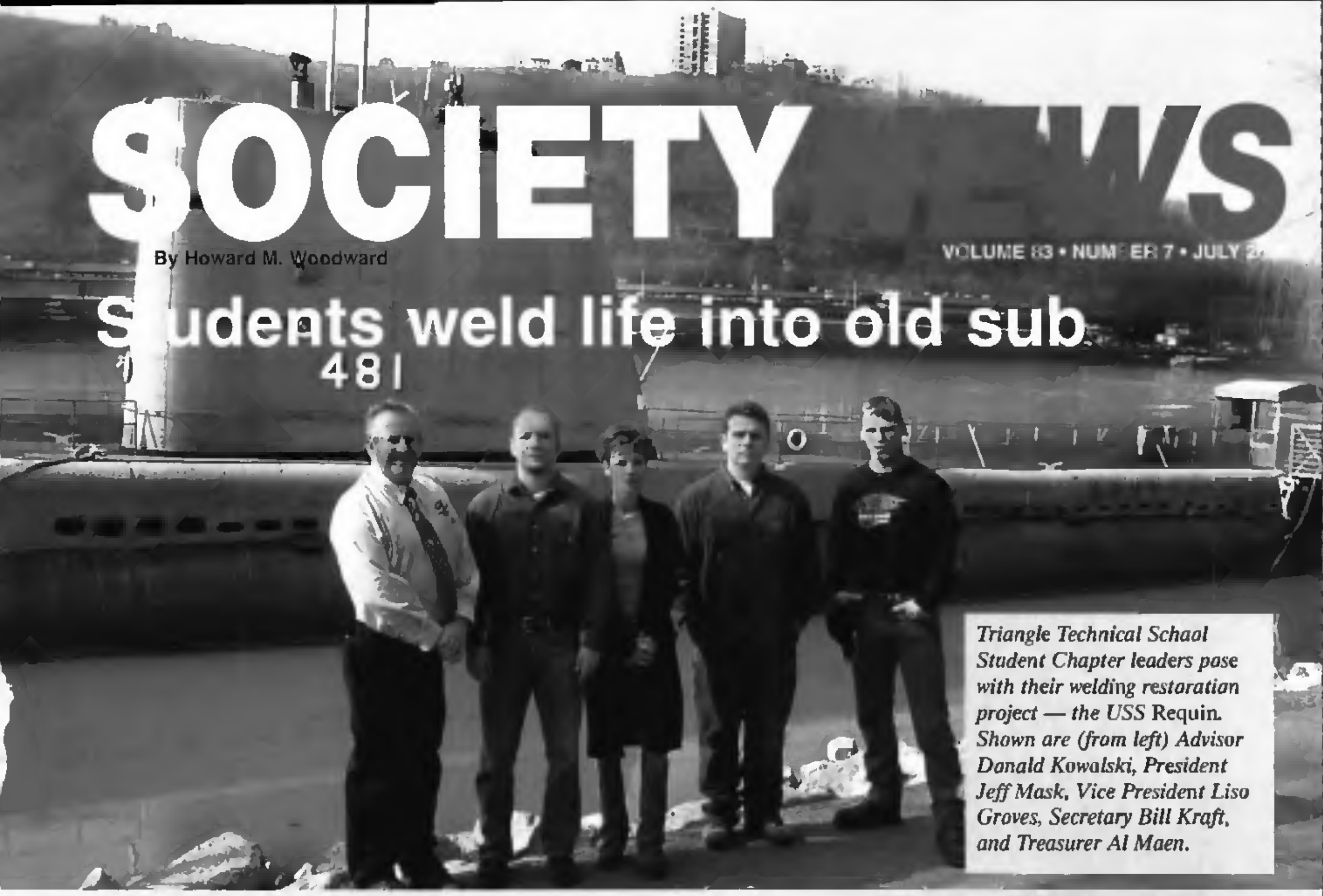
SUBMISSION DEADLINE: February 1, 2005

SOCIETY NEWS

VOLUME 83 • NUMBER 7 • JULY 2

By Howard M. Woodward

Students weld life into old sub



Triangle Technical School Student Chapter leaders pose with their welding restoration project — the USS Requin. *Shown are (from left) Advisor Donald Kowalski, President Jeff Mask, Vice President Lisa Groves, Secretary Bill Kraft, and Treasurer Al Maen.*

Welding students at Triangle Technical School, Pittsburgh, Pa., are using their welding skills to help restore the USS *Requin*, a 59-year-old submarine active for 30 years during the Cold War. Now dry docked, she serves as a major attraction for the hundreds of visitors to the Carnegie Science Center in Pittsburgh.

The *Requin* was unsafe for visitors when she arrived at the Center in 1990. Before being opened to the public, she had to be fitted with a new deck using many of the original supports. But down below, the ravages of time, rust, and corrosion had taken their toll, and major structural supports were failing.

Triangle Tech Student Chapter Advisor **Donald A. Kowalski** said, "Therefore, to eliminate the risk of injury to visitors, the Carnegie Science Center and Triangle Technical School decided to add new supports to the existing framework beneath the deck. But before the students are allowed to work on this project, they are required to take extensive detailed measurements, prepare design plans and templates, and devise a detailed course of action." This is not a simple undertaking. Welding instructors, engineers, and other professionals are consulted to verify the planned work complies with the applicable construction standards and codes.

American Bridge Co. and Vince's Gas and Welding are generously donating the materials and equipment required by the Chapter members to do the job. The restoration begun last summer will go on for many years.

The students have found the project to be a positive and enjoyable experience for many reasons. **Bill Caronni** said, "It is an excellent opportunity for us to use our skills in design and fabrication on a project that not only benefits us, but also the community."

Taylor Knepper noted, "It gives me a chance to leave my work on a site that will be seen by thousands of people."

Welding student **Chris Ruffner** added, "Because of the top-notch training I have received from my instructors at Triangle Tech, I am very confident to go into the workforce to be a knowledgeable and productive employee. This projects provides a hands-on experience in a real working environment."

Proud to be associated with the newly chartered AWS Student Chapter and its important project are **Jeff Mask**, president; **Lisa Groves**, vice president; **Bill Kraft**, secretary; **Al Moen**, treasurer; and advisor, **Donald A. Kowalski**, who keeps the project moving along.

Learning well the hard way, a Triangle student effects welded repairs according to code and a well-planned procedure.

Commissioned April 28, 1945, at Portsmouth Naval Shipyard, N.H., the USS *Requin* was built to be a formidable fighting machine — but she never fired a shot in anger. *Requin* left Portsmouth with ten torpedo tubes and 24 torpedoes. She boasted a range of 11,000 miles, and could go up to 90 days without refueling and could run 48 hours submerged. On the surface, its diesel engines moved her at 21 knots; underwater she cruised at 8 knots using battery power to drive the two screws. The *Requin* served most of her active life as a radar "picket" submarine, guarding the sea lanes. When she finally was called to active duty at Pearl Harbor, Hawaii, she arrived just in time for her crew to learn that WW II was over.

Now the *Requin*, a shadow of her former self, gives students a chance to learn, and they in turn are welding new life into her aging frame. ◆

New Fellows and Counselors Inducted

The American Welding Society has honored 12 of its members by conferring on them the titles of Fellow and Counselor to recognize their outstanding accomplishments. The new Fellows and Counselors were officially inducted at the AWS Annual Meeting held April 5 during the AWS Expo in Chicago, Ill.

In 1990, AWS established the Fellow of the Society designation to recognize AWS members for distinguished contributions to the field of welding science and technology, and for promoting the professional stature of welding. The 2004 Class of Fellows are as follows:

F. Michael Hosking for his sustained research and achievements leading to improvements in the understanding of soldering technology.

Samuel D. Kiser for his teaching skills and expertise in the field of welding nickel alloys.

Dr. Raduvan Kovacevic for his outstanding achievements in developing high-speed machine vision and arc sensing in welding technology.

Dr. Peter W. Marshall for his work in welded connections in the area of complex large tubular structures.

Dr. Charles V. Robino for his significant contributions to the field of welding metallurgy in a wide range of engineering alloys.

The Counselors Selection Committee elected the following members to the 2004 Class of Counselors. Each is recognized for his distinguished organizational and leadership skills, which has enhanced the image and impact of the welding industry. The 2004 Class of Counselors follows:

Jack R. Barckhuff for his career of more than 50 years promoting welding as an engineering science, helping individuals, companies, and the welding community to improve welding quality and productivity.

Richard W. Couch, Jr., for his dedication to progress in welding technology, especially in plasma arc cutting and welding, and for his leadership in the development of many products that have benefited the welding industry.

Jack Dammann for his contributions and long history as an employer and a community leader, noted for his personal involvement promoting quality education and its positive effects on the general public and welding community.

Alfred F. Fleury for his enthusiasm, and leadership as a lively and incisive communicator, highly regarded for his welding-related expertise.

Rudolph Murray who has enhanced the image of welding as a mentor dedicated to the welding community.

Ronald C. Pierce for his tireless promotion of the welding industry with his positive attitude and persistence in getting every job done.

F. R. Bob Schneider, Jr., for his management skills, and highly regarded opinions and recommendations.

For more information on the AWS Awards program, contact Wendy Sue Reeve at (800) 443-9353, ext. 293; *wreeve@aws.org.* ♦

F. M. Hosking

S. D. Kiser

R. Kovacevic

P. W. Marshall

C. V. Robino

J. R. Barckhoff

J. Dammann

A. F. Fleury

R. C. Pierce

F. R. Schneider, Jr.

Call for Papers

The AWS Technical Papers Committee seeks papers on topics related to welding and joining of products and components for pipeline and energy applications for presentation next year.

Authors are invited to submit a 500 to 1000-word abstract by July 30, 2004, to be considered for presentation at the 2005 Symposium on Welding for Pipeline and Energy Applications.

This two-day symposium will take place during the 53rd Annual AWS Welding Show, April 26–28, 2005, at the Dallas Convention Center, Dallas, Tex.

Papers are sought on original experimental investigations, theoretical and statistical modeling, and applications in welding and joining for pipeline and energy applications.

Typical topics will include properties and structural integrity of weldments, design and manufacture of welded structures, corrosion of weldments, NDE of weldments, weldability of high-strength steel and aluminum alloy pipelines, weld phase transformations and microstructures, welding of dissimilar materials and joining of graded materials, welding processes and procedures, innovative welding consumables, sensing, control and automation, computer modeling and simulation, advanced and alternative joining technologies, robotics and automation, and application studies.

Visit *www.aws.org/conferences*, click the Call for Papers icon, then download the Technical Program Abstract Submittal Form.

For more information, contact **Dorcas Troche**, manager, conferences and seminars, at *dorcas@aws.org*, or (800) 443-9353, ext. 313.

AWS Expands Its Mission Statement

Eighty-five years after its founding, the American Welding Society expanded its mission statement to reflect more accurately its wide variety of member interests. The new statement 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 spray.

The six months of strategic planning that resulted in the mission statement change also created 13 new Society initiatives affecting welding education and training programs, and the development of international standards.

District 21 Conference Meets in Palm Springs

Shown at the District 21 Conference held May 15 in Palm Springs, Calif., are (back row, from left) W. Sartin (Long Beach/Orange County), J. Fitzpatrick (Arizona), R. Schneider (San Diego), J. Hollenberg (Hawaii), Mrs. E. Schneider (San Diego), Mrs. N. Samanich (Nevada), R. Jablonski (Hawaii), G. Lawson (AWS Vice President), R. Gibson (Los Angeles/Inland Empire), T. Mustaleski (AWS President 2003–04), G. Niday (Kern), R. Samanich (Nevada), A. Davis (AWS Managing Director Technical Services), H. Jackson (Los Angeles/Inland Empire), S. Luis (California Central Coast); (front row, from left) G. Watkins (San Fernando Valley), L. Gustafson (Long Beach/Orange County), J. Compton (San Fernando Valley), M. Welsh (Kern), B. Callender (San Fernando Valley), and M. Jaquez (Los Angeles/Inland Empire).

Livelink® Puts Technical Committees Online

Livelink® software from Open Text Corp. has been implemented by the AWS Technical Department to dramatically streamline the technical standards development process. The new program not only serves as a repository for committee documents, but permits documents and ballots to be circulated quickly. Another major advantage is it permits Technical Committees to meet online using the companion software *Livelink MeetingZone®*.

Now, data can be disseminated both in real time and as-needed by committee members. It offers a long-awaited alternative to circulating lengthy e-mail attachments, which have caused delivery problems from firewall settings and e-mail account sizes.

Technical documents in-process are now stored on the AWS e-committees secure server. The volunteers are directed to the server to download relevant information at their convenience.

Livelink® is well suited for standards development and other teamwork-related activities that require individuals from various parts of the world to exchange ideas and develop consensus.

Andrew Davis, managing director, AWS Technical Services Division, said, "We have received positive feedback from a number of committee members who are impressed with its features."

For more information on the AWS Technical Committees activities, contact Andrew Davis at *adavis@aws.org*; (800) 443-9353, ext. 466. For more information on the new software, visit *www.opentext.com/livelink*.

Member-Get-A-Member Campaign

Listed below are participants in the 2003–2004 Member-Get-A-Member Campaign. For campaign rules and a prize list, see page 87. For more information, call the Membership Department at (800) 443-9353, ext. 480.

Winner's Circle

AWS Members who have sponsored 20 or more new Individual Members, per year, since June 1, 1999. ( ) Denotes the number of times the member has earned Winner's Circle status.

J. Compton, *San Fernando Valley* (4)
E. H. Ezell, *Mobile* (2)
J. Merzthal, *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. Woomer, *Johnstown/Altoona* (1)
R. Wray, *Nebraska* (1)

President's Guild

AWS Members sponsoring 20 or more new Individual Members between June 1, 2003, and May 31, 2004.

President's Roundtable

AWS Members sponsoring 11–19 new Individual Members between June 1, 2003, and May 31, 2004.

R. Purvis, *Sacramento* — 14
G. Taylor, *Pascagoula* — 13
P. Evans, *Chicago* — 12
T. Hart, *Mobile* — 12

President's Club

AWS Members sponsoring 6–10 new Individual Members between June 1, 2003, and May 31, 2004.

K. Baucher, *Fresno* — 10
C. Daily, *Puget Sound* — 9
J. Powell, *Triangle* — 9
W. Drake, Jr., *Ozark* — 8
J. Compton, *San Fernando Valley* — 7
P. Walker, *Ozark* — 7

President's Honor Roll

AWS Members sponsoring 1–5 new Individual Members between June 1, 2003, and May 31, 2004. Only those sponsoring 2 or more AWS Individual Members are listed.

R. Fontenot, *Oklahoma City* — 5
D. St.-Laurent, *Northern Alberta* — 5
B. Suckow, *Northern Plains* — 5
C. Wesley, *Northwestern Pa.* — 5
D. Wright, *Kansas City* — 5
S. Abarca, *Illinois Valley* — 4
B. Diephuis, *Detroit* — 4
C. Dynes, *Kern* — 4
J. Smith, *Columbus* — 4
C. Boulden, *North Texas* — 3
K. Campbell, *L.A./Inland Empire* — 3
J. Cantlin, *Southern Colorado* — 3
C. Chilton, *Ozark* — 3
R. Culbert, *L.A./Inland Empire* — 3
B. Franklin, *Mobile* — 3
J. Greer, *Chicago* — 3
S. Jamaluddin, *Long Island* — 3
T. Nichols, *West Tennessee* — 3
R. Norris, *Maine* — 3
H. Shore, *Tulsa* — 3
G. Ullman, *Lakeshore* — 3
C. Casey, *Arizona* — 2
S. Colton, *Arizona* — 2
A. DeMarco, *New Orleans* — 2
E. Duplantis, *San Antonio* — 2
S. Henson, *Spokane* — 2
R. Holman, *Florida Space Coast* — 2
R. Johnson, *Detroit* — 2
P. Krishnasamy, *India* — 2
T. Lettich, *Sacramento*– 2
S. Luis, Jr., *Calif. Central Coast* — 2
C. Morehouse, *L.A./Inland Empire* — 2
G. Mulee, *Rochester* — 2
J. O'Neal, *Ozark* — 2
R. Painter, *Holston Valley* — 2
S. Schreecngost, *Pittsburgh* — 2
T. Shirk, *Tidewater* — 2
R. Stobaugh, Jr., *Carolina* — 2
W. Strother, *Lake Charles* — 2
R. Warner, *Utah* — 2
M. Wilkes, *Mahoning Valley* — 2
R. Wright, *Southern Colorado* — 2

Student Sponsors

AWS Members sponsoring 4 or more new AWS Student Members between June 1, 2003, and May 31, 2004, are listed.

D. Scott, *Peoria* — 67
G. Euliano, *Northwestern Pa.* — 42
R. Olson, *Siouxland* — 36
R. Norris, *Maine* — 35
W. Kielhorn, *East Texas* — 34
H. Jackson, *L.A./Inland Empire* — 32
M. Pointer, *Sierra Nevada* — 27
C. Donnell, *Northwest Ohio* — 26
D. Hatfield, *Tulsa* — 26
F. Mong, *Pittsburgh* — 26
J. Sullivan, *Mobile* — 26
T. Buchanan, *Mid-Ohio Valley* — 25
S. Sivinski, *Maine* — 24
M. Arand, *Louisville* — 23
C. Overfelt, *Southwest Virginia* — 23
M. Wilkes, *Mahoning Valley* — 23
D. Combs, *Santa Clara Valley* — 22
D. Ketler, *Williamette Valley* — 21
L. Davis, *New Orleans* — 20
F. Juckem, *Madison-Beloit* — 20
D. Kowalski, *Pittsburgh* — 20
S. Robeson, *Cumberland Valley* — 20
C. Daily, *Puget Sound* — 19
F. Wernet, *Lehigh Valley* — 19
J. Carey, *Boston* — 18
B. Chesney, *Green & White Mts.* — 17
T. Baldwin, *Arrowhead* — 16
J. Daugherty, *Louisville* — 16
R. Durham, *Cincinnati* — 16
A. Reis, *Pittsburgh* — 16
J. Hepburn, *Johnston-Altoona* — 15
D. Roskiewich, *Philadelphia* — 15
M. Anderson, *Indiana* — 14
D. Vranich, *North Florida* — 14
W. Harris, *Pascagoula* — 13
T. Strickland, *Arizona* — 13
K. Ellis, *Central Pennsylvania* — 12
A. Badeaux, *Washington D.C.* — 12
W. Galvery, *Long Bch/Orange Cty* — 12
J. Miller, *San Diego* — 12
J. Smith, Jr., *Mobile* — 12
P. Walker, *Ozark* — 12
D. Weeks, *Southwest Virginia* — 12
J. Boyer, *Lancaster* — 11
G. Putnam, *Green & White Mts.* — 11
R. Tupta, Jr., *Milwaukee* — 11
R. Williams, *Ozark* — 11
M. Koehler, *Milwaukee* — 10
W. Komlos, *Utah* — 10
J. Pelster, *Southeast Nebraska* — 10
A. Vidick, *Wyoming* — 10
D. Zabel, *Southeast Nebraska* — 10
J. Albert, *Johnstown-Altoona* — 9
H. Browne, *New Jersey* — 9
G. Gammill, *Northeast Mississippi* — 9
W. Johnson, *Portland* — 9
S. Colton, *Arizona* — 8
W. Howell, *Sabine* — 8
J. Mendoza, *San Antonio* — 8
J. Morash, *Boston* — 8
R. Rux, *Wyoming* — 8
J. Swoyer, *Lehigh Valley* — 8
J. Compton, *San Fernando Valley* — 7
A. Dommer, *Kern* — 7
R. Gallagher, Jr., *Lehigh Valley* — 7
C. Kipp, *Lehigh Valley* — 7
A. Ochoa, *San Francisco* — 6
R. Richwine, *Indiana* — 6
M. Tryon, *Utah* — 6
J. Carney, *Western Michigan* — 5
J. Crosby, *Atlanta* — 5
T. Kienbaum, *Colorado* — 5
J. Livesay, *Nashville* — 5
A. Mattox, *Lexington* — 5
S. MacKenzie, *Northern Michigan* — 5
W. Miller, *New Jersey* — 5
H. Riviere, *South Florida* — 5
S. Williams, *Central Arkansas* — 5
J. Ciaramitaro, *North Central Fla.* — 4
R. Douglas-Wells, *Atlanta* — 4
F. Henry, *L.A./Inland Empire* — 4
S. Luis, Jr., *Calif. Central Coast* — 4
W. Menegus, *Lehigh Valley* — 4
J. Olivarez, Jr., *Puget Sound* — 4
D. Smith, *Niagara Frontier* — 4
W. Wilson, *New Orleans* — 4 ♦

Standards Notices

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

August 12, Technical Activities Committee. Columbus, Ohio. General meeting. Staff contact: **Peter Howe**, ext. 309.

Standards for PINS

Development work has begun on the following new or revised standards. Directly and materially affected individuals are invited to contribute to the development of such standards. Those wanting to participate may contact the Staff Engineer listed with the document.

Participation on AWS Technical Committees and Subcommittees is open to all persons.

B5.9:200X, *Specification for the Qualification of Welding Supervisors.* This standard establishes requirements for the qualification of welding supervisors. It describes how personnel are qualified, the principles of conduct, and the practice by which qualification may be maintained. Stakeholders: Employers and supervisors of welders. Revised standard. Engineer: **Steve Hedrick**, ext. 305.

D14.3/D14.3M:200X, *Specification for Welding Earthmoving, Construction, and Agricultural Equipment.* This specification applies to all structural welds used in the manufacture of earthmoving, construction, and agricultural equipment. It reflects the welding practices employed by manufacturers within the industry and incorporates various methods that have been proven successful by individual manufacturers. No restrictions are placed on the use of any welding process or procedure, provided the weld produced meets the qualification requirements of this specification. No attempt is made to limit or restrict technological progress in the welding of earthmoving, construction, and agricultural equipment, nor should any such limitation be inferred. Stakeholders: Manufacturers of earthmoving, construction, and agricultural equipment.

Revised standard. Engineer: **Peter Howe**, ext. 309.

Standards for Public Review

The American Welding Society (AWS) was approved as an accredited standards-preparing organization by the American National Standards Institute (ANSI) in 1979. AWS rules, as approved by ANSI, require that all standards be open to public review for comment during the approval process. This column also advises of ANSI approval of documents. The following standards are submitted for public review. A draft copy may be obtained by contacting **Rosalinda O'Neill** at AWS, Technical Services Business Unit, 550 NW LeJeune Rd., Miami, FL 33126; telephone (800/305) 443-9353, ext. 451, e-mail: *roneill@aws.org.*

B2.1:200X, *Specification for Welding Procedure and Performance Qualification.* Revised standard — $77.00. ANSI Public Review expires July 20, 2004.

ISO Draft Standards for Public Review

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

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

ISO/DIS 10042 – *Welding — Arc-Welded Joints in Aluminum and Its Alloys — Quality Levels for Imperfections.* ♦

AWS Foundation Scholarship Update

The American Welding Society Foundation's Harley Davidson Raffle raised more than $5500 to be used to fund welding scholarships to high school and college students. **Robert Flores** of La Porte, Ind., won the 1200 Custom Sportster Harley-Davidson motorcycle.

The drawing took place April 8 during the 2004 AWS Welding Show in Chicago, Ill.

AWS Foundation scholarships support the growth and development of the welding industry. In 2003, it awarded more than $400,000 in scholarships to 275 students. Financial support from companies and individuals in industry is crucial to the success of the programs.

Visit *www.aws.org/foundation*; or e-mail: *vpinsky@aws.org*; or call (800) 443-9353, ext. 212, for information on AWS Foundation scholarships and programs.

Let AWS Help You Find a Job or an Employee

Jobfind, an AWS free service for job seekers, is the right place to start looking for a job, a better position, or hiring that needed employee. Here is the meeting place for welders, CWIs, engineers, technicians, welding managers, supervisors, and consultants.

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

All job seekers enjoy free access to job listings specific to the materials joining industry. They can post a public or confidential résumé in a searchable database, and apply directly online for positions with prospective employers. They also can edit a résumé at any time and upload additional résumés without cost. Check out ***Jobfind*** first, it's online at ***www.aws.org/jobfind.***

membership

supporters

Supporting Companies

All Steel Consultants, Inc.
6162C 15th St. E
Bradenton, FL 34203

DDS, Inc.
4121 Wagon Trail Ave.
Las Vegas, NV 89118

ICON Shelter Systems, Inc.
7900 Logistic Dr., Ste. C
Zeeland, MI 49464

Educational Institutions

Blackstone Valley Regional Vocational
Technical High School
65 Pleasant St.
Upton, MA 01568

Garden City High School C.C.
1412 N Main
Garden City, KS 67846

Middle East Industrial Training Centre
P.O. Box 33229
Mafrag, Abu Dhabi, U.A.E.

Senai Centro de Technologia de Solda
Rua São Francisco Xavier #601
Rio de Janiero, RJ 20.550-011, Brazil

Distributor Members

EWIE Co., Inc.
1099 Highland Dr.
Ann Arbor, MI 48108

Affiliate Companies

Herco, Inc.
92 Hill Ave.
Fort Walton Beach, FL 32548

Liberty Welding Co.
1235 Washington Blvd.
Pittsburgh, PA 15206

PBP Fabrication, Inc.
1117 S Tripp Ave.
Odessa, TX 79763

R. J. Ilten
10170 Beech Ave.
Fontana, CA 92335

Robert Mitchell, Inc.
350 Decarie
St. Laurent, QC, Canada H4L 3K5

Ruffner's Railroad Services, Inc.
2451 Rainbow Ct.
Cincinnati, OH 45230

Sanweld Industries
25 Southgate St.
Worcester, MA 01610

Did you know?

As an AWS Sustaining Company Member you are entitled to have up to ten Individual Members on your company's roster at no extra charge.

You can even add your customers to your roster as a special "thank you" to them.

AWS Welding Distributor Members enjoy five Individual Memberships (a $375 value), a listing on the Distributor Locator Map on the AWS Web site with a hyperlink to take visitors directly to their Web page.

Educational Institution Members receive three Individual Memberships. Each Member receives the *Welding Journal* and *The American Welder* publications, discounts on AWS publications and American Welder™ products.

To obtain member application forms or more information, contact AWS Membership Dept., (800) 443-9353, ext. 259; or e-mail: *marthac@aws.org*.

membership counts

Member Grades	As of 6/1/04
Sustaining Companies	408
Supporting Companies*	203
Educational Institutions	332
Affiliate Companies	235
Welding Distributor Companies	49
Total Corporate Members	**1,227**

** During March 2003, the Society initiated the Welding Distributor Company membership category. Those Supporting Company members identified as welding distributors were at that time upgraded to this new corporate member category.*

Individual Members	42,984
Student & Transitional Members	4,511
Total Members	**47,495**

new sustaining members

CRYOSTAR USA
2670 Lehigh St.
Whitehall, PA 18052
Representative: Mark Sutton

Cryostar provides equipment solutions to the cryogenic industry, including centrifugal single- and multistage, reciprocating, turbo-expanders, boil-off gas compressors for industrial gas, LNG, and hydrogen applications. Its equipment features increased reliability, safety of operation, ease of installation, and reduced maintenance costs.

METKA S.A.
11 Marinou Antipa St.
N. Traklio, Athens 141-21, Greece
Representative: Demetris Poulakis

Metka S.A. has been a leading contractor in the energy and defense sectors in Greece for 35 years. With headquarters in Athens, it maintains two industrial facilities in Volos (in central Greece near the Volos port).

Metka employs more than 500 experienced and skilled personnel, including 120 highly qualified engineers with expertise in the fields of energy projects, sophisticated metal constructions, and defense projects.

ARC SPECIALTIES, INC.
7775 Little York Rd.
Houston, TX 77016
Representative: Daniel W. Allford

ARC Specialities, founded in 1983, designs and builds automated manufacturing systems, robots, and custom equipment with emphasis on weld joining, overlay, cladding, cutting, and forming. ARC is a major supplier for engineering services, process development, systems integration, service, parts, and training. ARC Specialties has installed and supported systems worldwide. Its success in the marketplace is due to a combination of experience, reputation, equipment functionality, and cutting-edge technology.

SECTION NEWS

Jim Cambell (right) and Tom Ferri, Boston Section chair, discuss the major welding projects needed to complete the restoration of the steamship SS Nobska.

Shown are eleven of the twelve eager SkillsUSA welding contest applicants who polished their skills at the Green and White Mountains Section hands-on program held March 20.

DISTRICT 1

Director: Russ Norris
Phone: (603) 433-0855

BOSTON

May 3
Activity: The Section toured the SS *Nobska* in dry dock at the old Boston Navy Yard in Charlestown, Mass. **Jim Cambell**, restoration coordinator for the New England Steamship Foundation, made a presentation then led a tour of the ship and the dry dock. More than $3 million in federal money has already been spent on the *Nobska*. New ribs have been installed, and all of its hull plates have been replaced. But before she can float, more than 5000 feet of seam welding will be required to join those new plates.

GREEN & WHITE MOUNTAINS

March 20
Activity: The Section hosted the Vermont SkillsUSA Welding Contest for ten secondary and two postsecondary students. The event was held at Advanced Welding Institute in South Burlington, Vt.

April 8
Activity: The Green & White Mountains Section members toured Lyndon Institute in Lyndon, Vt., then critiqued the welding contest they hosted March 20. Welding instructor **Jim Blanchard**, judge **Joe Tokarski**, and organizer **Geoff Putnam** presented gold awards to **Chad Franklin** and **Jason Koch**; silver awards to **Damon Carr** and **Mike Greenwood**; and a bronze award to **Leif Trott**.

May 13
Activity: The Green & White Mountains Section held its executive committee meeting in West Lebanon, N.H. **Russ Norris** presented the chairman's pin to **Ray Henderson**. Members discussed SkillsUSA, the District conference, scholarships, and fundraisers.

Shown at the Green & White Mountains Section awards-presentation program April 8 are (from left) Joe Tokarski, Geoff Putnam, Chad Franklin, Leif Trott, Damon Carr, Jim Blanchard, Mike Greenwood, and Jason Koch.

MAINE

March 11
Speaker: **Jeff Fields**
Affiliation: Bath Iron Works
Topic: Preparing for the Maine SkillsUSA Contest
Activity: The program included hands-on training for everyone on FCA, GTA, SMA, and PAC welding using machines provided by Hypertherm, Miller, Lincoln Electric, and Hobart. The event was held at United Technology Center in Bangor, Maine.

DISTRICT 2

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

NEW JERSEY

April 26–29
Activity: The Section hosted a four-day hands-on seminar featuring orbital welding. The sessions were held at GMP Systems in Pine Brook, N.J.

Historian Gus Manz spoke at the New Jersey Section meeting in May.

Shown are some of the participants at the New Jersey Section's orbital welding seminar held in April.

Shown at the May New Jersey Section program are (from left) Bill Miller, Donald Gibson, Charles Dominguez, Jason Kubilus, Mike Smiecinski, Jeff Yannetta, and Joe Scarangello.

Speaker Bojidar Yanev (left) is shown with Tom Colasanto, membership committee chair, at the March 29 New York Section program.

Robert Blauser accepts a speaker gift from Claudia Bottenfield at the April meeting of the Lancaster Section.

Shown are the Lancaster Section members during their tour of the Direct Wire & Cable facilities in May.

MAY 18
Speaker: **Gus Manz**, engineer
Topic: A history of welding
Activity: The New Jersey Section presented awards to participants in its student welding contest. Those honored included students **Donald Gibson, Charles Dominguez, Jason Kubilus, Mike Smiecinski, Jeff Yannetta, Joe Scarangello**, and instructor **Bill Miller.**

NEW YORK

MARCH 29
Speaker: **Bojidar Yanev**, director of bridge inspections
Affiliation: NYC Bureau of Bridges
Topic: Restoration of the Manhattan Bridge and other major bridge projects worldwide

DISTRICT 3

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

LANCASTER

APRIL 22
Speaker: **Robert Blauser**, senior welding engineer
Affiliation: Harley-Davidson
Topic: Welding motorcycles
Activity: The program was held at Apple Tree Restaurant in Lancaster, Pa.

MAY 13
Activity: The Lancaster Section toured Direct Wire & Cable, Inc., in Denver, Pa. The presenters were **Eric Laubach**, vice president of sales; and **Mike Diem**, sales department.

DISTRICT 4

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

NORTHEAST CAROLINA

APRIL 22
Speaker: **David Schaefer**, technical representative
Affiliation: The Lincoln Electric Co.
Topic: Visual inspection techniques
Activity: **Joe Lyon**, an instructor at Wayne Community College, was elected both education and membership committee chair. A new Section banner was presented by Chairman **Roy Lanier** to replace the banner lost during Hurricane Floyd.

SOUTHWEST VIRGINIA

APRIL 19
Speaker: **Clay Dillard**

Ed Wyatt (left) presents the Chairman's Appreciation Certificate to Bill Rhodes at the Southwest Virginia program in April.

Affiliation: United Abrasives
Topic: Grinding safety
Activity: **Bill Rhodes**, Section chairman, presented the Industry Support Certificate of Appreciation to Airgas. Accepting the award were **Richard Watson** and **Barry Cumbie,** Airgas southwest region vice president and branch manager, respectively. Rhodes accepted the Chairman's Appreciation Citation from Awards Chair **Ed Wyatt**.

DISTRICT 5

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

PUERTO RICO

MARCH 4
Speaker: **Harry Rosario**, operations manager
Affiliation: Technical Welding Services
Topic: The value of becoming an AWS Student Member
Activity: The program was held at Tomás Hongay Vocational School for 47 attendees.

MARCH 17
Speaker: **Harry Rosario**, operations manager
Affiliation: Technical Welding Services
Topic: The AWS CWI program
Activity: This Puerto Rico Section program was held for 30 attendees at Salón América in San Juan.

MARCH 18
Speaker: **Harry Rosario**, operations manager
Affiliation: Technical Welding Services
Topic: Building Student Chapter membership
Activity: The Puerto Rico Section held two programs this day. The morning program attracted 73 students and adults, and the afternoon session drew 84. The programs were held at Antonio Lucchette Vo-Tech School. Arecibo Job Corps representatives attended.

Shown (from left) are speaker Eric Laubach, John Ament, speaker Mike Diem, and Claudia Bottenfield at the Lancaster Section's May meeting.

Shown at the April Northeast Carolina Section program are (from left) speaker David Schaefer, John Cavenaugh, and Carl Yeager.

Shown at the Southwest Virginia Section program are (from left) Chair Bill Rhodes, Richard Watson, and Barry Cumbie.

Harry Rosario, an energetic promoter of the Puerto Rico Section, makes a presentation for welding students in March.

The Antonio Lucchette Vo-Tech students proudly pose at the Puerto Rico Section's introduction to welding program led by Harry Rosario, held March 18 at Antonio Lucchette Vo-Tech School.

Speaker Dave Lackey (right) is shown with Gale Mole, chairman of the South Carolina Section, at the April meeting.

Chris Anderson described the benefits of the new digital welding machines for Dayton Section members in April.

Sparks flew when Dayton Section members tried the new inverter technology at its April meeting held at Motoman.

SOUTH CAROLINA

April 20

Speaker: **Dave Lackey**, district manager

Affiliation: The Lincoln Electric Co.

Topic: GMA welding of aluminum

Activity: The Section held its nominations for officers for 2004–2005.

These welding students appear eager to get started on the welding contest sponsored by the Greater Huntsville Section.

DISTRICT 6

Director: Neal A. Chapman

Phone: (315) 349-6960

DISTRICT 7

Director: Donald C. Howard

Phone: (814) 269-2895

COLUMBUS

May 13

Activity: The Section hosted its election of officers event at Hooters Restaurant in Columbus, Ohio. **Jerry Van Meter** presented the chairman's pin to outgoing chair **John Lawmon.**

DAYTON

April 13

Speaker: **Chris Anderson**, marketing director

Affiliation: Motoman, Inc.

Topic: Digital GMAW machines

Activity: Anderson demonstrated high-frequency inverter power sources and offered hands-on "test drives" for the 30 members in attendance. The program was held at Motoman, Inc., in Troy, Ohio.

May 11

Activity: The Dayton Section members toured KTH Parts Industries, St. Paris, Ohio, a Tier One just-in-time supplier to Honda.

Triangle Tech Pittsburgh Campus Student Chapter

April 13

Speaker: **David Bloom**

Affiliation: Vince's Gas and Welding Supply Co.

Topic: Safety rules for the oxyfuel processes

Activity: Chartered in April 2004, the Chapter's first meeting accentuated the importance of safety. This hands-on program prepared the students to work on their long-term project to restore the USS *Requin* SS481, a 59-year-old submarine dry docked at the Carnegie Science Center in Pittsburgh, Pa. Read the illustrated story of their project featured on page 71 of this issue of Society News.

DISTRICT 8

Director: Wallace E. Honey

Phone: (256) 332-3366

GREATER HUNTSVILLE

April 16

Activity: **Joe Smith**, a welding instructor at Marshall Technical School, conducted a welding contest for students from Blount, Morgan, Etowah, Dekalb, Marshall, and Jackson counties. More than 100 attended the event. First-year student winners were **Kyle Ayers, Zack Nail**, and **Randy Mnore.** Advanced-level winners included **Henry Carden, Derric Freeman**, and **Joey Turner.** The college student-level top awards went to **Mark Parker, Sharron Chelsey**, and **Keith Colkitt.** The event was held at Marshall Technical School.

DISTRICT 9

Director: John Bruskotter

Phone: (504) 363-5900

MOBILE

April 15

Activity: Several members made presentations about their personal experiences in the welding industry to inspire the many students in attendance. **Jim Sullivan,** a welding instructor at Locklin Technical Center, accepted funds from the Section to support his team's expenses to participate in the Florida State SkillsUSA-VICA competition held April 26–28. Honored were **Matthew Myers** and **Kevin Green,** from

Greg Pierce (left) accepts the past chairman's pin from his dad, Ron Pierce, at the May meeting of the Mobile Section.

Shown at the Mobile Section program are (from left) Chair Greg Pierce, Jim Sullivan, Career Specialist Anita Hosking, Matthew Myers, and Kevin Green.

Locklin Tech, who won the first and second place trophies in the local welding competition.

May 13
Activity: The Mobile Section hosted its annual Past Chairmen's Night program, highlighted by honoring **Greg Pierce** for serving as chair for the past year. His father, **Ron Pierce**, a past AWS president and two-time Mobile Section chair, presented his son with the past chairman's pin. **Leo Veal**, the first Mobile Section chair, attended.

NEW ORLEANS

April 20
Speaker: **Kyle Cortello**, sales representative
Affiliation: McDonough Marine Service
Topic: Economic impact of the barge and tugboat industry
Activity: The program was held at C&C Marine and Repair, Belle Chasse, La., owned by **Anthony Cihilich.**

May 1
Activity: The New Orleans Section hosted its Sixth Fishing Rodeo at C-Way Marina at Lafitte, La., for 100 attendees including 50 contestants. **Ron Crotwell** and **Norman Gauthreaux** took top honors in the redfish category, **Ron Perez** landed a 39-lb calcutta, while **Randy Stevenson** and **Butsie Duhun** snagged the speckled trout category prizes. **Lloyd Lemle** won the auction for an original oil painting. **Mike Skiles** served as rodeo master, and **Ivy Bernard** officiated as weighmaster for the event.

DISTRICT 10

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

The proud winners in the Detroit Section's welding contest pose with their awards. Shown are (standing, from left) Jesse Holbrook, Justin Ferguson, and David Dowd; (front row, from left) Richard Neifert, Lance Kujawski, Shawn Jedinak, Kyle McNew, and Shaun Thorsrud.

Secretary Paul Hebert (left) presents a speaker gift to Kyle Cortello at the New Orleans Section program in April.

(from left) Paul Hebert presents a host gift to Anthony Cibilich and Joe Autin at the April New Orleans Section program.

Shown at the March Milwaukee Section program are (from left) Scott McCallister, Dick Tupta, Daniel Hunt, Larry Gross, David Maloney, Michael Brown, and Christopher Nielsen.

The Airgas Fishing Team displays its prize-winning redfish catches at the New Orleans Section contest held May 1st.

Indiana Section Chair Mike Anderson (left) presents the speaker plaque to Dick Alley at the April meeting.

Shown at the April Milwaukee Section program are (from left) John Kozenieki, chairman, and speaker David Bertsche.

DISTRICT 11

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

DETROIT

May 1
Activity: The Section hosted its 31st annual high school welding contest at Schoolcraft College. Students from seven schools participated in the written exam and practical exercises. Taking the top eight spots were **Shawn Jedinak, Kyle McNew, Shaun Thorsrud, Lance Kujawski, Richard Neifert, Justin Ferguson, Jesse Holbrook** and **David Dowd.**

May 7
Activity: The Detroit Section held its annual Ladies' Night event at the Cobo Center in downtown Detroit. Attended by 430 members and their families, the event's guest of honor was AWS President **Tom Mustaleski.**

DISTRICT 12

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

MILWAUKEE

March 18
Speaker: **Joel Donohue**
Affiliation: American Friction Welding
Topic: The friction welding process
Activity: The Section hosted its Scholarship Awards Night. Honored were scholarship recipients **Scott McCallister, Daniel Hunt, David Maloney,** and **Christopher Nielsen;** and their instructors **Dick Tupta, Larry Gruss,** and **Michael Brown.** Fifty people attended the event.

April 15
Speaker: **David L. Bertsch,** manager, mechanicals
Affiliation: Avalon Rail Co.
Topic: Reconditioning railroad cars for use on Amtrak trains
Activity: This Milwaukee Section program was held at Avalon Rail Co. in Milwaukee, Wis.

DISTRICT 13

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

CHICAGO

May 11
Speakers: **Randy Counselman,** and **Craig Brown**
Affiliation: Stork Technimet
Topic: Failure analysis of weldments
Activity: This was a joint meeting with members of the local chapter of ASM International.

DISTRICT 14

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

INDIANA

April 19
Speaker: **Richard L. Alley,** AWS past president (1989–90)
Topic: The image of welding
Activity: The Section held its election of officers. The program was held at MCL Cafeteria in Indianapolis, Ind.

LEXINGTON

April 29

Activity: The Section met at Central Kentucky Vo-Tech School for a program presented by Victor Torches. Products shown included oxygen and acetylene welding equipment. District 14 Director **Tully Parker** and about 90 members and guests attended the program. Student **Carl Watsnn** received the VICA award for earning first place in the welding competition.

DISTRICT 15

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

ARROWHEAD

April 15

Activity: The Section toured the L&M Radiator, Inc., designing, manufacturing, fabricating, and welding facilities located in Hibbing, Minn. **Douglas Pioske**, general manager, discussed the manufacturing processes used to make radiators and heat exchangers for industrial applications.

DISTRICT 16

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

KANSAS

April 28

Activity: The Section met at Barton County Community College's welding shop where **Mark Ward**, owner of Ward Welding, gave a demonstration on carbon arc gouging and the proper use of the torch. Following the demonstrations, the attendees took turns testing their welding and gouging skills.

KANSAS CITY

April 15

Activity: The Section toured the Shawnee Steel & Welding Co. plant to study the robotics and fixturing used in its operations. Host for the tour was **Scott Gronberg**, project manager. The Section held its nominations of officers. Nominated were **Barry Hamiltun**, chairman; **Jim Benny** and **Scott Grnnberg**, vice chairs; and **Dennis Wright**, secretary.

DISTRICT 17

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

Shown at the Lexington program are Chair Allen Mattox (left) and Frank McKinley presenting the VICA award to first-place award winning student Carl Watson at the April program.

Lexington Section Chair Allen Mattox (left) welcomes District 14 Director Tully Parker to the April meeting.

Several Arrowhead Section members are shown during their tour of L&M Radiator, Inc., in April.

EAST TEXAS

May 5

Activity: **Mike Player** accepted the Section Educator of the Year Award from **Robert Warke**, chairman, and **Bill Keilhnrn**, secretary-treasurer. Player, an AWS Certified Welding Inspector, was cited for his outstanding improvements to the welding lab and training at Kilgore College, Kilgore, Tex.

NORTH TEXAS

April 20

Speaker: **Tom Mustaleski,** AWS president, BWXT Y-12 LLC, Oak Ridge, Tenn.

Topic: AWS educational opportunities

Activity: District 17 Director **Oren Reich** presented **Kirk Jordan** the CWI of the Year Award and **Paul Stanglin** the Distinguished Service Award.

TULSA

April 27

Activity: The Section toured the John Zink Co., in Tulsa, Okla., to study the building of industrial heaters and drilling rig flares. **Todd Fradd**, project coordinator, made a presentation on the company's operations. **Dennis Armiger**, machine shop supervisor, and **Finis Richardson**, supervisor of aftermarket products, conducted the tour.

Mike Player displays his Educator of the Year Award presented to him by Bill Kielhorn (left) and Robert Warke, East Texas Section chair.

Shown at the North Texas Section program are (from left) District 17 Director Oren Reich, CWI awardee Kirk Jordan, and AWS President Tom Mustaleski.

Shown April 27 during the Tulsa Section's Zink Company tour are (from left) Dennis Armiger, Paul Morgan, and Finis Richardson.

Tom Holt (right) accepts the Meritorious Award from John Mendoza, District 18 Director, at the April Sabine Section meeting.

Sabine Vice Chair Tom Holt (left) presents James Amy with the chairman's pin and an appreciation certificate at the April program.

Grady Hatton (right) accepts the CWI of the Year Award from John Mendoza, District 18 director, at the Sabine Section awards program.

Larry Smith, outgoing Houston Section chair, displays his certificate of appreciation for his great service to the Section.

Dennis Eck, Houston Section vice chair (left), presents a speaker gift to Art Fabra at the Houston Section program in May.

HOUSTON

May 19

Speaker: **Art Fabra**

Topic: Lean manufacturing, the use of strategic management, quality systems, and safety

Activity: **Dennis Eck** presented the Dr. Daryle Morgan Scholarship to welding student **Phillip Thorton. John Husfeld** introduced **Barbara Cupial,** the winner of the AWS 2004 Poster Exhibition. Chair **Larry Smith** accepted a certificate of appreciation for his services during the past year.

SABINE

April 20

Activity: The Section members toured American Valve & Hydrant in Beaumont, Tex., conducted by **Philip Bean, Tim Sudela,** and **Pat Lowry.** District 18 Director **John Mendoza** presented District Director Awards to **Morris Weeks** and **Mark Clark**, the Section Educator Award to **Randy Howell**, CWI of the Year Award to **Grady Hatton**, Private Instructor Award to **Darrell Posey,** and the Meritorious Award to **Tom Holt**. The Section announced the establishment of its fifth annual $850 scholarship. This one was named in honor of longtime member **Alton Wolf**. Mendoza presented Wolf with a proclamation formally dedicating the scholarship in his name.

DISTRICT 18

Director: John L. Mendoza
Phone: (210) 860-2592

DISTRICT 19

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

John Mendoza, District 18 Director (left), presents Randy Howell the Sabine Section Educator Award.

DISTRICT 20

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

EASTERN IDAHO/ MONTANA

JANUARY 23

Activity: The Section toured the Montana Resources Co. welding and mining operations in Butte, Mont. The tour included a trip through the mine. Employees discussed the employment opportunities for welders in its extensive operations. Dinner was held at the Red Lion Hotel.

APRIL 29

Activity: The Eastern Idaho/Montana Section members toured the Idaho Falls City Power division hydroelectric plant located on the Snake River.

DISTRICT 21

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

Welding engineers and inspectors assembled for the welding seminar conducted jointly by the AWS India Section and the Indian Institute of Welding.

Shown at the Sacramento Valley Section program are (from left) Elmer Crain, Milt Heft, and Kerry Shatell, vice chair.

DISTRICT 22

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

SACRAMENTO VALLEY

APRIL 21

Speakers: **Milt Heft**, owner
Affiliation: Petrogen, Inc.
Topic: Oxy-gasoline cutting

Activity: **Milt Heft** demonstrated his patented oxy-gasoline cutting system designed to cut through steel up to 14 in. thick steel with no slag. The event was held at Elmer's Portable Welding facility, hosted by **Elmer Crain**, owner, and **Milt Heft**.

India Section Chair Baskaran opened the Trends in Weld Quality Assurance Seminar held April 17.

International Section

INDIA

APRIL 17

Activity: The Section joined the Indian Institute of Welding to sponsor a full-day workshop for 52 attendees titled Trends in Weld Quality Assurance. Prominent speakers from industry addressed welding processes, weld discontinuities, NDE, weld codes, and a system approach for QA of welds. The seminar was held at IQC Training and Services Pvt. Ltd., in Chennai, India.

New Student Chapters

American River College, *Sacramento Section, Dist. 22;* Bellingham Technical College, *Puget Sound Section, Dist. 19;* Columbiana County Career & Technical Center, *Mahoning Valley Section, Dist. 10;* Columbus Technical College, *Atlanta Section, Dist. 5;* Seacoast School of Technology, *Maine Section, Dist. 1;* John Handley High School, *Cumberland Valley Section, Dist. 3;* Lake Washington Technical College, *Puget Sound Section, Dist. 19;* Triangle Technical School, Pittsburgh Campus, *Pittsburgh Section, Dist. 3;* WI TC — Rice Lake, *Northwest Section, Dist. 15.*

And the Winners Are . . .

The Board of Directors established the **Student Chapter Member Award** to recognize Student Chapter members who have produced outstanding school, community, or industry achievements.

This award is presented to **Matthew R. Bnnidie**, and **Will H. Bouzel** by the *Tri-State Business Institute AWS Student Chapter in Erie, Pa., District 10.*

To qualify for this award, candidates must be an AWS Student Member affiliated with an AWS Student Chapter. Visit *www.aws.org/sections/awards/student_chapter.pdf* to download form.

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

District 1 Director **Russ Norris** has nominated the following members for this award for 2003–2004:

Al Moore — *Connecticut Section*
John Gullotti — *Connecticut Section*
John Jones — *Connecticut Section*
Walter Chojnacki — *Connecticut Section*
Glenn Myrick — *Boston Section*
James Shure — *Boston Section*

Guide to AWS Services

550 NW LeJeune Rd., Miami, FL 33126
Phone (800) 443-9353; (888) WELDING; FAX (305) 443-7559
Internet: www.aws.org
Phone extensions appear in parentheses.

AWS PRESIDENT

James E. Greer ....*profjimg@aol.com*
Moraine Valley Community College
248 Circlegate Rd., New Lenox, IL 60451

ADMINISTRATION

Executive Director
Ray W. Shook.. *rshook@aws.org* ....(210)

Deputy Executive Directors
Jeffrey R. Hufsey .. *hufsey@aws.org* ....(264)

John J. McLaughlin.. *jackm@aws.org* ..(235)

CFO/Deputy Executive Director
Frank R. Tarafa.. *tarafa@aws.org* ....(252)

Corporate Director of Quality
Management Systems
Linda K. Henderson.. *lindah@aws.org* (298)

Executive Assistant for
Board Services and IIW
Gricelda Manalich.. *gricelda@aws.org* ..(294)

HUMAN RESOURCES

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

DATABASE ADMINISTRATION

Corporate Director
Jim Lankford.. *jiml@aws.org*..................(214)

INTERNATIONAL INSTITUTE OF WELDING

Information..*sissi@aws.org* ....(319)

Provides liaison activities involving other professional societies and standards organizations, nationally and internationally.

GOVERNMENT LIAISON SERVICES

Hugh K. Webster ....*hwebster@wc-b.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)

WELDING EQUIPMENT MANUFACTURERS' COMMITTEE

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

WELDING INDUSTRY NETWORK (WIN)

Mary Ellen Mills.. *memills@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.

PUBLICATION SERVICES

Department Information ....(275)

Managing Director
Andrew Cullison.. *cullison@aws.org*......(249)

Welding Journal

Publisher/Editor
Andrew Cullison.. *cullison@aws.org*......(249)

National Sales Director
Rob Saltzstein.. *salty@aws.org* ....(243)

Welding Handbook

Welding Handbook Editor
Annette O'Brien.. *aobrien@aws.org* ......(303)

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

MARKETING

Corporate Director
Bob Bishopric.. *bbish@aws.org*.............(213)

Plans and coordinates marketing of AWS products and services.

Marketing Communications

Senior Manager
George Leposky.. *gleposky@aws.org* ....(416)

Manager
Amy Nathan.. *nathan@aws.org*. ....(308)

MEMBER SERVICES

Department Information ....(480)

Associate Executive Director
Cassie R. Burrell.. *cburrell@aws.org* ....(253)

Director
Rhenda A. Mayo.. *rhenda@aws.org* ......(260)

Serves as a liaison between Section members and AWS headquarters. Informs members about AWS benefits and activities.

PROFESSIONAL INSTRUCTION SERVICES

Managing Director
Debrah C. Weir.. *dweir@aws.org* ....(482)

Proposes new products and services. Researches effectiveness of existing programs.

Educational Product Development

Director
Christopher Pollock.. *cpollock@aws.org*(219)

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

Conferences and Seminars

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

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

CERTIFICATION OPERATIONS

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

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

INTERNATIONAL BUSINESS DEVELOPMENT

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

AWS AWARDS, FELLOWS, and COUNSELORS

Managing Director
Wendy S. Reeve.. *wreeve@aws.org* ....(293)

Coordinates AWS awards and AWS Fellow and Counselor nominees.

TECHNICAL SERVICES

Department Information ....(340)

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

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

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

Technical Publications

Senior Manager,
Rosalinda O'Neill.. *roneill@aws.org* ....(451)

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

Engineers

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

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

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

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

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

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

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

WEB SITE ADMINISTRATION

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

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 on-line 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.*

Nominees for National Office

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

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

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

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

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

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

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

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

This material should be sent to Ernest D. Levert, 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 John J. McLaughlin, Secretary, Honorary-Meritorious Awards Committee, 550 NW LeJeune Rd., Miami, FL 33126. A description of the awards follow.

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

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

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

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

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

TeleWeld
FAX: (305) 443-5951

Publications Sales/Orders
Global Engineering Documents
(800) 854-7179 or (303) 397-7956,
or online at: *www.global.ihs.com.*

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

AWS Mission Statement

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

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

AWS Foundation, Inc.

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

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

CD Catalog Displays Vast Selection of Sensors

A 38-page catalog outlines the company's inductive, photoelectric, capacitive, magnetic field, and electromechanical sensors, ID systems, remote systems, accessories, connectors, and transducers. The accompanying CD provides a thousand pages of detailed technical information, plus Internet links for product updates.

Balluff, Inc. 116
8125 Holton Dr., Florence, KY 41042

Guide Details Machine Safeguarding Equipment

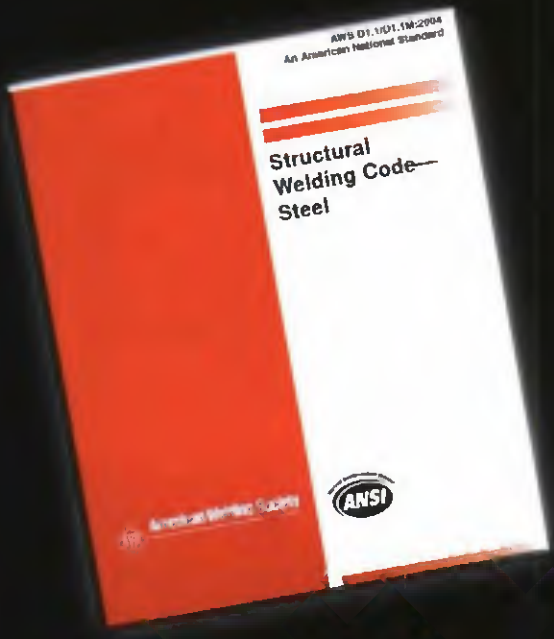
The 750-page *Engineering Guide to Machine and Process Safeguarding* details safety light curtains, safety contact strips, hydraulic press brake guards, safety interlock switches, plus hundreds of other industrial products. A 125-page section includes illustrated safety regulations and directives, risk assessment articles, and other useful data for the safety engineer.

Scientific Technologies, Inc. 115
6550 Dumbarton Cir., Fremont, CA 94555-3605

Heavy-Duty Electrical Hand Tools Pictured

The 8-page, full-color Spring 2004 new-products brochure displays the company's lines of heavy-duty D-Stroyer™ rotary hammers, Torque-Plus™ cordless drill/drivers, and 5-in. angle grinders. Included are slicers and a new chop saw wheel.

Metabo Corp. 117
1231 Wilson Dr., West Chester, PA 19380


AWS D1.1/D1.1M:2004
An American National Standard
Structural Welding Code—Steel
American Welding Society
ANSI

Select-Arc Fills New Sales Post


Jeff Schnabel

Jeff Schnabel was appointed to the new position of sales manager, hardfacing and stainless alloys, at Select-Arc, Inc., Fort Loramie, Ohio. Schnabel, with 15 years of experience in the industry, will oversee the company's new line of welding electrodes.

Hulvy Joins Alloy Engineering

The Alloy Engineering Co., Berea, Ohio, has appointed **Steve Hulvey** as sales engineer for its Ohio, Michigan, western West Virginia, and the Ohio-river area of Kentucky. Hulvy has 25 years of experience with the company in various positions, including specialty products sales manager, quality assurance manager, and product manager.

VP Named at Rolled Alloys

Rolled Alloys Canada, Inc., Mississauga, Ontario, has named **Hugh Khan** vice president and director of Canadian operations. With the company since 1996, Kahn previously served as sales manager.

EWI Fills Nine Key Positions


Brian Lu


Evgueni Todorov


Yu-Ping Yang


V. Thyagarajan


Brian Girvin


Brandon Shinn


Brian Baughman


Joe Dirksheide

Edison Welding Institute, Columbus, Ohio, has appointed three senior engineers: **Brian Lu**, for microjoining, previously worked for Stellite Coatings; **Evgueni Todorov**, for nondestructive evaluation, formerly was employed at Bombardier Aerospace, Toronto, Canada; and **Yu-Ping Yang**, for computational modeling of welding, cutting, and forming, came from Battelle Memorial Institute.

Five applications engineers were appointed: **Vikram Thyagarajan, Brian Girvin, Brandon Shinn, Brian Baughman,** and **Joe Dirksheide.** Thyagarajan specializes in nondestructive evaluation; Girvin will pursue resistance and solid-state welding projects; Shinn is experienced in laser beam welding; Baughman works with pulsed gas metal arc welding; and Dirksheide's line is advanced gas metal arc welding processes.


Leah Kohr

Leah Kohr joins the company as a proposal coordinator in the Technical Division. Previously, Kohr was a project manager and quality engineer with Bell Laboratories/Lucent Technologies.

President Named at Cellar Services

Sue Vivian was named president of Cellar Services, Inc., Sterling Heights, Mich. **Jack Goodrich**, CSI founder, is director of research and development for the resistance welding equipment company. Vivian, a CPA, has ten years of experience in the resistance welding industry.

L.A. NTMA Taps Its Trustee


Mike Kartsonis

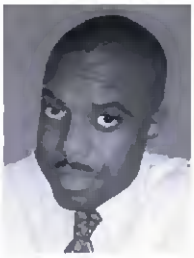
Mike Kartsonis, president and founder of Dynamic Fabrication, Inc., Santa Ana, Calif., was appointed trustee for the Los Angeles chapter of the National Tool and Machining Assn. (NTMA). Kartsonis will act as a liaison between the chapter and the NTMA's governing body based in Washington, D.C.

Four Posts Filled at Tregaskiss


Brian Krieger


Dongmei Sun

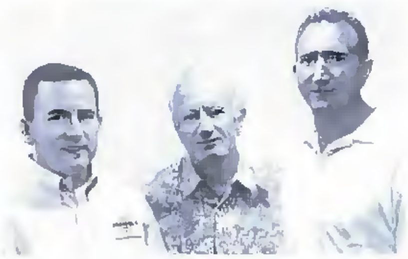
Tregaskiss Ltd., Windsor, Ont., Canada, named **Brian Krieger** as a regional business manager; **Dongmei Sun** as a design engineer; and customer service representatives **Stanley Cox** and **Richard Hinds.** Krieger, with 25 years of experience in the industry, will be responsible for the company's northeast region of Ontario. Sun has worked as a research welding engineer for five years in robotic


Stanley Cox


Richard Hinds

welding and quality control systems. Cox previously worked as an engineer in the aerospace industry for several years. Hinds brings considerable experience in international sales management.

Coxreels Announces Top- Level Changes



Brad Cox, Don Cox, and Jeff Cox

Coxreels, Tempe, Ariz., a manufacturer of hose, cord, and cable reels, has appointed **Brad Cox** as president and COO, and his brother **Jeff Cox** as executive vice president. Former president, **Don Cox**, will manage as chairman of the board and CEO for the company. Previously, Brad was executive vice president, and Jeff served as vice president of manufacturing.

Real Time Solutions Names Sales Manager

Jeff Runnion

Jeff Runnion was named Midwest regional sales manager for Real Time Solutions, Emeryville, Calif., an FKI Logistex company. The company is a provider of hardware and software order-filling solutions for warehouses and distribution centers. Runnion has 22 years of experience in the materials handling industry.

Matheson Tri-Gas President to Sit on Nippon Sanso Board

William J. Kroll, president and CEO of Matheson Tri-Gas, Inc., Parsippany, N.J., was appointed to the board of directors of Tri-Gas's parent company Nippon Sanso Corp. Kroll has held senior-level positions at Matheson Tri-Gas since 1994.

Techalloy Designates Product Manager

Gary Powell was appointed product manager at Techalloy's Baltimore Welding Division where he manages the Customer Service and Shipping Departments with sales responsibilities in North America and the United Kingdom. Prior to joining the company, Powell was a welding specialist for several metal supply companies.

TRUMPF Appoints Three Managers

TRUMPF Inc., Farmington, Conn., has named **Donald Forrest** as national service manager; **James Rogowski** as product manager for the automation and bending groups; and **Tony Mirisula** as product manager for the portable power tools unit. Forrest formerly served the company as manager of VectorMark (laser marking) service. Rogowski previously was a product engineer in the automated systems group. Mirisola previously served as a sales engineer in the portable power tools group.

Lincoln Appoints Manager

Leo Landers was named distributor account manager for The Lincoln Electric Co., Cleveland, Ohio. An employee since 1984, Landers has served as a country manager for South Korea and Taiwan, and regional sales manager for South America. He most recently was district manager in Lincoln's Milwaukee office.

Minser Joins ESAB

Jack Minser has joined ESAB Welding & Cutting Products, Florence, S.C., as business product manager for gas apparatus. Previously, Minser worked for Victor Equipment Co. for 25 years in various marketing positions.

Koike Aronson Names Manager

Eric Christofferson was appointed to the new position of field sales manager at Koike Aronson, Inc., Arcade, N.Y. With many years of sales experience with Miller Electric Co. and Airgas Intermountain, Christofferson most recently was owner and president of Integrated Technologies & Services, Inc., Colorado Springs, Colo.

NEW PRODUCTS

— continued from page 31

Sectioning Machines Handle Small Parts

Automated, pulse sectioning of small parts is performed using MSX200-A sectioning machines, with flexible design configurations that handle sample types for many applications. The unit features an advanced spindle design that promotes long life and precise sectioning, an LCD touch-screen control panel, and large T-slotted tables for easy sample maneuvering. The machine features a 1.5-hp motor and an 8-in blade capacity for longitudinal sections.

LECO Corp. 114
3000 Lakeview Ave., St. Joseph, MI 49085-2396

CAREER OPPORTUNITIES

WANTED

Welding Alloy Sales Reps

Vulcan Systems is seeking professionals for the next level of profitability. Unique opportunity to build and secure your future. Protect your profits and income.

Contact Christopher Biggar
(800) 642-9885

CERTIFICATION & TRAINING

Get REAL Educational Services, Inc.

SPECIAL COURSE

AWS D1.1 CODE SEMINAR
40 HOURS TOWARD RECERTIFICATION COVERING REQUIREMENTS, QUALIFICATION & DOCUMENTS
Houma, LA Jul. 26–30

CWI PREPARATORY

Guarantee - Pass or Repeat FREE!

SAT–FRI COURSE (7 DAYS)
EXTRA INSTRUCTION TO GET A HEAD START
Pascagoula, MS Aug. 14–20 Oct. 9–15
Houma, LA Sep. 11–17 Nov. 6–12

MON–FRI COURSE (5 DAYS)
GET READY - FAST-PACED COURSE!
Pascagoula, MS Aug. 16–20 Oct. 11–15
Houma, LA Sep. 13–17 Nov. 8–12
Sulphur, LA Aug. 23–27

2 WEEK COURSE (10 DAYS)
MORE HANDS-ON/PRACTICAL APPLICATIONS
Pascagoula, MS Aug. 9–20 Oct. 4–15
Houma, LA Sep. 7–17
(Test follows on Saturday at same facility)

Continue Your Education With:

APPLICATIONS OF VISUAL WELDING INSPECTION

Hands-on training for real work situations

RT FILM INTERPRETATION

Challenging practicals using real welds

WELDING PROCEDURES

Learn code requirements to write/audit

ADVANCED VISUAL INSPECTION

For experienced inspectors & engineers

MT/PT/UT/RT LEVEL I & II
Classroom training per ASNT SNT-TC-1A

For our entire class schedule, call or e-mail
1-800-489-2890 or

info@realeducational.com

CORPORATE DIRECTOR OF CERTIFICATION SERVICES

The American Welding Society seeks a corporate director for its growing Certification Services. The ideal candidate has a degree, preferably in engineering sciences, 5–7 years experience in running an operation along with P&L responsibility. The Corporate Director of the Certification Business Unit will ultimately answer to the AWS Board of Directors for program revenues, cost projections, and strategic goal accomplishment. Successful experience in new product development and rollout a plus. An understanding of welder procedures and performance qualification, the certification process, and the interface between AWS, its volunteer structure, and industry is important.

Interested parties should send a resume and salary range along with a cover letter outlining interest to:

American Welding Society
550 N.W. LeJeune Rd.
Miami, FL 33126

Attn.: Luisa Hernandez
Personnel Department
luisa@aws.org

AWS – An Equal Opportunity Employer
Visit our Website at www.aws.org

BUSINESS FOR SALE

BUSINESS FOR SALE

Established 1983. Make small stored energy welding equipment. Pulse arc, spot resistance and fusion percussion mini stud welder. International markets through distributors, reps and direct sales. Miniature tech joining of similar and dissimilar metals for medical, dental, optical, jewelry, crafts, appliance, auto, aircraft, and electronics industries. Very strong gross profit @84%, before tax earnings @26% and after tax profits of 15%. Strictly confidential, please write:

Business 4 Sale
PO Box 893
E. Greenwich, RI 02818

BUSINESS/CAREER OPPORTUNITY

Take immediate ownership with no investment in the steel fabrication arm of a midwestern machine tool and machining firm. Family-owned business will give up to 25% ownership to attract strategic thinker with strong sales skills to run steel plate fabrication operation. Must have strong relations with buyers and reps, ability to develop new markets, top sales and sales management skills, engineering ability a plus. Be prepared to undertake turnaround of 21-year old company in Great Lakes region. Cover letter/resume with salary history to Dbs328@sbcglobal.net. Include "FABRICATOR" in subject line.

WANTED

Independent Sales Reps

To demonstrate welding alloys to end users.

-Consumable market
-Repeat Customers
-Complements Industrial Rep's present line(s) of products.

Very unique opportunity.

Contact Christopher Biggar
(800) 642-9885

EQUIPMENT TO BUY OR SALE

WELD PLUS

www.weldplus.com
E-mail: jack@weldplus.com
800-288-9414 Jack, Pete, Paul or Dennis
Fax: 513-467-3585

JUST IN! Sciaky AcuWeld 1000, 6 Axis, Dabber Pulse Control, 200 Amp DC Power Supply, 2500 lb. Positioner

New "2004" Pandjiris 1500 lb, 3000 lb & 4500 lb Positioners!!
Call for "SPECIAL SALE PRICING"

OVER 40 "NEW 2004" POSITIONERS in STOCK!!!

Well Over 100 Positioners Total, Up to 350 Tons!! Head/Tailstocks, Turntables up to 60 tons. Manipulators up to 14' x 14', Travel Cars, Longitudinal Seamers from 12" to 26 ft., Turning rolls up to 400 Tons, Circular Weld Systems, Welding Lathes, Arc Machines & other Orbital Welders.

WELDING RELATED MACHINERY IS OUR ONLY BUSINESS
If Your Business Does Weld Fabricating—YOU NEED TO VISIT US!!!
TALK TO US!!—"WE KNOW WELDING"

USED PLATENS
Re-Ground Tops
FOB: Shipping Point • Call for Details
Weldsale Company (215) 739-7474
www.weldsale.com

We buy and sell
WELDING RODS & WIRE
**ALL TYPES ** ALL SIZES **
ALL QUANTITIES

Excess Welding Alloys, Inc.
A division of Weld Wire Company Inc.

800-523-1266 FAX 610-265-7806
www.weldwire.net

We Buy & Sell Surplus
Welding Rod & Wire
All types, sizes & Quantities

Liberty Alloys INC.

Call us first!

800-523-2791
PA: 610-825-1250
FAX: 610-825-1553

robots4welding
.com

Toll free: 1-800-762-6862

ATTENTION!

Welding Equipment Sales Personnel.
We pay you for finding us good used welding systems, seamers, positioners, manipulators, turning rolls, etc.
We will buy your customers' trade-ins.

WELD PLUS, INC.
1-800-288-9414

EQUIPMENT SALES/RENTAL

FOR SALE - FOR RENT

Welding Positioners
Headstock Tailstock
Tank Turning Rolls
Manipulators, Subarc
Welding Machines

800-218-9620
713-943-8032

www.mitrowskiwelding.com
sales@mitrowskiwelding.com

RED-D-ARC®
Quality-Checked™ Used Equipment
www.red-d-arc.com

An Excellent Selection of Used Welding and Positioning Equipment for Sale

1-800-245-3660
Service Centers Across North America

EQUIPMENT USED

Used-Robots
.com

We buy and sell
1-877-4usedrobots

SERVICES

ADVERTISER INDEX

Abicor Binzel	www.binzel-abicor.com	IBC
Aelectronic Bonding, Inc.	www.abiusa.net	90
ArcOne	www.arc1weldsafe.com	16, 17, 18
Astro Arc Polysoude	www.astroarc.com	27
AWS Conference Dept.	www.aws.org	53, 224S
AWS Convention Sales	www.aws.org	37
AWS Foundation Dept.	www.aws.org	20, 21
AWS Member Services	www.aws.org	12, 19, 41
AWS Technical Services	www.aws.org	91
Centerline Ltd.	www.cntrline.com	RI
Chinese Mech. Eng. Society	www.jkrall@aws.org	26
ClimaTech	wwwclimatechsafety.com	13
College of Oceaneering	www.coo.edu	9
Commercial Diving Academy	www.commercialdivingacademy.com	29
Cor-Met	www.cor-met.com	8, 93
C-Spec	www.weldoffice.com	65
D. L. Ricci, Corp.	www.dlricci.com	64
DE-STA-CO Industries	www.destaco.com	65
Divers Academy International	www.diversacademy.com	32
ESAB Welding & Cutting Prod.	www.esabna.com	OBC
Fischer Technology, Inc.	www.Fischer-Technology.com	30
GE Inspection Technology	www.GEInspectionTechnologies.com	1
Gedik Welding Inc.	www.gedik.com.tr	11
H&M Pipe Beveling Machines Inc.	www.hmpipe.com	28
Hobart Inst. of Welding Tech.	www.welding.org	66
Hodgson Custom Rolling, Inc.	www.hodgsoncustomrolling.com	7
ICALEO	www.icaleo.org	61
Intercon	www.intercononline.com	30
IWE Consulting, Inc.	www.iweconsulting.com	28
Jackson Products	www.jacksonproducts.com	2
LECO	www.leco.com	14
Lincoln Electric Co.	www.lincolnelectric.com	5
Linders Specialty Co., Inc.	www.lscmetalfab.com	64
Magnatech Limited Partnership	www.magnatech-lp.com	10
MK Products	www.mkproducts.com	29, 31
Phoenix International, Inc.	www.phx-international.com	66
Porta-Vise	www.porta-vise.com	31
Select Arc, Inc.	www.select-arc.com	IFC, 33
Thermal Arc/Thermadyne	www.thermalarc.com	23
Thermal Dynamics/Thermadyne	www.thermal-dynamics.com	25
Tri Tool	www.www.tritool.com	15
Triangle Engineering	www.trieng.com	66
Weld Hugger, L.L.C	www.weldhugger.com	90

IFC = Inside Front Cover

IBC = Inside Back Cover

OBC = Outside Back Cover

RI = Reader Information Card

WELDING RESEARCH

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

Resistance Spot Welding of Aluminum Alloy to Steel with Transition Material — Part II: Finite Element Analyses of Nugget Growth

An aluminum-clad steel transition layer can be used in forming a structural weld between aluminum and steel parts

BY X. SUN AND M. A. KHALEEL

ABSTRACT. This paper summarizes work on finite element modeling of nugget growth for resistance spot welding of aluminum alloy to steel. It is a sequel to a previous paper on experimental studies of resistance spot welding of aluminum to steel using a transition material. Since aluminum alloys and steel cannot be readily fusion welded together due to their drastically different thermal physical properties, a cold-rolled clad material was introduced as a transition to aid the resistance welding process. Coupled electrical-thermal-mechanical finite element analyses were performed to simulate the nugget growth and heat generation patterns during the welding process. The predicted nugget growth results were compared to the experimental weld cross sections. Reasonable comparisons of nugget size were achieved. The finite element simulation procedures were also used in the electrode selection stage to help reduce weld expulsion and improve weld quality.

Introduction

Steel and aluminum are the most important construction materials for the mass production of today's automotive structures. It is well known that metallurgical bonds between aluminum and steel are difficult to achieve with fusion welding because of the inherent discrepancies in electrical, thermal, and mechanical properties between the two materials. For fusion welding processes such as direct resistance spot welding (RSW), little or no mutual solubility of aluminum and steel exists. The intermetallic compound that is formed between the two metals often results in cracking, brittleness, and susceptibility to corrosion. The use of a transition material to facilitate the spot welding process of aluminum to steel is a concept that has shown promise in the past (Refs. 1, 2). Use of this transition insert allows for two separate weld nuggets to be formed in their respective aluminum/aluminum and steel/steel interfaces. Bonding at the aluminum/steel interface is achieved by the cold-clad process (Ref. 1).

Very few previous studies exist on this subject matter, and almost all of these studies focus on experimental nugget growth studies using consecutive metallurgical cross-sectioning. There is a lack of fundamental understanding on the heat generation and nugget growth kinetics as well as the effects of different electrode combinations on nugget growth kinetics. The purpose of this study was to use the incrementally coupled finite element modeling procedure to simulate the heat generation and nugget formation sequence in resistance welding of aluminum to steel with a transition layer. As discussed in Part I of this study, the transition layer used was a cold-rolled clad material of aluminum to steel with 20% cladding ratio. The process development and joint performance issues were addressed in Part I of this study using experimental approaches. The following welding parameters were used for spot welding of 2-mm 5182-O to 1.4-mm SAE1008 with 1.5-mm-thick transition material:

- Electrode on Al side: 30-deg truncated cone Class 2 electrode with 8-mm face diameter and 3-in. face radius
- Electrode on steel side: 30-deg truncated cone Class 2 electrode with 8-mm diameter, flat-faced
- Electrode force: 1050 lb-ft.
- Welding current: 13.6 kA with 97% heat
- Welding schedule: 3 pulses of [12 cycles welding + 3 cycles holding]
- Cooling water flow rate: 1.75 gallons per min

KEY WORDS

Welding Process Simulation
Finite Element Analysis
Resistance Spot Welding
Dissimilar Metals Joining
Aluminum Alloy
Transition Material
Aluminum-Clad Steel
Nugget Growth

With the rapid advancements in software and hardware for scientific computing, finite element weld process simulation has been a powerful tool in understanding the fundamental physics associated with the resistance spot welding process. Several authors have developed different finite element models to address various aspects associated with the resistance spot welding process. Among them are Nied (Ref. 3), Tsai et al. (Ref. 4), Sheppard (Ref. 5), Murakawa (Ref. 6), and Dong et al. (Ref. 7). Most of the above-mentioned studies use sequentially coupled finite element modeling in which a one-step electrical-thermal analysis is performed after the initial mechanical analysis of the holding cycle. No changes in contact areas between the electrode and worksheet are monitored and updated during the modeling process.

During actual welding, however, the contact area changes on the faying interface and the two electrode/sheet interfaces can significantly influence the heat

X. SUN is with Battelle Memorial Institute, Columbus, Ohio. M. A. KHALEEL is with Pacific Northwest National Laboratory, Richland, Wash.

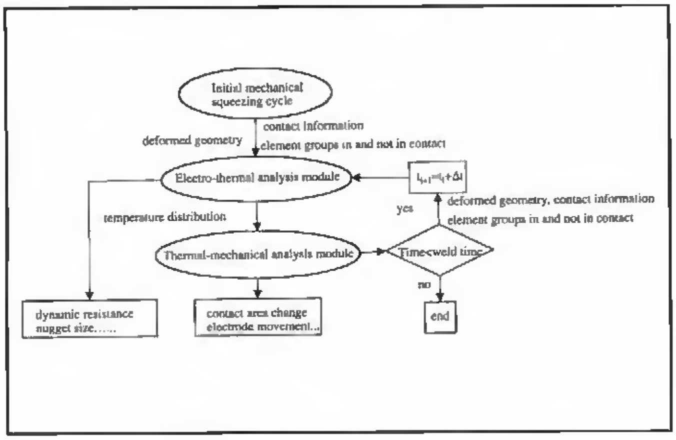


Fig. 1 — Flowchart of analysis procedure.

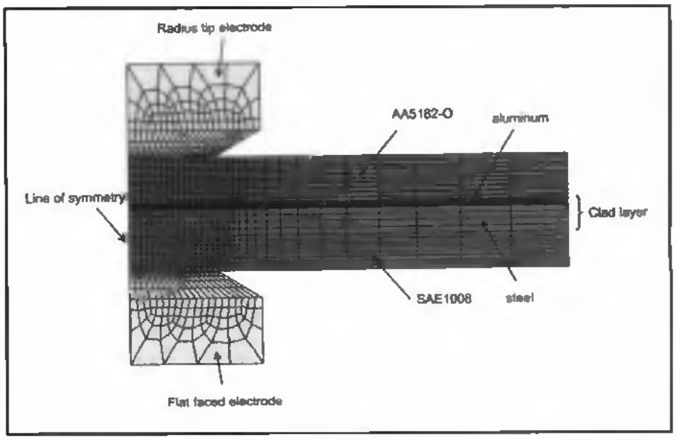


Fig. 2 — Typical finite element mesh.

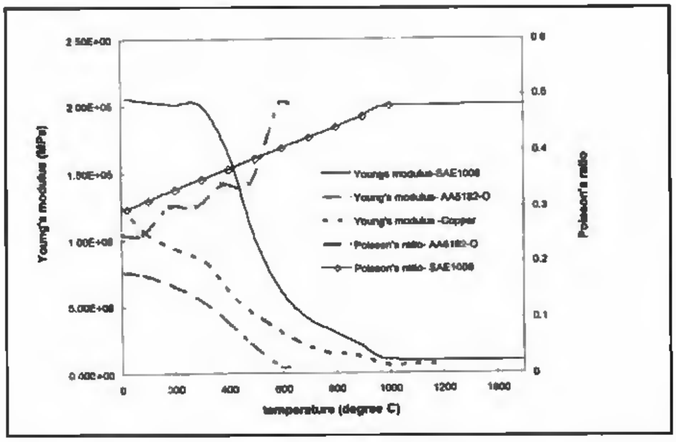


Fig. 3 — Young's modulus and Poisson's ratio of different materials.

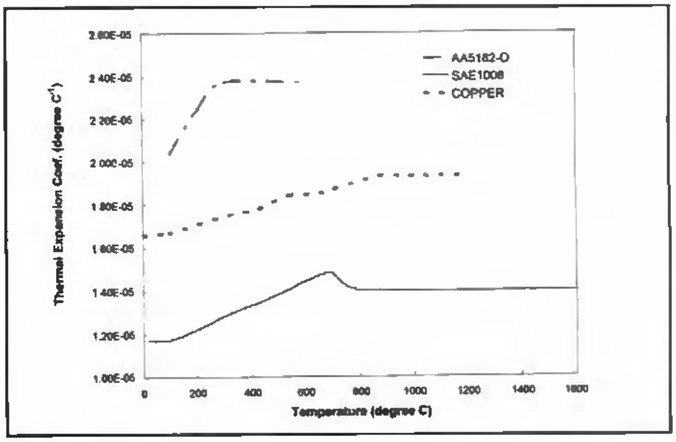


Fig. 4 — Thermal expansion coefficient of different materials.

generation and nugget formation processes (Ref. 8). This is particularly true for aluminum spot welding with radius-tip electrodes. In this study, we used the incrementally coupled finite element procedure developed by Sun and Dong (Ref. 9) to simulate the nugget growth and heat generation process for resistance spot welding of aluminum to steel. The theoretical framework regarding the coupled electrical-thermal-mechanical phenomena associated with spot welding was presented in Ref. 9 and its implementation procedure with commercial code (e.g., *ABAQUS*) is illustrated in Fig. 1. This incrementally coupled modeling procedure has been proven successful in modeling aluminum spot welding and steel projection welding processes (Refs. 9–11).

Finite Element Modeling Procedure

Figure 2 shows the typical finite element mesh for half of the electrode-sheet assembly with axisymmetric condition being assumed. The 2-mm AA5182-O is in contact with the top electrode and the aluminum side of the transition clad layer. The 1.4-mm SAE1008 sheet is in contact with the bottom electrode and the steel side of the transition layer. The total thickness of the transition material is 1.5 mm. The model consists of four-node linear elements.

The initial squeeze cycle is modeled by a mechanical analysis. Uniformly distributed pressure calculated according to the specified electrode force is applied on the top surface of the upper electrode, and the bottom of the lower electrode is restrained from motion in the vertical direction. Contact pairs are set up for the electrode/sheet interfaces and the two faying interfaces to model surface interactions (Refs. 9, 12). Results generated from the squeezing cycle mechanical analysis, including deformed shape and coordinates, contact pressure, contact radius, element groups in and not in contact, etc., are extracted and passed to the subsequent electrical-thermal analysis in which the welding current is applied. Temperature-dependent mechanical properties are used for AA5182-O and SAE1008, as well as the copper electrodes. These data are collected from various references (Refs. 13–16). For example, Figs. 3 and 4 show the temperature-dependent Young's modulus, Poisson's ratio, and thermal expansion coefficient for the different materials used in the analyses. Note that the material properties for the aluminum and steel layers in the transition material are assumed to be the same as AA5182-O and SAE1008, respectively.

In the electrical-thermal analysis, the deformed shape of the electrode-sheet assembly calculated from the previous mechanical analysis is used. Zero electrical potential is imposed on the bottom of the lower electrode tip, and distributed current density input calculated from the current input value is applied on the top of the upper electrode. All the free surfaces of the electrode and sheet assembly that are not in contact at this time increment are assumed to have free convection with the surrounding air, and the two electrodes are assumed to be water cooled with a forced-convection coefficient spec-

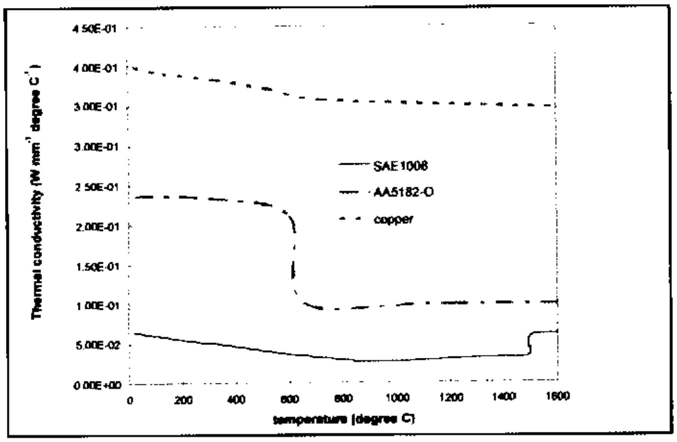


Fig. 5 — Thermal conductivity of different materials.

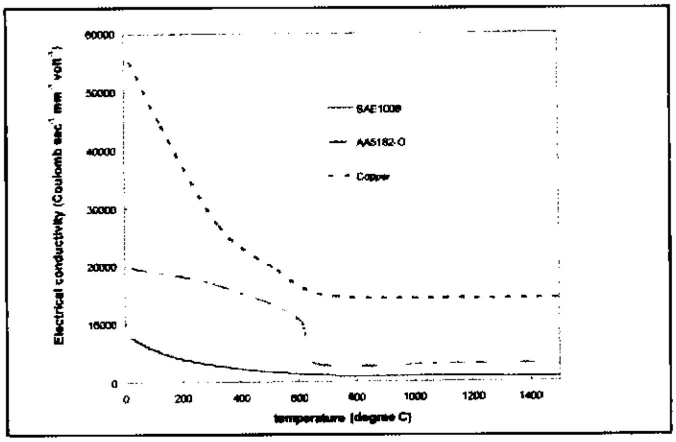


Fig. 6 — Electrical conductivity of different materials.

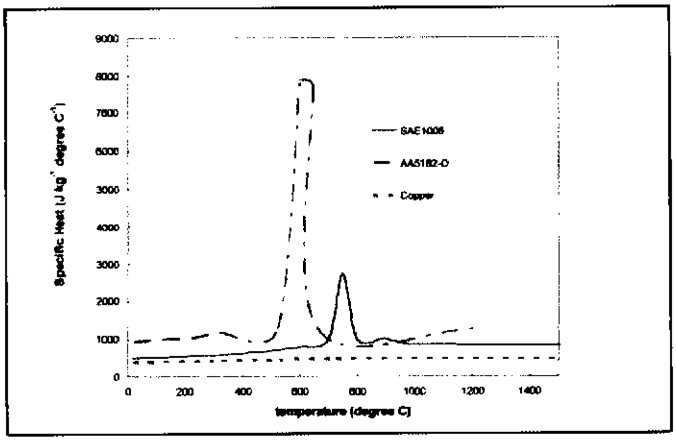


Fig. 7 — Specific heat of different materials.

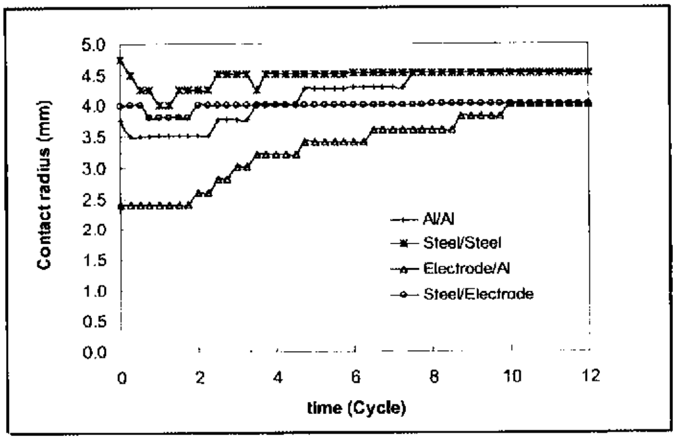


Fig. 8 — Predicted evolution of contact radii on different interfaces during the first welding pulse.

ified on their upper and lower free edges. Figures 5–7 show the temperature-dependent physical properties used for the materials during the entire modeling process (Refs. 13–16).

The contact electrical conductance for the faying interfaces and the electrode/sheet interfaces is determined using the formulation developed by Li et al. (Ref. 8):

$$\sigma_g = \frac{1}{\rho h} = \frac{1}{R_c A_c} = \frac{I}{2\sqrt{L(T_s^2 - T_0^2)}\,\pi r_c^2} \qquad (1)$$

in which L is the Lorentz constant; T_s is the solidus temperature of the interface; and T_0 is the interface temperature (both in Kelvin). For most metals, L is found to be around 2.4×10^{-8} $(V/°K)^2$. The contact radius r_c for the electrode-sheet interfaces and the faying interface is extracted from the previous increment mechanical analysis results. The solidus temperatures T_s for different interfaces used in the analyses are

$T_{s\text{-}electrode/aluminum} = 200°C$

$T_{s\text{-}aluminum/aluminum} = 550°C$

$T_{s\text{-}steel/steel} = 1200°C$

$T_{s\text{-}electrode/steel} = 500°C$

The temperature distribution computed from the above electrical-thermal analysis for a certain time increment is then imposed as thermal loading conditions for the subsequent thermal-mechanical analysis module. This updating procedure repeats itself for a specific time increment, i.e., the updating frequency, until the entire welding cycle is totally completed. The flowchart of the analysis procedure is shown in Fig. 1. The entire analysis procedures are fully automated with a suite of user-interface routines.

Results and Discussions

Nugget Development Study

The modeling procedure described above was used to simulate the RSW process of aluminum to steel with transition clad material. In the coupled finite element analyses, the updating frequency for the first welding pulse (12 cycles of welding current) was set to be ¼ cycle to capture the rapid changes of the contact radii on different interfaces as depicted in Fig. 8. Toward the end of the first welding pulse, the contact radii on different interfaces reached their respective plateaus, then single-step thermal-electrical analyses were performed for the subsequent second and third welding pulses.

The predicted nugget shape and size compared with the weld cross sections from the actual weld samples are shown in Figs. 9–13. It should be mentioned that since aluminum and steel have different melting temperatures, different contour scales had to be used in plotting the temperature contours of the model prediction in order to show molten zones in both aluminum and steel in one picture. In Figs. 9–13, the red areas in the predicted results represent molten metal, and the gray areas in the predicted results represent base material: light gray for aluminum and dark gray for steel. The sharp transition

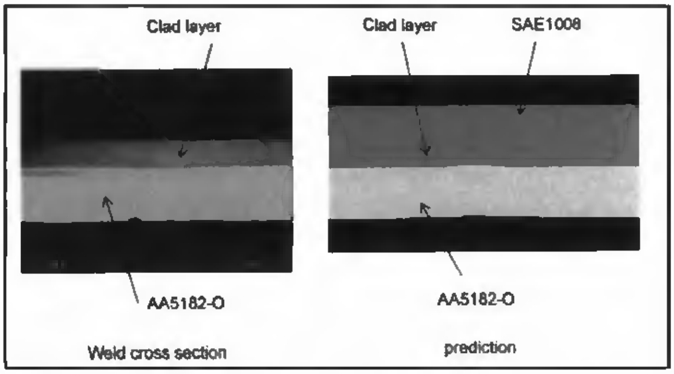


Fig. 9 — Weld structure at four cycles weld time: no melting observed. The steel sheet separated from the transition clad layer due to short weld time.

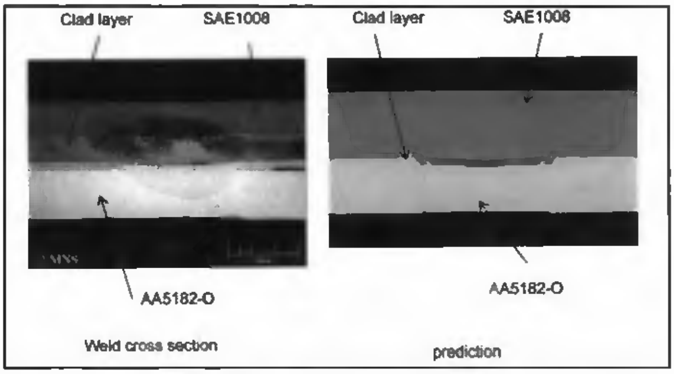


Fig. 10 — Weld structure at eight cycles weld time.

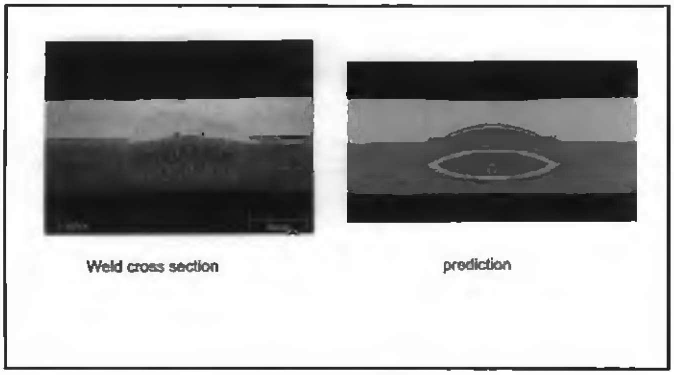


Fig. 11 — Weld structure at 12 cycles weld time (first pulse).

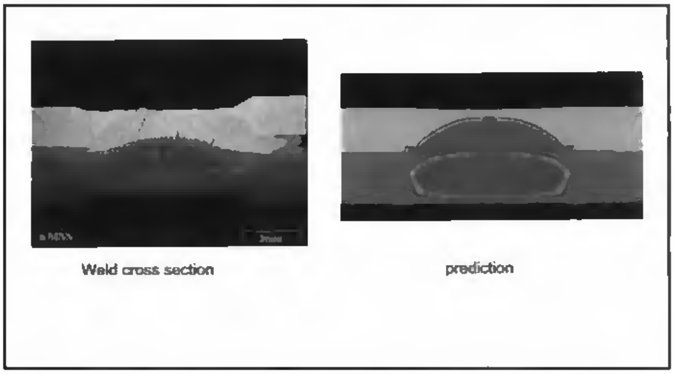
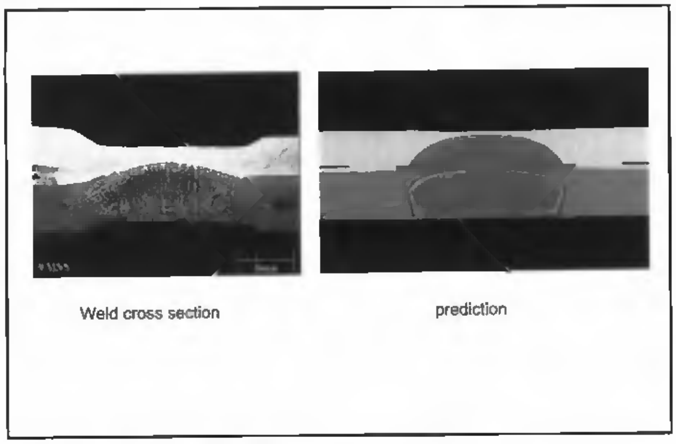


Fig. 12 — Weld structure at the end of the second welding pulse.

regions between the base material and the molten zone are the predicted heat-affected zone (HAZ). Furthermore, in order to show the model predicted fusion zone size and shape, Figs. 9–13 were plotted at the end of the welding cycles, not at the end of the holding and cooling cycles as those in the experimental cross sections. Since the materials are still hot at the end of the welding cycle and are still undergoing thermal expansions, these temperature contour plots can only be used to determine the fusion zone width and its depth relative to the original sheeting thickness. They do not represent the final weld indentation and sheet separation. This is particularly true for the softer aluminum side, where large deformation will occur during the cooling and holding cycle. And it explains why the contour plots in Figs. 9–13 do not show significant weld deformations as shown in the experimental cross sections.

Figures 9–11 show the molten zone formation sequence for the first welding pulse (12 welding cycles). At the end of the first four welding cycles, no melting is predicted, neither on the aluminum side nor on the steel side. This is consistent with the experimental observations in Fig. 9. At the end of the eighth welding cycle, a small amount of melting is predicted on the aluminum side of the transition material in Fig. 10. This melting is caused primarily by the heat conducted from the steel/steel interface. Since the melting temperature for steel is much higher than aluminum, melting is not yet observed for the steel side at the end of the eighth cycle. Some discoloration is observed on the steel/steel interface in the metallurgical cross section in Fig. 10 with no clear columnar weld structure present. This discoloration could be the result of recrystallization, grain growth, and reaustenization of the material. The maximum temperature predicted for the steel/steel faying interface at the end of the eighth welding cycle is 1437°C, very close to the melting temperature of steel. The metallurgical cross section in Fig. 10 shows that some amount of melting occurred in the aluminum base material in addition to the aluminum layer in the transition material. Since the steel side of the entire cross section was much hotter than the aluminum side at the end of the eighth cycle, heat from the steel side continued to be conducted to the much cooler aluminum side when the weld current was turned off. This "postweld" heat conduction may cause additional melting on the aluminum side after the current was turned off. Again, since our prediction results are only depicted at the end of the eighth welding cycle, it does not include any additional melting caused by the heat transfer after the current was turned off. This effect should be particularly strong for the first welding pulse when thermal gradients between the two sides were very high.

At the end of the first welding pulse (12 cycles), both metallurgical cross section and prediction indicated clear molten zones on the steel side as well as the aluminum side — Fig. 11. The molten zone on the steel side has a regular, elliptical shape, with major axis along the interface of the SAE1008 and the steel side of the transition material. Clear dendritic solidification structures surrounded by the heat-affected zone can be observed in the steel nugget. These structures start at the outer edge of the molten nugget and grow like fingers stretching toward the center of the nugget. The molten zone on the aluminum side is only the top half of a regular elliptically shaped spot weld with a slightly larger molten zone diameter in the transition material. This again suggests that the heat for nugget formation on the aluminum side is conducted from the steel side. In addition, pores and gaps were also seen on the aluminum/steel interface. The possible reasons for the pores and gaps to



Weld cross section

prediction

Fig. 13 — Weld structure at the end of the third welding pulse.

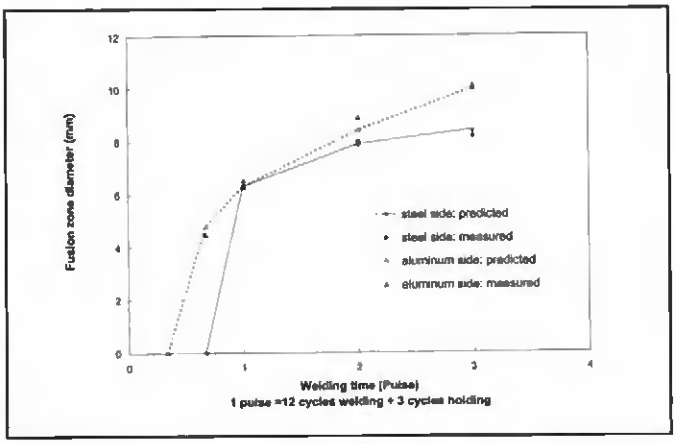


Fig. 14 — Comparison of predicted and measured fusion zone diameter on aluminum/aluminum interface and steel/steel interface.

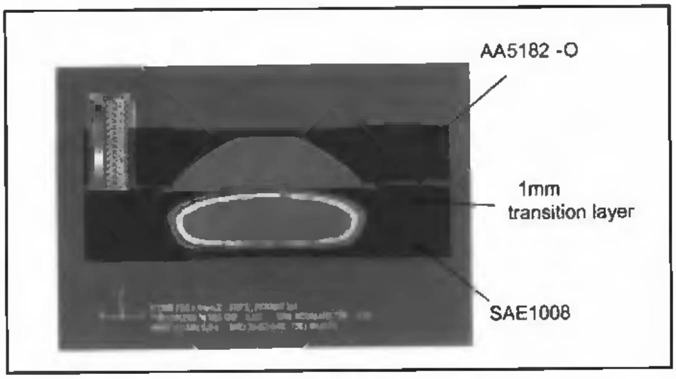


Fig. 15 — Weld structure and sheet separation for radius electrodes on both sides.

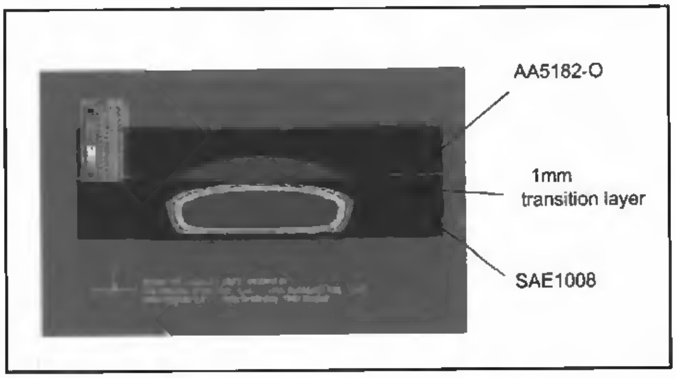


Fig. 16 —Weld structure and sheet separation for radius electrode on aluminum side and flat-faced electrode on steel side.

form were discussed in Part 1 of our study, and their influence on the weld performance was also discussed. It should be mentioned that the finite element analyses procedure used here cannot be used to predict the formation and location of such pores and gaps.

The predicted weld cross sections at the end of the second and the third welding pulses are shown in Figs. 12 and 13 together with experimental cross sections. Figure 14 compares the predicted and measured fusion zone diameters along the aluminum/aluminum interface and steel/steel interface. Overall, the predicted fusion zone diameters and depths (relative to sheet thickness) are in good comparison with the experimental cross sections on both steel and aluminum sides.

It should be noted that the experimental cross sections shown in Figs. 12 and 13 indicate a large amount of one-sided weld indentation and interface metal squeeze-out. These could be the results of electrode misalignment during the actual welding process. Since the analysis procedures used in this study were based on axisymmetric assumption, the effects of electrode misalignment and one-sided expulsion were not predicted using the current modeling procedure.

Electrode Selections

As discussed in Part 1 of this study, during the initial electrode selection stage, the electrode pair first used was based on a Ford specification (Ref. 17) in which 30-deg truncated Class 2 electrodes with 8-mm face diameter and 3-in. face radius were used on both sides. Initial experimental welding trials with this electrode pair resulted in frequent weld expulsion and large sheet separation.

In parallel with the experimental efforts, the coupled finite element modeling procedures described above were also used to study the effects of electrode combinations on the fusion zone size and sheet separation. Figure 15 shows the predicted nugget size and sheet separation with the original electrode pair in which radius-faced weld tips were used on both sides. The welding parameters used in the analyses are also indicated in Fig. 15. It is worth mentioning again that different contour scales were used for the steel and the aluminum sides in generating the contour plots to illustrate two fusion zones in one picture. In Figs. 15 and 16, the red areas represent the molten metal and the blue areas represent the base metal. The sharp transition regions between these two colors are the heat-affected zone.

The predicted temperature contour and weld deformation show that this electrode combination generates a rather large sheet separation and a much larger fusion zone on the aluminum/aluminum faying interface. As a result of the large fusion zone and sheet separation, there is a lack of contact pressure confinement at the fusion zone periphery, which suggests a strong tendency for expulsion and metal squeeze-out at those locations. This prediction is consistent with the experimental observations from our initial welding trials using this pair of electrodes, where expulsion frequently occurred. In addition, a ring of softened aluminum was observed being squeezed out from the nugget periphery, and it formed a collar of aluminum outside the nugget area on the aluminum/aluminum faying interface, which further aggravated the final sheet separation.

In order to better contain the molten metal on the aluminum side, a larger contact area on the faying interface needed to be established. This was achieved by machining off the radius portion of the electrode tip on the steel side. Using the same welding parameters, the predicted fusion zone size at the end of the welding cycle for this electrode combination is shown in Fig. 16. Compared with the fusion zone shape and contact area at the aluminum/aluminum interface with the results in Fig. 15, this new pair of electrodes offers much larger contact area to contain the molten aluminum and therefore should reduce the occurrence of weld expulsion. Indeed, the experimental welding trials validated this prediction. Therefore, this pair of electrodes with modified electrode tip on the steel side was used for further weld sample fabrication.

Conclusions

The objective of this research was to investigate whether spot welding between aluminum and steel can be achieved using a transition material. Both experimental welding trials and finite element simulations were used in determining the optimal electrode combinations and welding parameters. The nugget formation process was then examined using consecutive metallurgical cross-sectioning and finite element analyses. It was found that two distinct fusion zones formed during the spot welding process of aluminum to steel using a transition aluminum-clad steel strip. The nugget on the steel side is a regular, elliptical weld with dendritic grain structure inside the nugget region. The nugget on the aluminum side is the top half of the elliptical shape. It demonstrated that the incrementally coupled finite element simulation procedure can be used to study the nugget growth kinetics during the welding process. The analysis procedure was also used in rationalizing the welding test results and in selecting the final electrode combinations for weld coupon fabrication.

Together with the results of Part 1 of our study, this study suggests that the aluminum-clad steel transition layer can be used in forming a structural weld between aluminum and steel. Moreover, it can be used as a material transition between the aluminum parts and the steel parts of a vehicle to optimize safety and weight reduction of a particular vehicle design.

Acknowledgments

Pacific Northwest National Laboratory is operated by Battelle for the U.S. Department of Energy under Contract DE-AC06-76RL01830. The Department of Energy Office of Transportation Technology funded this work. The DOE program manager is Dr. Joseph Carpenter, and the USCAR program manager is James Quinn.

References

1. Johnson, J., Theile, R., and Kobeloer, N. 2000. Transition material — characteristics of aluminum-clad strip steels. *Proceedings of the IX Sheet Metal Welding Conference*. October, Detroit, Mich.

2. Chang, H. S., Johnson, G. E., Dickinson, D. W., and Tsai, C. L. 1999. Spot welding aluminum to steel — transition material inserts help to overcome incompatibility. *Practical Welding Today*. May/June.

3. Nied, H. A. 1984. The finite element modeling of the resistance spot welding process. *Welding Journal* 63(4): 123-s to 132-s.

4. Tsai, C. L., Jammal, O. A., Papritan, C., and Dickinson, D. W. 1992. Modeling of resistance spot weld nugget growth. *Welding Journal* 71(2): 47-s to 54-s.9.11997. Weldability analysis of spot welding on aluminum using FEM. *Mathematical Modeling of Weld Phenomena*. Ed. H. Cerjak, pp. 944–966. The Institute of Materials.

7. Dong, P. Li, M. V., and Kimchi, M. 1997. Analysis of electrode wear mechanisms: face extrusion and pitting effects. *Science and Technology of Welding and Joining*.

8. Li, M. V., Dong, P., and Kimchi, M. 1997. Modeling of contact resistance during resistance spot welding. *Proc. 7th Int. Conf. on Computer Tech. in Welding*. Ed. T. Siewert, pp. 423–435. NIST Special Publication 923, U.S. Dept. of Commerce.

9. Sun, X., and Dong, P. 2000. Analysis of aluminum resistance spot welding processes using coupled finite element procedures. *Welding Journal* 79(8): 215-s to 221-s.

10. Sun, X. 2001. Effect of projection height on projection collapse and nugget formation — a finite element study. *Welding Journal* 80(9): 211-s to 216-s.

11. Sun, X. 2000. Modeling of projection welding processes using coupled finite element analyses. *Welding Journal* 79(9): 244-s to 251-s.

12. *ABAQUS/Standard* and *ABAQUS/Explicit* user's manuals, Version 6.3. Hibbitt, Karlsson & Sorensen, Inc.

13. Properties and selections: irons and steels. 1978. *Metals Handbook*, Ninth Ed., Vol. 1. ASM International, Metals Park, Ohio.

14. Properties and selections: nonferrous alloys and pure metals. 1979. *Metals Handbook*, Ninth Ed., Vol. 2. ASM International, Metals Park, Ohio.

15. *High-Temperature Property Data: Ferrous Alloys*. 1988. Metals Park, Ohio: ASM International.

16. *Physical Constants of Some Commercial Steels at Elevated Temperatures*. 1953. Ed. British Iron and Steel Research Association. London: Butterworth's Scientific Publications.

17. Ford Laboratory Test Method BA 113-07: Welding Acceptance Test for Aluminum.

IIW Annual Assembly Convenes in Japan

The 57th Annual Assembly of the International Institute of Welding (IIW) will be hosted by the Japan Institute of Welding (JIW), at the Osaka International Convention Center, Osaka, Japan, July 11–16, 2004

The IIW is the global body in the science and application of joining technology providing networking and knowledge exchange. Its technical field encompasses the joining, cutting, and surface treatment of metallic and nonmetallic materials by such processes as welding, brazing, soldering, thermal cutting, thermal spraying, adhesive bonding, and microjoining and embraces allied fields including quality assurance, nondestructive testing, standardization, inspection, health and safety, education, training, qualification, design, and fabrication.

The United States will be represented by members of The American Council of the IIW, which is the United States' national committee for the IIW. As a comprehensive forum for professional cooperation through interaction with representatives of the other 41 member countries, the IIW provides a unique opportunity for sharing technological innovations and can be an important avenue for international trade.

For further information on the IIW and membership on The American Council, please contact Andrew Davis, Managing Director, Technical Services Division, at *adavis@aws.org*, (305) 443-9353, ext. 466; or Gricelda Manalich, IIW Coordinator, at *gricelda@aws.org*, (305) 443-9353, ext. 294. Further information, including registration forms, can also be obtained from the IIW Secretariat in Paris, France, at *www.iiw-iis.org*.

An Investigation on the Effects of Gases in GTA Welding of a Wrought AZ80 Magnesium Alloy

Argon, helium, and nitrogen, some enriched with hydrogen, were investigated for their effects on melting and penetration

BY M. MARYA, G. R. EDWARDS, AND S. LIU

ABSTRACT. Magnesium alloy components are frequently gas tungsten arc welded despite magnesium's high thermal diffusivity. Gases such as argon, helium, and nitrogen — enriched or not with hydrogen — have been investigated to determine if melting, and in particular weld penetration, can be increased. Images of the arcs, voltage readings, dimensions, defects, and microstructure of weld fusion zones have been examined. Due to a greater first ionization potential, helium increased the constant-current voltage and created more melting than argon. With diatomic gases such as nitrogen and hydrogen, voltage and weld dimensions were even further increased. However, hydrogen caused porosity, and nitrogen interacted with magnesium by leaving a nitride deposit at weld surfaces. While consequences of alloying with nitrogen were probably not disadvantageous, hydrogen pores were of greater concern. Both welding parameters and hydrogen concentration in the arc atmosphere were important in controlling porosity. The two-dimensional heat-flow conditions of fully penetrating welds were capable of eliminating porosity and could make welding with hydrogen additions a possibility to consider.

Introduction

The demand for vehicles with improved fuel efficiency has created greater incentives for the engineering of components of aluminum and magnesium. Among other attractive properties, magnesium alloys have two-thirds the density of aluminum alloys, and their strength-to-weight ratios are greater. However, industrial exploitation of magnesium alloys is still restricted, partly due to magnesium's low formability. To date, magnesium components are mainly cast, but routes are being developed to produce formable magnesium alloy sheets. In the absence of sheet products, welding has been confined to isolated applications (Ref. 1). However, realizing that welding, like forming, would open a whole new range of applications, weldability of magnesium alloys has recently been investigated with a variety of processes, particularly gas tungsten arc welding (GTAW), laser beam welding, and friction stir welding (Refs. 1–5). Of all commercial magnesium alloys, those with aluminum as the primary alloying element are most weldable using any of these three processes (Refs. 2–6). With arc welding processes, lack of weld penetration is generally a limitation of the magnesium alloys. In arc welding with a nonconsumable tungsten electrode (i.e., GTAW), the electric arc is struck by applying a direct current, an alternating current, or a current with other waveforms. For magnesium alloys, alternating current offers a major advantage over the direct current to initiate a weld pool, and this advantage is the cathodic cleaning of the magnesia covering the surfaces (Ref. 6). However, compared to direct current where the electrode is negative and operates as a cathode, alternating current lowers the heat input to the base material and produces shallower welds, especially when argon is selected over helium (Refs. 6–8). Here, the addition of a diatomic gas, like hydrogen (H_2) or nitrogen (N_2), to a monatomic gas, like argon (Ar) or helium (He), is proposed to increase the melting of magnesium alloys during GTA welding.

KEY WORDS

Magnesium
Gas
Arc Physics
Fusion Zone Dimensions
Porosity
Phase Stability

While hydrogen and nitrogen have been safely introduced to argon or helium for increasing weld penetration in transition-metal alloys, their use has not been reported for joining magnesium. The magnesium-hydrogen phase diagram (Ref. 9) shows that hydrogen solubility in magnesium decreases by about 25 wt-% when magnesium solidifies at 650°C. This characteristic alone indicates that hydrogen accumulates rapidly at the solid/liquid interface, and if hydrogen partial pressure is sufficient, gaseous bubbles will form. In general, pores appear in welds when the ratio of solubility at the average pool temperature and at the melting temperature (either in the liquid phase or solid phase) is high (Refs. 8–10). The concentration of a gas absorbed by the weld pool depends upon its partial pressure in the the arc atmosphere and the temperatures at the weld pool surface. Knowing that surface temperatures of GTA weld pools must approach the material's boiling temperature (1090°C for magnesium) and that pure magnesium solidifies at 650°C, Sievert's law can be applied to estimate the propensity of hydrogen to generate porosity. For liquid magnesium (Ref. 10), Sievert's law can be represented as:

$$[H] = 608 \cdot p^{1/2} e\left(-\frac{24{,}400}{RT}\right) \qquad (1)$$

where [H] is the total volume of hydrogen in the liquid metal in mL/100 g, p is the partial pressure of hydrogen in the arc expressed in atmospheres, R is the universal gas constant (8.31 $J \cdot mol^{-1} \cdot K^{-1}$), and T is molten metal temperature (in kelvin). Equation 1 predicts that the equilibrium solubilities at 1-atm hydrogen pressure for 1090° and 650°C are 70.6 and 25.3 mL/100 g, respectively, as validated by independent measurements by Fromageau et al.

M. MARYA, G. R. EDWARDS, and S. LIU are with the Center for Welding, Joining, and Coatings Research, the G. S. Ansell Department of Metallurgical and Materials Engineering, Colorado School of Mines, Golden, Colo.

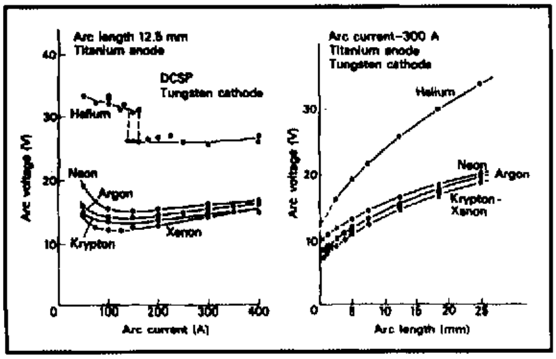


Fig. 1 — Arc voltage with various monatomic gases as a function of arc current and arc length during direct current electrode negative (DCEN) gas tungsten arc (GTA) welding of carbon steel (Ref. 7).

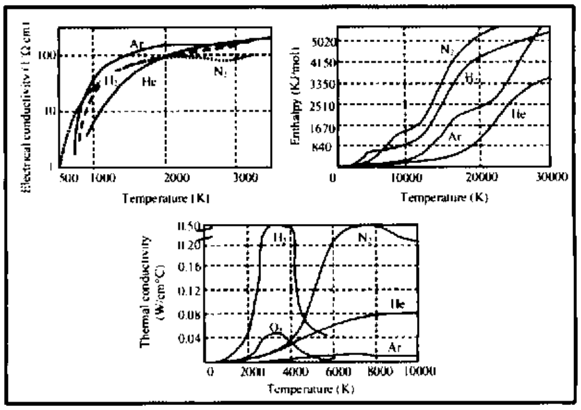


Fig. 2 — Electrical conductivity and enthalpy (Refs. 7, 20), and thermal conductivity of several pure ionized gases as a function of temperature (pressure is one atmosphere) (Refs. 7, 19).

(Ref. 11). It follows that hydrogen solubility in solid magnesium at the melting temperature, being about 25% less, is in the vicinity of 19 mL/100 g. Although all these values of solubility will be affected by welding, the proposed estimates using equilibrium conditions are valuable to assess hydrogen potency in porosity formation. Equation 1 shows that the pressure required to keep all the hydrogen gas in solution is $(70.6/25.3)^2 = 7.8$ atm when the pool cools from 1090° to 650°C. For gas bubbles to form, which requires that the amount of dissolved hydrogen exceeds the equilibrium solubility at 1-atm hydrogen pressure, the hydrogen partial pressure at 1090°C must be greater than $1/7.8 = 0.13$ atm (i.e., hydrogen concentration must exceed 13% of the arc atmosphere). This calculation shows that the minimum concentration of hydrogen to induce porosity is significant in magnesium. A comparable calculation for aluminum would show that hydrogen partial pressure is smaller by about two orders of magnitude (Ref. 8). This prediction that hydrogen potency to produce pores in magnesium is far less than in aluminum has been verified by comparing data from various investigators (Refs. 12, 13). However, no research to date has established if hydrogen is always detrimental to magnesium during welding. Similarly, the effects of nitrogen have not been reported. Further, since the magnesium-nitrogen phase diagram has not been entirely established (Ref. 14), it is even difficult to predict the potential effects of nitrogen on the weld fusion zone. Based upon work of Aizawa et al. on plasma sprays (Ref. 15), an alloying with nitrogen may be expected for the weld region, and this alloying could in fact result in an improved corrosion resistance. However, the literature does not tell how nitrogen will influence the arc and especially how nitrogen compares to the other gases under comparable welding conditions.

This research pursues complementary objectives: 1) determine if diatomic gas additions can increase GTA weld penetration in magnesium alloys, 2) determine if hydrogen can be introduced to argon or helium, and 3) investigate the role of nitrogen during arc welding of magnesium. In this paper, the physical properties of gases are first discussed, followed by a description of the experimental procedure and results. The discussion of the results first addresses the effects of gases on the arc, and then their effects on melting, defect formation, and fusion zone microstructure.

Physical Properties of Gases

In GTA welding, the voltage established between the nonconsumable tungsten electrode and the base material is normally self-regulated to deliver a constant current. With the current being approximately invariant, Ohm's law indicates that voltage and electrical conductance of the arc are inversely proportional. The conductance of the arc is a function of its dimensions, particularly the distance between the electrode and the base material (i.e., the arc length), as well as the local values of its electrical conductivity. As a simple definition, the electric arc is a sustained discharged plasma with physical properties that relate mainly to the ionization of its gaseous species. In the arc, electrical conductivity is greater where electrons are generated at low temperatures. A monatomic gas, thus a gas only consisting of unbound atoms in their gaseous state, has a high electrical conductance when its first ionization potential (i.e., the energy barrier to release a first electron) is small. The lower the gas first ionization potential, the smaller is the voltage necessary to produce a given current, and the smaller are the energy and thus the average arc temperature. Figure 1 (Refs. 7, 16) demonstrates that voltage across a GTA arc decreases noticeably when gases with a small first ionization potential, as found going down the periodic table, are selected. Helium, because of its high first ionization potential (24.6 eV), conducts the current least and consequently requires the greatest voltage of all monatomic gases to carry a given current. Comparatively, arc voltages with argon and particularly xenon are smaller as explained by the smaller first ionization potential of these two monatomic gases (15.6 eV for argon and 12.1 eV for xenon). Since the current carrying capability of the arc depends upon its electron population, itself dependent upon the temperatures established within the arc, any properties that would affect arc temperatures are relevant to GTA welding. Thermal conductivity and specific heat are therefore two important properties that must be considered to understand the effects of the various gases selected for this study.

For monatomic gases, electrical conductivity, heat capacity, and thermal conductivity all increase when first ionization potential decreases (Refs. 7, 16). For diatomic gases, the physical properties are strongly affected by the dissociation that precedes the thermal ionization of the gaseous unbound atoms (Refs. 7, 18–20). The dissociation energy of diatomic nitrogen is greatest (9.8 eV), followed by that of diatomic oxygen (5.1 eV) and diatomic hydrogen (4.5 eV) (Refs. 7, 19). Figure 2 (Refs. 7, 20) compares physical properties of argon, helium, and several diatomic gases. The graph at the top-left corner is a semilog representation of the electrical conductivity as a function of temperature. It is seen that electrical conductivity of argon is considerably greater than that of helium at temperatures less than about 3000 K. This is a direct consequence of argon's smaller first ionization potential. However, at higher temperatures, the population of charged particles (i.e., positive ions and electrons) rapidly levels off in both gases (Refs. 7, 16) and the electrical conductivities become comparable, at least until secondary ionization takes place. Compared to argon, diatomic nitrogen and diatomic hydrogen exhibit smaller electrical conductivities. Beyond 2000 K, their conductivities are also less than that of helium. Of the properties seen in Fig. 2, enthalpy and thermal conductivity of diatomic gases differ most significantly from those of argon and helium. The top-right corner graph reveals that enthalpies of the diatomic gases are considerably greater than those of argon or helium. As a direct consequence, raising the temperature of these gases will require more energy than with either argon or helium, regardless of the extents of the gas ionization. Diatomic gases also extract thermal energy more efficiently, as well-depicted by the lower graph. The fact that thermal conductivity of hydrogen and oxygen rapidly decrease after 4000 K indicates that a large fraction of the diatomic molecules have already split into single atoms. Due to a substantially greater dissociation energy (9.8 eV), electrical conductivity of nitrogen does not drop before 7000 K. All the property differences depicted in Fig. 2 between argon, helium, nitrogen, and hydrogen will influence GTA welding, particularly the voltage necessary to stabilize the arc, the heat that this arc generates, and thus the heat input to the base material.

Experimental Procedure

To study the effects of monatomic and diatomic gases using a limited number of experiments, only five gases were selected. They were commercially pure argon, argon with 1% and 6% hydrogen, helium with 1% hydrogen, and nitrogen with 1% hydrogen. With the first three gases, the influences of hydrogen additions could be investigated. Further, considering 1% hydrogen, the effects of argon, helium, and nitrogen could be compared. However, a direct comparison of the two diatomic gases, hydrogen and nitrogen, could not be made. In addition to five gases, three currents (30, 40, and 50 A) and four arc lengths (0.5, 1.0, 2.0, and 4.0 mm) were used, leaving a total of 60 bead-on-plate welding experiments and, with two cross sections per weld bead, 120 cross sections to examine.

Bead-on-plate gas tungsten arc (GTA) welding was completed using constant current conditions, a travel speed of 100 mm/min, and a gas flow rate of 40 L/min. A set of 2-mm-diameter tungsten electrodes was prepared with a typical tip angle of 60 deg. When tip wear was observed, the tungsten cathodes were replaced to guarantee consistent and comparable experimental results. A digital multimeter with a precision of 0.01 V and a digital camera with a dark filter were utilized to investigate contributions of the various gases on the arcs. Visual characteristics of the arc as well as voltages, measured at the welding power supply, were captured. This voltage, although not measured directly across the arc, is closely related to the arc voltage, and was therefore sufficient to compare the various gases quantitatively. Later in the paper, this voltage is referred to as welding voltage.

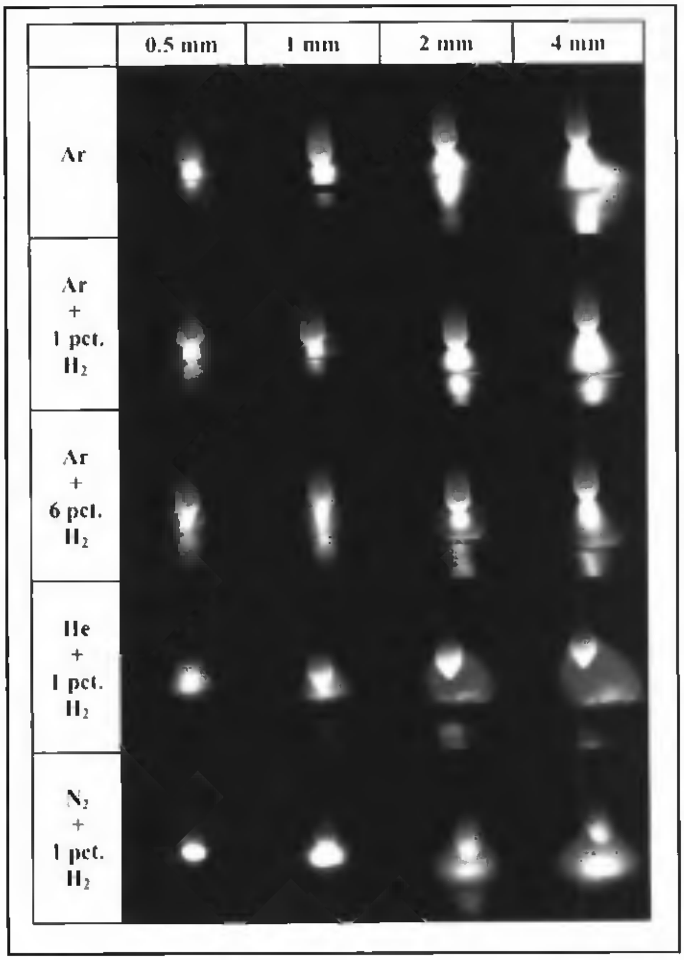


Fig. 3 — Digital images of the arc produced with several combinations of shielding gases and arc lengths (current: 30 A).

All the welding specimens were fabricated from a single 180-mm-diameter extruded AZ80 magnesium alloy plain cylinder. The selection of a wrought alloy as opposed to a cast alloy guaranteed that the initial material did not contain any pores, in particular hydrogen pores. The AZ80 alloy of this study had approximately 8.50 wt-% aluminum and 0.60 wt-% zinc, as estimated using glow discharge spectroscopy. In this investigation, the extruded cylinder was sliced into 3.8-mm-thick circular plates, which were then ground to exhibit smooth and shiny surfaces. Depending upon welding parameters and gases, partial and fully penetrating welds were obtained. On each plate, six bead-on-plate welds were deposited parallel to each other. No fixtures were applied during welding, as the plates were simply positioned on top of a flat and bulky aluminum support, which also eliminated the need for a secondary root shielding.

After bead-on-plate welding, the specimens were cross-sectioned, ground, and polished with silicon-carbide papers and diamond pastes (6 and 1 μm), etched with 2% nital, and examined with a stereomicroscope at magnifications from 10 to 40 ×. Dimensions of fusion zones (penetration and width) were measured and porosity (if encountered) was quantified using conventional image analyses based on area measurements. Optical microscopy, scanning electron microscopy, electron dispersive spectroscopy (EDS), X-ray diffraction (XRD), and thermodynamic calculations were also used to complement the analyses of the weld fusion zones.

Results and Discussion

Arc Morphology

Figure 3 displays digital images of the arc produced using various combinations of gases and arc lengths, as the arcs were viewed from the side. For the purpose of photographing the arc, the welding current of 30 A was preferred. Of the three selected currents, this current generated

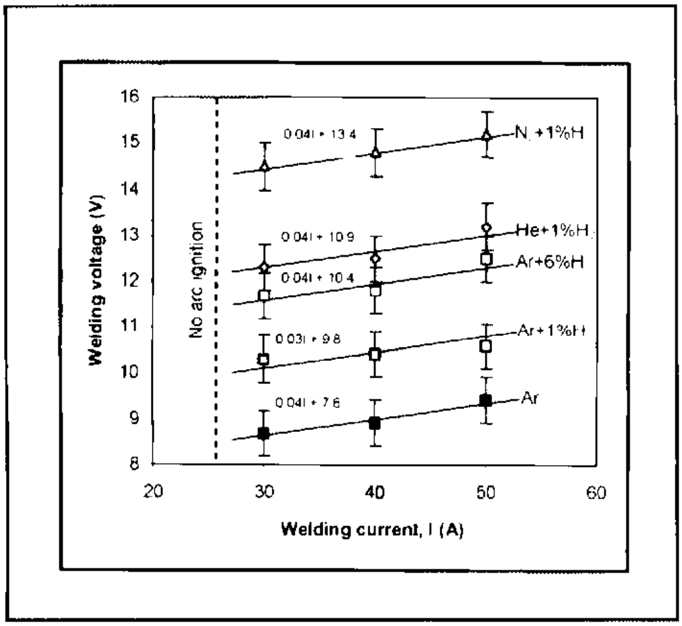


Fig. 4 — Voltage vs. current characteristics for the five gases (arc length: 0.5 mm).

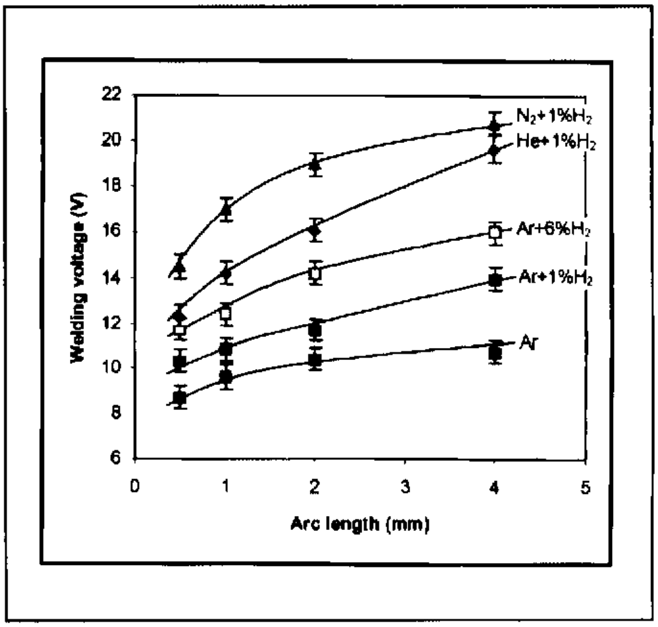


Fig. 5 — Welding voltage vs. arc length for the five selected gases (current: 30 A).

the least heat, and therefore minimized the brightness of the arc on the captured images. With a few exceptions, the images exhibited good contrast and they were clear enough for analyses.

By first examining the images of Fig. 3 from top to bottom, the influence of each gas can be examined. The color of the arc was found to vary with the composition of the gases. Since temperatures, radiation wavelength, and color are related, as proven by emission spectroscopy, the colors captured on the images were important features to examine. Behind the dark filter, the arcs with pure argon were yellow. The additions of hydrogen caused the yellow arcs of argon to become increasingly green. The substitution of argon by helium and nitrogen produced entirely green arcs. The arcs were also considerably larger. A comparison of the various argon arcs reveals that hydrogen did not broaden the arc, as could have been expected from the arc colors observed with helium and nitrogen. On the contrary, the argon-hydrogen arcs appeared as if they were constricted, which was particularly apparent by examining the brightest region of the 2.0- and 4.0-mm arcs. Based upon this observation, the possibility was raised that fusion zone penetration might be improved by the use of hydrogen additions, likely through an increase in current density and thus Lorenz electromagnetic force.

The observation that arcs were narrower in the presence of hydrogen is consistent with Fig. 2, where both thermal conductivity and specific heat are significantly increased by hydrogen, especially at the low temperatures where hydrogen is still in its diatomic form. In the arc periphery, where temperatures are lower than in the arc central region, hydrogen is therefore most effective in restraining the arc from expanding. In the case of the helium enriched with 1% hydrogen, the arcs did not appear to be as bright as the argon arcs. The arcs were also distinctively deflected in the direction opposite to the displacement of the tungsten electrode. This arc deflection was most evident when the arcs were longer, as seen by comparing the pictures of Fig. 3 from left to right.

Compared to the other gases, the arcs produced with the nitrogen-rich gas were noticeably different. Figure 3 does not indicate that these arcs were deflected. On the contrary, they were quite symmetrical, and therefore the direction of electrode displacement, thus arc deflection, could not be determined, as was found with the other gases. As shown in Fig. 3, the digital images of the arcs with the nitrogen-rich gas were also all blurry irrespective of the welding parameters. These hazy images were attributed to the heavy fumes encountered when welding was conducted with this diatomic gas. Figure 3 shows that the images corresponding to arc lengths of 0.5 and 1.0 mm exhibited the brightest features. This observation could be indicative of exceptionally high arc temperatures, and most probably high welding voltages, since these two characteristics are largely related, as explained previously.

Voltage

Figure 4 shows five voltage-current lines, all constructed from average voltage readings with the different gases and all accompanied with a least-square root equation. The error bars indicate that voltage readings were dispersed within a range that represented about 10% of their values. Due to scatter, the voltage measurements made with the different gases occasionally overlapped. However, the data points could still be properly fit using five distinct straight lines. These five separate lines are proof that electrical conductance (defined as the ratio of current over voltage) for the various arcs differed noticeably. Also, the fact that the five lines were parallel (with a constant slope of 0.04 V/A) indicates that voltage and current varied at a constant rate, and this rate did not depend on the gas.

Regardless of the current, the arcs with pure argon exhibited the smallest voltages, followed by the arcs with argon containing 1% and 6% hydrogen, respectively. On average, the addition of 1% hydrogen increased voltage by about 15% over that of argon, and the addition of 6% hydrogen doubled this voltage increase. The helium enriched with 1% hydrogen increased the voltage even further, leading to an average 25% increase in voltage over the 1% hydrogen-enriched argon gas, and about 40% over the pure argon gas. With nitrogen as a substitute to argon and hydrogen concentration still at 1%, the voltage was increased by 45% beyond that of

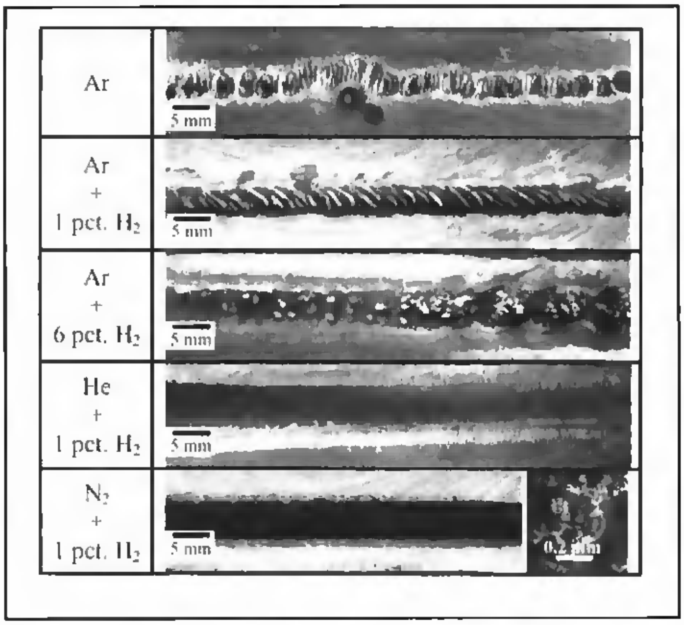


Fig. 6 — Optical macrographs of bead-on-plate welds as seen in top views (current: 30 A, arc length: 4 mm).

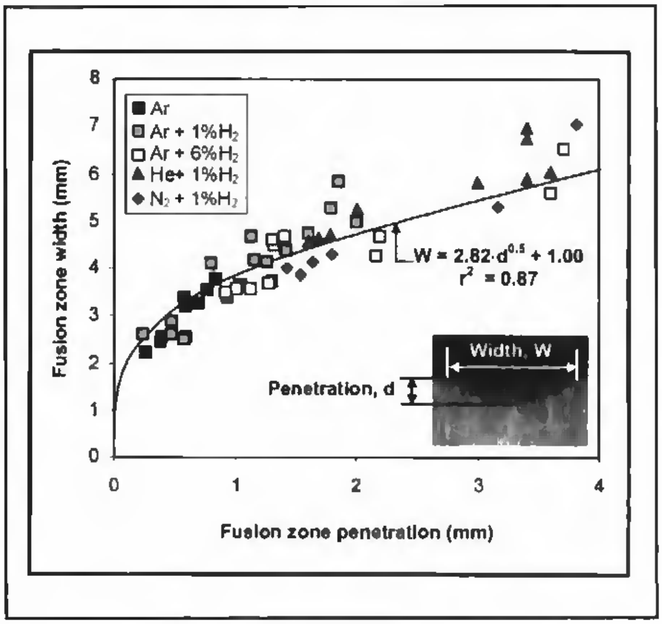


Fig. 7 — Relationship between fusion zone dimensions regardless of gases and welding parameters.

the 1% hydrogen-enriched argon and about 65% over that of the pure argon gas. The dramatic increase in voltage observed with nitrogen compared to argon was well substantiated by Fig. 2, where enthalpy and thermal conductivity of the nitrogen arc considerably greater than those of argon and helium. These characteristics suggest that the elevated temperatures needed to ionize and thus create an electrically conductive arc gap require more heat generation with nitrogen. Such a heat generation, and thus heat input to the material, was confirmed by the voltage readings, the fumes observed during welding (which explained the hazy images seen in Fig. 3 with nitrogen), and the bright spots revealed in the same images.

Figure 5 directly complements the set of photographs of Fig. 3 by also describing the effects of both arc length and gas. In agreement with Fig. 3, the voltage (thus the heat generated by the arc) increased with the arc length. As in Fig. 4, the voltage was minimum with argon and increased with the other gases, as given by the sequence shown from top to bottom in Fig. 3. Figure 5 also demonstrates that voltage reached about 21 V when electrode and base material were 4 mm apart, and when 1% hydrogen was added to nitrogen. When examining the effects of arc length, note that voltage appeared to increase at a greater rate in the presence of short arcs.

With both Figs. 4 and 5, the effects of hydrogen could be further analyzed. In both figures, the argon gas containing 1% hydrogen is located about halfway between the pure argon and the argon with 6% hydrogen. This result indicates that the first 1% hydrogen was about as effective in increasing the voltage as the 5% hydrogen that was subsequently added. Consequently, the arcs produced with hydrogen were conceivably sustained with both a limited dissociation of the diatomic molecules and a slight ionization of the hydrogen atoms. If that is the case, the major contribution of hydrogen would be to cool the arc central region, which would be made possible by increasing thermal conductivity and specific heat of the arc atmosphere.

Weld Fusion Zone Morphology

Figure 6 reproduces optical macrographs of five bead-on-plate welds for which the arcs were presented in the last column of Fig. 3. The welds gathered in Fig. 6 have striking differences. First, starting with the weld made with argon, the presence of transverse striations at its surface as well as frequent lateral deviations suggest that the heat input to the base material was unsteady and insufficient to form a stable and penetrating weld pool. In contrast, the introduction of 1% hydrogen to argon clearly improved arc stability, as the welds were straight and rather indistinguishable from beginning to end. Since the striations at the weld surface were still present, melting also probably occurred within a shallow depth under the surface. However, with an addition of 6% hydrogen, the welds were distinctly wider, as expected from the voltage measurements presented previously. With 6% hydrogen, spherical-like protrusions, perhaps representing subsurface pores caused by the rejection of hydrogen during solidification, also became visible. When helium was replaced by argon, the widths of the welds were further increased. The surface of the welds was also smooth, a condition that signaled the presence of lesser defects. If that was indeed the case, the 1% hydrogen added to helium could be advantageous. When nitrogen was selected as replacement to argon or helium, weld surface looked noticeably different. As seen in Fig. 6, the coloration of the nitrogen-rich welds was darker. Closer examination by scanning electron microscopy revealed that an agglomerate of fine particles, as shown by the inset image, covered the entire weld surface. Such proof of chemical interactions between the weld fusion zone and nitrogen will be further developed later where the bulk of the fusion zone will be examined in great detail.

Relationships between penetration and width of fusion zones were searched to further characterize the morphology of the produced bead-on-plate welds. As shown in Fig. 7, widths, as seen in Fig. 6, and penetration of the fusion zones were mathematically related irrespective of the gases. Since dimensions of fusion zones were at a first estimate interdependent, the results of Figs. 6 and 7 infer that fusion zone penetration with the hydrogen additions was greater than those made with pure argon, and the same ranking of gases seen for the

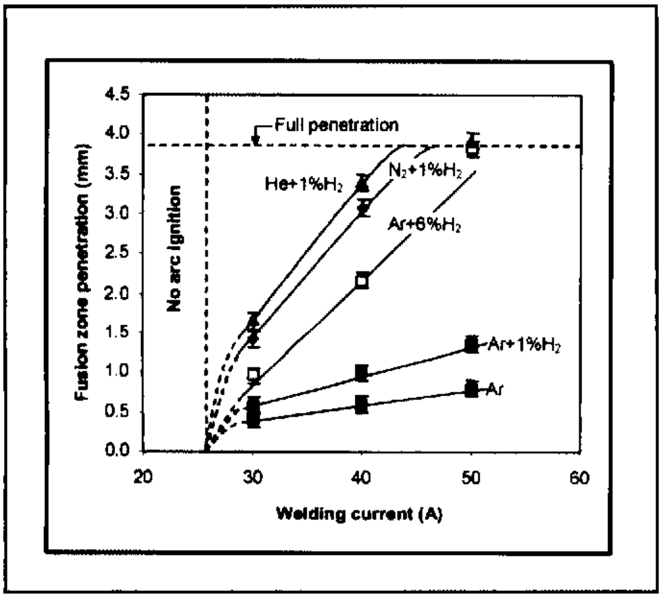


Fig. 8 — Fusion zone penetration vs. welding current for the five gases (arc length: 0.5 mm).

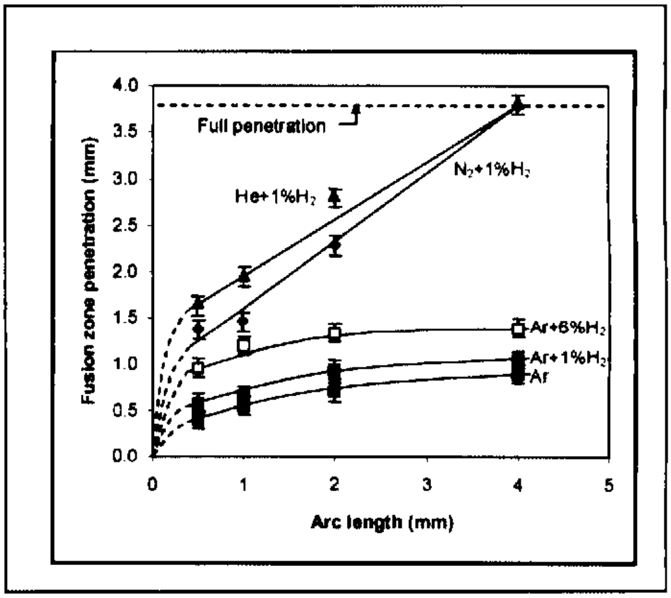


Fig. 9 — Fusion zone penetration vs. arc length for the five gases (current: 30 A).

voltage probably applied to the fusion zone penetration.

Figures 8 and 9 specifically show how fusion zone penetration with the different gases varied as a function of arc length and current. Despite scatter caused by measurements on different cross sections, the scatter was small enough to guarantee excellent comparisons. Both Figs. 8 and 9 appear to substantiate the ranking earlier established with the voltage readings, except that the helium with 1% hydrogen gas produced slightly greater voltages than the 1% enriched nitrogen gas. As found for the voltage, fusion zone penetration increased with both arc length and current. In contrast with voltage readings, however, the slopes for each line seen in Figs. 8 and 9 varied differently from one gas to the other. The argon line exhibited the smallest slope, followed by that of the argon with 1% hydrogen and that of the argon with 6% hydrogen. The lines for the helium and nitrogen gases were noticeably steeper, although precise values for their slopes could not be determined from the two data points only available. Figures 4, 7, and 8, among others, clearly reveal that enlargements of the fusion zones are to some extents related to the voltage readings. Despite significant scatter, Fig. 10 confirms that such a correlation between fusion zone penetration and voltage existed. Figure 10 not only describes the effects of both voltage and current on fusion zone penetration, it also clearly shows that differentiating between gases becomes practically irrelevant when the voltage is considered.

Figures 8–10 also reveal that the fusion zones left by the nitrogen enriched with 1% hydrogen were slightly smaller than those anticipated from the voltage readings — Figs. 4, 5. An explanation can perhaps be found by considering the distinct arc profiles seen in Fig. 3 for the nitrogen-rich gas. With nitrogen as a substitute for argon or helium, both the arcs and the fusion zone penetrations indicate that more heat must have been dissipated into the surrounding of the arc. In other words, nitrogen likely created less energy density than the other gases, although overall heat generated within the arc was greater, as indicated by voltage. This possibility is also strongly suggested by Fig. 2, which indicates that nitrogen had the greatest electrical conductivity of all the gases, in addition to a particularly high enthalpy.

Similar to the effects of nitrogen, the effects of the hydrogen concentration added to argon could also be further examined. As mentioned earlier for the voltage, the line for the 1% hydrogen argon gas was located approximately halfway between the lines of the pure argon and the argon with 6% hydrogen. Figures 8 and 9 indicate that the contribution of 1% hydrogen on the fusion zone dimensions was closer to that of pure argon than to that of the argon with 6% hydrogen. This result, which might appear counterintuitive at first, could also simply suggest that the heat flow had changed, as voltage started to exceed some critical values from which heat flow quickly changed from three-dimensional to two-dimensional (Refs. 6, 22, 23). Figure 10 confirms that fusion zone penetration and voltage were not proportional to each other, but that fusion zone penetration appeared to increase at a greater rate with the voltage.

Weld-Gas Interactions

The cross-sectional views of Fig. 11 demonstrate that hydrogen is a source of porosity, as theorized previously, whereas nitrogen created weld fusion zones with two distinct regions, which for convenience were designated as FZ1 and FZ2. The first region, FZ1, possessed the normal composition and microstructure of welds made with the monatomic gases, and therefore will not be described in this article. However, the second region found in the upper part of the weld fusion zone, FZ2, revealed an unusual microstructure, as already detected in Fig. 6. In this section, interactions between the AZ80 magnesium alloy and gases like hydrogen and nitrogen are discussed.

Effects of Hydrogen

As suggested in Fig. 6 with the weld produced with 6% hydrogen, Fig. 11 confirms that large spherical pores were encountered when hydrogen was present in the arc atmosphere. However, based upon Figs. 6 and 11, the size and perhaps amount and concentration of pores appeared to be influenced by the concentration of hydrogen, the gas that is mixed with hydrogen, as well as the current that is selected. In this section, the influence of welding parameters is therefore pri-

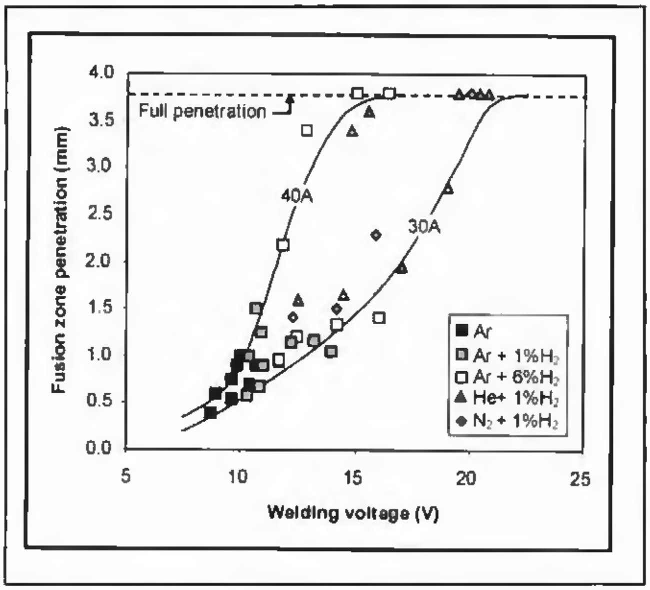


Fig. 10 — Fusion zone penetration vs. welding voltage at two current levels (40 and 50 A), as measured using arc lengths from 0.5 to 4.0 mm

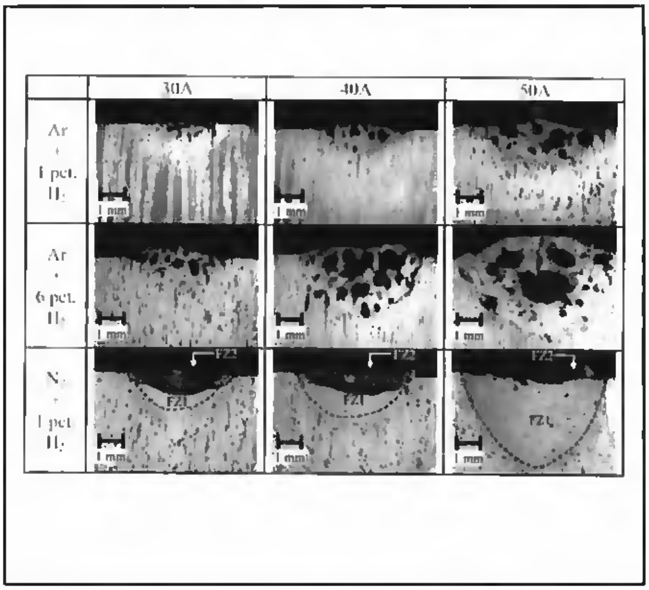


Fig. 11 — Optical micrographs of bead-on-plate welds produced with various combinations of current and gas (arc length: 0.5 mm).

mary to discuss. Since porosity is the result of a nucleation and growth process depending upon mass transport and solubility of hydrogen (Ref. 21), the effects of process parameters that affect hydrogen transport, particularly the arc length and the current, were studied. Further, relations with weld fusion zone morphology, already discussed, were searched.

In Fig. 12, the concentration of hydrogen pores (defined in percent of fusion zone area) at currents of 30 and 40 A is graphically represented as a function of the arc length for each of the hydrogen-enriched gases. Due to variations between weld cross sections, the data were considerably dispersed. While the contribution of current to porosity could not be established using the two currents shown in Fig. 12, a clear correlation between pore concentration, arc length, and hydrogen concentration was found. Figure 12 shows that porosity decreased when the arc length was increased and when hydrogen concentration was reduced.

To understand this last result, some of the results already presented must be reviewed. First, recall that voltage stepped up significantly when the arc length was increased (Fig. 5) and that resulted in wider and deeper weld fusion zones — Figs. 7 and 9. Also, full penetration occurred with a shorter arc when the 1% hydrogen-enriched helium gas was used with a current measuring at least 40 A — Fig. 8. When these conditions were satisfied, porosity was reduced to the greatest extent. In fully penetrating welds, and in welds where fusion zone penetration was over two-thirds of the workpiece thickness (Refs. 22, 23), the heat flow could be categorized as two-dimensional. A consequence of two-dimensional heat flow is that cooling rates are typically one to two orders of magnitude smaller (Refs. 4, 6, 8, 22, 23). Based upon Fig. 12, in welds associated to two-dimensional heat flows, the hydrogen dissolved in liquid magnesium had sufficient time to diffuse out of the pool and effectively reduce porosity. The concentration of pores was considerably different when the arc length was reduced. The fusion zone then partially penetrated into the base material (Fig. 9) and established three-dimensional heat flow conditions, where cooling is comparatively faster.

To address the mechanisms of pore formation, pore diameters were measured, and pore size distributions were established for various welding parameters and the 6% hydrogen gas. Figure 13 shows that the nucleation and growth of pores within the liquid pool did not appear to be measurably restricted by the faster cooling of partially penetrating welds. In fact, Fig. 13 shows that the shallow fusion zones produced with the 0.5-mm arcs and the current of 30 A, where heat flow was three-dimensional, included more pores of any sizes than any other welds considered in Fig. 13. In contrast, population and size of pores were considerably less when the heat flow was two-dimensional, as promoted by the 4-mm arc length. Regardless of welding parameters, Fig. 13 reveals that the population in any given pores gradually decreases as their average diameter increases. This trend demonstrates that there was always sufficient hydrogen to nucleate small hydrogen pores regardless of the welding parameters. With both large currents and extended arc lengths (i.e., two-dimensional heat flow conditions), the larger pores were eliminated. Porosity was practically eliminated, not because nucleation and growth of pores were restricted, but because hydrogen could leave the weld pool.

Effects of Nitrogen

Figure 14A–D depicts optical and secondary electron images with EDS and XRD results for the region in Fig. 11 that has been designated as FZ2. This new region demonstrates that a measurable amount of nitrogen had permanently entered the weld, most particularly its upper part, FZ2. In one of two reasonable explanations, nitrogen interacted with the weld pool well before its dimensions reached that of the fusion zone. The presence of nitrogen at the weld pool surface, either in solution or as a nitride layer covering the pool, could explain why hydrogen did not induce porosity. In this situation, the contribution of nitrogen would have been to prevent hydrogen to enter the weld pool. Alternatively, nitrogen could have been dissolved in the entire fusion zone, implying that during solidification, hydrogen would have been gradually rejected by the fast-growing magnesium solid phase. In this second explanation, FZ2 would have formed the last, after the material in FZ1 would have solidified without being effectively influenced by hydrogen or nitrogen. To vali-

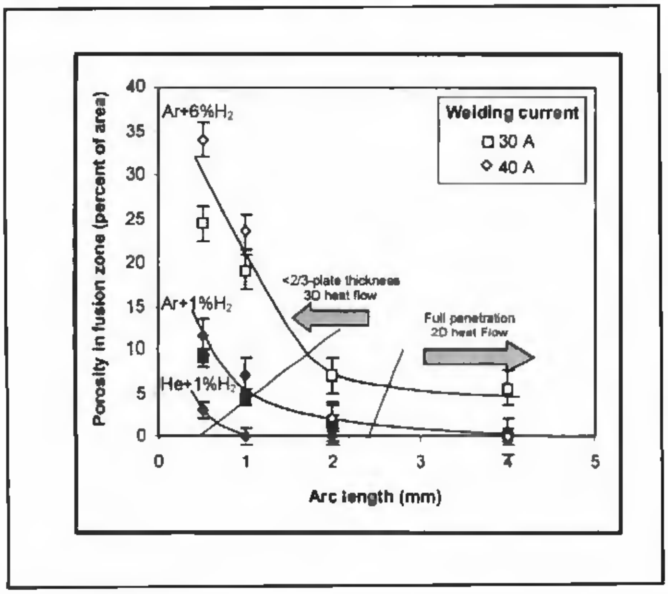
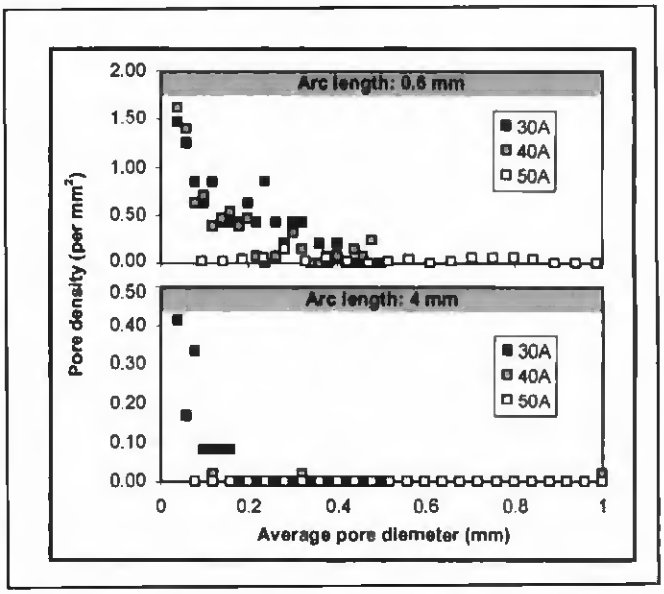


Fig. 12 — Porosity vs. arc length for the hydrogen-containing gases (current: 30 A).



13 — Pore size distribution as a function of arc length and current for the welds produced with the 6% hydrogen-enriched argon gas.

date this second explanation, hydrogen would have been dissolved in restricted amounts in the magnesium liquid phase. Reduced hydrogen solubility, thus low hydrogen partial pressure for pore nucleation, could well explain the absence of pores in all the fusion zones made with nitrogen. Although a complete understanding of the interaction between the magnesium weld pool, nitrogen, and hydrogen might be out of reach given the initial purposes of this study, the data of Fig. 14 are worth examining to better understand weld formation with the nitrogen-rich gas.

Figure 14A and B clearly shows that FZ2 exhibited an uncharacteristic banded microstructure. Such microstructure is as intriguing and puzzling as the presence of the two regions, FZ1 and FZ2. The banded microstructure of FZ2 indicates that nitrogen had entered the weld pool, and had possibly partitioned from a magnesium-rich phase to periodically reach concentrations large enough to stabilize at least one new nitrogen-rich phase. If that is the case, the rejection of nitrogen from a magnesium-rich phase would demonstrate that this magnesium alloy has no solubility for nitrogen. Thermodynamically, this would mean that enthalpy of mixing for a solution comprising magnesium, its alloying elements, and nitrogen is strongly positive, at least when the solution composition is far from that of the new nitrogen-rich phase. If the microstructures of Fig. 14A and B are the result of normal partitioning, the new nitrogen-rich phase must have formed after the magnesium-rich phase, as would be seen in a eutectic transformation. In the presence of a eutectic transformation, the temperatures where the alloyed region, FZ2, would be liquid would be lower than that of the AZ80 alloy (i.e., the material of FZ1). The presence of a lower melting point eutectic mixture, although not validated by other measurements or a complete binary phase diagram (unavailable), is in agreement with the observation that FZ2 is located near the weld upper surface, where it would be expected if it had solidified at last.

However, the fact that nitrogen accumulated along concentric bands, well following the solid/liquid interface, also appears to be untypical of eutectic decompositions, and this last explanation may therefore be invalid. Although no data are provided to support this discussion, the unusual phase morphology seen in Fig. 14A and B may be better explained if capillarity is considered. Rejection of nitrogen from magnesium-rich growing dendrites and transport of nitrogen along the dendrite boundary toward the dendrite tips (driven by capillarity) would be a satisfactory explanation for the banded microstructures of Fig. 14A and B, if supporting data were available. In that particular situation, nitrogen would constantly advance at the same time as the solid/liquid interface until the nitrogen buildup would become enough for a new phase to form and magnesium to continue solidifying beyond the magnesium nitride phase.

Figure 14C presents a typical energy dispersive spectrum for the darker phase seen in the banded microstructure of Fig. 14A and B. The inset secondary electron image, accompanying the energy spectrum, reveals that this new phase is less conductive than magnesium (because brighter in the SEM), and also hard and brittle, as revealed by its granular appearance. The EDS measurements revealed that nitrogen constituted 40 at.-% of this brittle-looking phase, whereas nitrogen was not present in the magnesium-rich phase, as was suspected from previous analysis. These measurements not only confirm that magnesium and nitrogen did not mix, but that nitrogen and magnesium formed a stochiometric compound with 40 at.-% nitrogen. Measurements by XRD, presented in Fig. 14D, identified this phase as the normal magnesium nitride phase, Mg_3N_2. Compared to other nitrides, magnesium nitride could have been expected. Of the elements present in an AZ80 alloy (i.e., magnesium, aluminum, and zinc), magnesium's interaction with nitrogen is the strongest, as indicated by comparing Pauling's electronegativity differences with nitrogen, or comparing free energies of magnesium nitride, aluminum nitride, and zinc nitride.

To determine when during welding nitrogen interacted with magnesium, thermodynamic calculations of the equilibrium state of an equi-molar mixture of magnesium, nitrogen, and hydrogen were conducted. Although the proposed stochiometry is likely different from those found in the weld, results of this calculation were sufficient to incorporate temperature in the analysis. Results of the thermodynamic calculation are graphi-

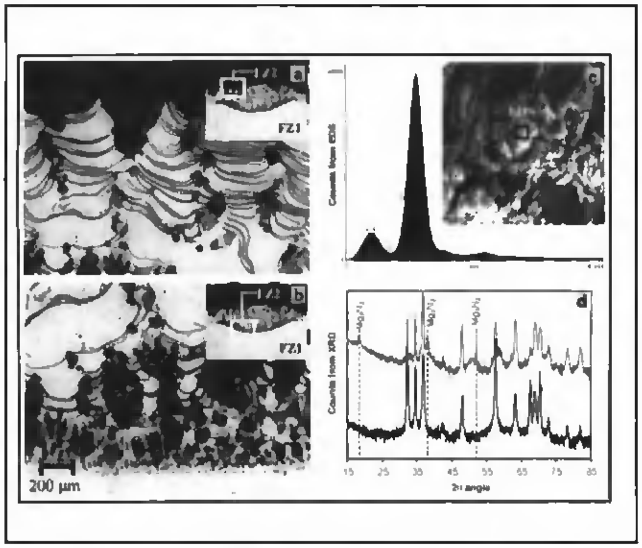


Fig. 14 — Microstructures of the FZ2 region shown in Fig. 11. A and B — Optical micrographs; C — secondary electron image with an EDS spectrum; D — X-ray diffracted intensities of the surface of a weld made with nitrogen enriched with 1% diatomic hydrogen gas.

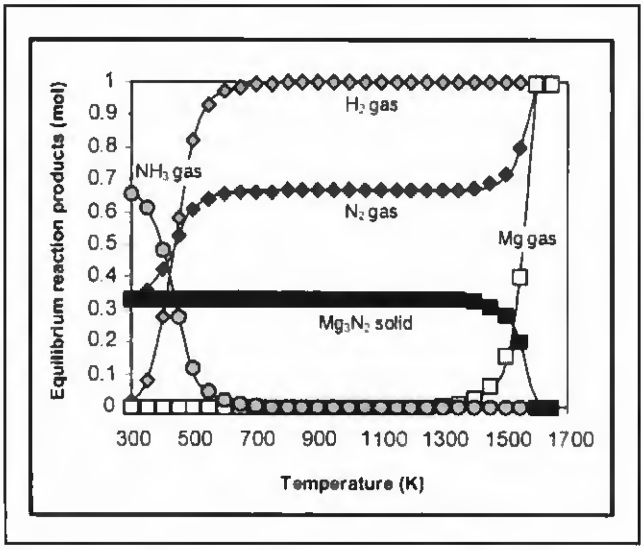


Fig. 15 — Equilibrium products of the equi-molar reaction between magnesium, hydrogen, and nitrogen as a function of temperature..

cally represented as a function of temperature in Fig. 15. In this figure, it is confirmed that the magnesium nitride phase, Mg_3N_2, was the most stable equilibrium product. However, it is also shown that the Mg_3N_2 phase formed at much higher temperatures than anticipated (about 1500 K), and certainly at temperatures where magnesium was still in a gaseous state. This new result therefore strongly indicates that some unknown fraction of the magnesium nitride seen in Fig. 14 had formed in the arc atmosphere before condensing on top of the weld. Consequently, the first analysis, suggesting that hydrogen was prevented from entering the weld pool because of nitrogen at the weld surface, is validated. This new result still does not mean that the second explanation, invoking the nitrogen partitioning, is invalid. It simply means that understanding weld pool formation in the presence of nitrogen is more complicated than initially thought and requires further research.

Conclusions

The effects of gases, in particular hydrogen and nitrogen, have been investigated with the general objective of increasing melting during GTA welding of magnesium alloys. The following conclusions were reached:

- The weld fusion zone dimensions, particularly the penetration (Fig. 7), were increased with gases having a high first ionization potential, because voltage and thus heat input (under a constant current condition) were increased — Figs. 4, 5. Helium, due to its high first ionization potential (24.5 eV), produced deeper fusion zones than argon (15.9 eV).
- When 1% hydrogen was added to either argon or helium, the fusion zones were more penetrating than with only the monatomic gases. Also, nitrogen substituted for either argon or helium, generated even more melting, although its first ionization potential is less than that of either argon or helium. The properties of diatomic gases (Fig. 2), particularly enthalpy and thermal conductivity, could well explain the increased voltage and penetration observed with these gases — Figs. 4, 5.
- Despite desirable increase in melting, hydrogen was also a powerful source of porosity — Fig. 13. However, porosity could be prevented by establishing fully penetrating welds, where heat flow is two-dimensional. Due to a slower cooling than in partial-penetration welds, pores could nucleate, grow, and leave the weld pool.
- Regardless of the welding parameters, nitrogen stabilized a second phase near the weld surface — Fig. 14. Although examined in this paper, the interaction between magnesium and nitrogen is not yet well understood.
- Minor additions of hydrogen to argon or helium could be recommended to increase melting. With nitrogen, the properties of the nitride layer must be further investigated.

Acknowledgments

The authors acknowledge Visteon Automotive Systems (Dearborn, Mich.) for the funding to support graduate-level magnesium welding studies. Because part of this work was achieved at CSM as an undergraduate welding project, the authors acknowledge the technical support of the 2002 welding metallurgy class.

References

1. Friedrich, H., and Schumann, S. 2000. The second age of magnesium — research strategies to bring the automotive industry's vision to reality. *Proceedings of the Second Israeli International Conference on Magnesium Science and Technology*, Beer Sheva, Israel: Magnesium Research Institute, pp. 9–18.

2. Stern, A., and Munitz, A. 1999. Partially melted zone microstructural characterization from gas tungsten-arc bead-on-plate welds of magnesium AZ91 alloy. *Journal of Material Science Letters* 18: 853–855.

3. Weisheit, A., Galun, R., and Mordike, B. L. 1998. CO_2 laser beam welding of magnesium-based alloys. *Welding Journal* 77 (4): 149-s to 154-s.

4. Marya, M., Edwards, G. R., Marya, S. K., and Olson, D. L. 2001. Fundamentals in the fusion welding of magnesium and its alloys. *Proceedings of Seventh International Symposium of the Japan Welding Society on Today and Tomorrow in the Science and Technology of Welding and Joining*, Ed. T. Ohji. Tokyo, Japan: Japan Welding Society.

5. Zhao, H., and DebRoy, T. 2001. Pore formation during laser beam welding of die-cast magnesium alloy AM60B — mechanism and remedy. *Welding Journal* 80(8): 204-s to 210-s.

6. *ASM Handbook*, Vol. 6, *Welding*,

Brazing and Soldering. 1993. Materials Park, Ohio: ASM International.

7. Lancaster, J. F. 1984. *The Physics of Welding*, Second Edition. U.K.: Pergamon Press.

8. Lancaster, J. F., 1999. *Metallurgy of Welding*, Sixth Edition: Abington, Cambridge, U.K.

9. Baker, H.,and Okamoto, H. 1992. *ASM Handbook*, Vol. 3, *Alloy Phase Diagrams*. Materials Park, Ohio: ASM International.

10. Popovic, Z. D., and Piercy, G. R. 1975. Measurement of the solubility of hydrogen in solid magnesium. *Metallurgical Transactions* 6A(10): 1915–1917.

11. Fromageau, R., Mairy, C., and Tzanétakis, P. 1980. Hydrogen dissolution in magnesium: a resistometric study under pressure. *Scripta Metallurgica* 14: 395–398.

12. Saperstein, Z. P., Prescott, G. R., and Monroe, E. W. 1964. Porosity in aluminum welds. *Welding Journal* 40(10): 443-s to 453-s.

13. Woods, R. A., 1974. Porosity and hydrogen absorption in aluminum welds. *Welding Journal* 53(3): 97-s to 108-s.

14. Wriedt, H. A. 1988. *Mg-N (Magnesium-Nitrogen), Phase Diagrams of Binary Magnesium Alloys*. Metals Park, Ohio: ASM International, pp. 205–208.

15. Aizawa, T., Kuwahara, H., and Luangvaranunt, T. 2000. Surface modification of magnesium base alloys by gas/plasma nitridation. *Proceedings of Magnesium Alloys 2000*, Nagaoka City, Japan.

16. Jackson, C. E. 1960. The science of arc welding. *Welding Journal* 39: 129-s to 140-s, 177-s to 190-s, 225-s to 230-s.

17. Milner, D. R., Salter, G. R., and-Wilkinson, J. B. 1960. Arc characteristics and their significance in welding. *British Welding Journal* 2: 73–88.

18. Onsoien, M., Pieters, R., Olson, D. L., and Liu, S. 1995. Effect of hydrogen in an argon GTAW shielding gas: arc characteristics and bead morphology. *Welding Journal* 74(01): 10-s to 15-s.

19. Allim, C. J. 1986. Nitrogen absorption from welding arcs, IIW Doc. 212-569-86: International Institute of Welding.

20. Tusek, J., and Suban, M. 1998. Influence of hydrogen in argon as a shielding gas in arc welding of high-alloy stainless steels, IIW Doc. 212-938-98: International Institute of Welding.

21. Devletian, J. H., and Wood, W. E. 1983. Factors affecting porosity in aluminum welds — a review. *Welding Research Council Bulletin 290*: 1–17.

22. Jhaveri, Moffat, W. G., and Adams, C. 1962. The effect of plate thickness and radiation on heat flow in welding and cutting. *Welding Journal* 41(2): 12-s to 16-s.

23. Burgardt, P., and Heiple, C. R. 1993. Weld penetration sensitivity to welding variables when near full joint penetration. *Welding Journal* 72(9): 341-s to 347-s.

24. *www.matweb.com*

Call for Papers

The American Welding Society announces a Call for Papers for the 2005 Professional Program to be held as part of Welding Show 2005 on April 26–28, 2005, in Dallas, Texas.

Submissions should fall in one of the following three categories and will be accepted only in a specific format. Individuals interested in participating should contact Dorcas Troche, Manager, Conferences & Seminars via email at dorcas@aws.org for specific details. Deadline for submission of paper is Friday, July 30, 2004.

Technical/Research Oriented

- New science or research
- Selection based on technical merit
- Emphasis is on previously unpublished work in science or engineering relevant to welding, joining and allied processes.
- Preference will be given to submittals with clearly communicated benefit to the welding industry

Applied Technology

- New or unique applications
- Selection based on technical merit
- Emphasis is on previously unpublished work that applies known principles of joining science or engineering in unique ways
- Preference will be given to submittals with clearly communicated benefit to the welding industry.

Education

- Welding education at all levels
- Emphasis is on education/training methods and their successes
- Papers should address overall relevance to the welding industry

Fundamental Studies on the Effect of Distortion Control Plans on Angular Distortion in Fillet Welded T-Joints

The effect of distortion control plans on the relationship between cumulative plastic strains and angular distortion in fillet welded T-joints was investigated

BY G. H. JUNG AND C. L. TSAI

ABSTRACT. The effect of external restraints and thermal management techniques (heat sinking and gas tungsten arc [GTA] preheating) on the relationship between cumulative plastic strains and angular distortion in fillet welded T-joints was investigated using plasticity-based distortion analysis (PDA). External restraints reduced the bend-up angular distortion by increasing the bend-down angular distortion induced by the transverse cumulative plastic strain. The higher restraint produces the less angular distortion. Heat sinking increases the bend-up angular distortion. This technique mainly controls the nominal cumulative plastic strains. The bend-down angular distortions induced by the transverse and vertical components are decreased. Those changes resulted in an increase of the total bend-up angular distortion.

Gas tungten arc preheating reduced the angular distortion by decreasing the bend-up angular distortion induced by the xy-plane shear cumulative plastic strain. The characteristic relationship between cumulative plastic strains and angular distortion in fillet welded T-joints was not affected by the external restraints and thermal management techniques.

Introduction

Distortions induced by welding have been regarded as a critical issue in terms of performance, quality, and productivity. Many techniques have been developed to minimize the distortions induced by welding, such as external restraining, preheating, auxiliary side heating, heat sinking, and others. In general, most of the distortion mitigation techniques have been developed according to conventional understanding to explain their effectiveness in distortion controls, and then evaluated by comparing with test results. These conventional understandings may include not only theoretical and mathematical knowledge, but also generally accepted knowledge from experience or analogy. For example, the concept of predeformation is based on direct intuition after observing the distortion patterns; welding-induced deformation is compensated for by the counterdeformation formed in joints prior to welding. The other example can be heat control techniques applying preheating or side heating in order to reduce the temperature gradient. Once the basic idea is tested and evaluated, a number of parametric studies may follow to find the optimum condition and explain the effect of mitigation parameters.

Masubuchi (Ref. 1) summarized methods for reducing distortions in welded joints based on the research. He reviewed the general distortion-reduction methods in terms of weld dimensions, joint designs, welding processes, multipass welding, constraints, welding sequences, intermittent welding, and peening. More detailed discussions on the effects of external restraints and thermal-pattern alterations were presented. Pavlovsky and Masubuchi (Ref. 2) reviewed the various distortion control methods studied by U.S.S.R. researchers. Conrardy and Dull (Ref. 3) reviewed the distortion control techniques applicable in thin ship panel structures. To reduce buckling, modifying panel design, applying intermittent welding, reducing heat input, and applying thermal tensioning were recommended. Restraining, back-bending and backside line heating were recommended as techniques for reducing angular distortion.

Recently, the finite element method has been used to investigate the performance of various distortion control techniques, and has provided the fundamental understanding of the distortion mechanism and the effects of distortion control techniques on distortion patterns. Park (Ref. 4) developed a model to predict the thin plate panel distortion, and simulated the effect of welding sequences on the reduction of the distortions. Ohata et al. (Ref. 5) introduced the GTA preheating method to reduce the angular distortion in fillet welded aluminum thin plates, and performed weld tests and finite element analyses to evaluate its effectiveness. Michaleris and his coworkers (Refs. 6, 7) studied the effect of thermal tensioning buckling in panel structures using tests and finite element analysis. Ma et al. (Ref. 8) simulated the effects of weld sequences, a working table, and external restraints on the angular distortion of fillet welded T-joints, using 2-D finite element analysis. Han (Ref. 9) simulated the effects of side heating, heat sinking, and their combination on the distribution pattern of the longitudinal plastic strain associated with the longitudinal compressive stress causing buckling, using 2-D finite element analysis.

However, no rigorous studies have been carried out to investigate how these techniques affect the relationship between cumulative plastic strains and distortion. Recently, Han (Ref. 9) investigated how heat sinking and side heating affect the longitudinal cumulative plastic strain, and explained the effectiveness of the methods based on the relationship between the longitudinal cumulative plastic strain and the longitudinal residual stress associated with buckling in butt joint welded plates.

Jung (Ref. 10) developed the procedure, the so-called plasticity-based distortion analysis (PDA), which enables the investigation of the relationship between

KEYWORDS

Angular Distortion
Cumulative Plastic Strains
Gas Metal Arc Welding
Heat Sinking
Gas Tungsten Arc Preheating
T-Joints
Fillet Welds
Thermal Management Techniques

G. H. JUNG is with Edison Welding Institute, Columbus, Ohio. C. L. TSAI is with Industrial, Welding and Systems Engineering at The Ohio State University, Columbus, Ohio.

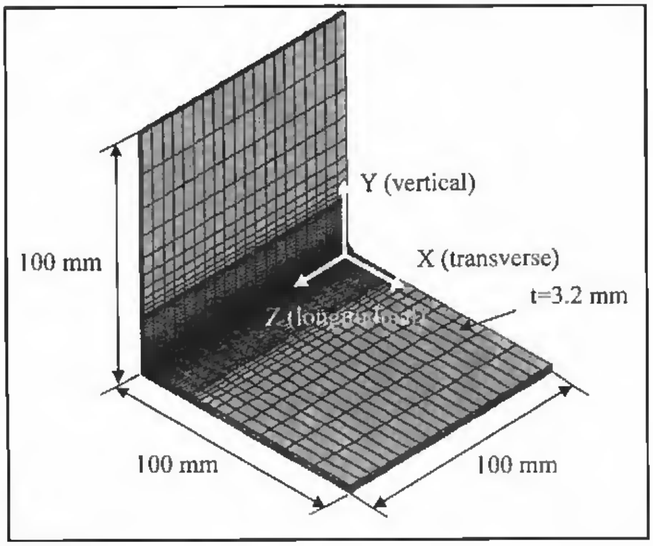


Fig. 1 — Symmetric half finite element model for the T-joint.

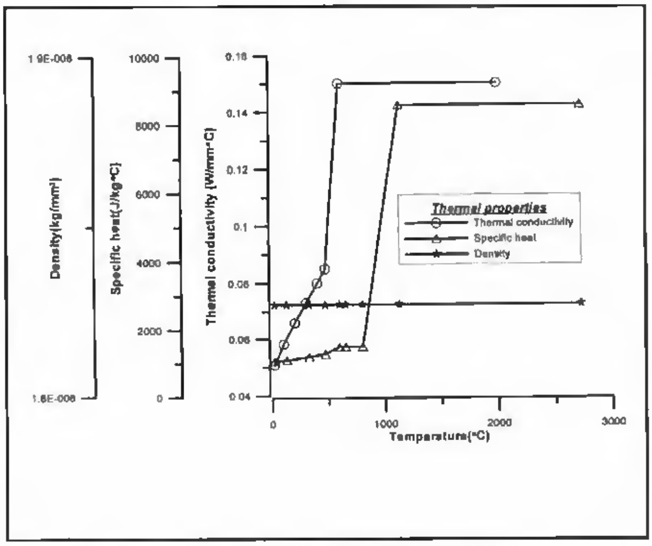


Fig. 2 — Temperature-dependent thermal material properties of magnesium Alloy AZ91 C.

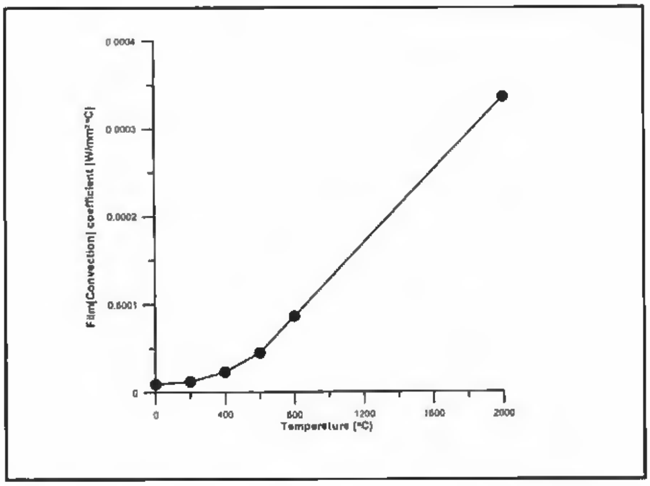


Fig. 3 — Temperature-dependent natural convection (film) coefficients.

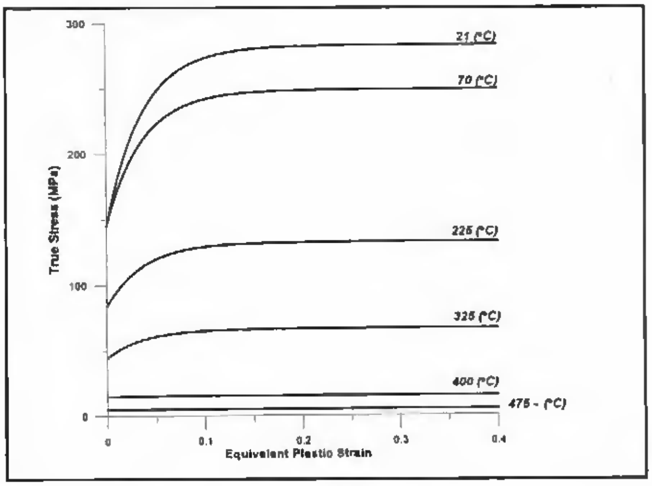


Fig. 4 — Temperature-dependent nonlinear kinematic strain-hardening model of magnesium alloy.

cumulative plastic strains and angular distortion in fillet welded T-joints. The PDA successfully explained each cumulative plastic strain's contribution to angular distortion in fillet welded T-joints.

This study investigated the effect of external restraints and two specific thermal management techniques (heat sinking and GTA preheating) on the relationship between cumulative plastic strains and angular distortion for fillet welded thin plate T-joints using PDA.

Plasticity-based Distortion Analysis (PDA) for Fillet Welded T-Joints

During welding, materials experience plastic deformation due to the thermal stresses induced by the temperature gradient, the external restraints, and the material softening. Plastic strains are cumulated during the plastic deformation, and then remained permanently after temperature reaches room temperature and some temporary restraints are removed. These cumulative plastic strains result in residual stresses and distortions in the welded joints. The inherent shrinkage model is one of the methods to incorporate these cumulative plastic strains in the welded joints using the equivalent forces and moments, and to predict the welding-induced distortions without performing the thermal-elastic-plastic analysis (Refs. 11, 12). However, when the joint configuration is complex, such as T-joints, it is difficult to calculate the equivalent forces and moments because of the lack of knowledge about the relationship between cumulative plastic strains and distortions.

On the other hand, PDA enables us to predict distortions by mapping all cumulative plastic strains into elastic models using the equivalent thermal strains instead of the equivalent forces and moments, and provides the quantitative relationship between cumulative plastic strains and distortions.

The PDA includes the following three parts:

- Part 1: Thermal-elastic-plastic analyses (EPA) to obtain cumulative plastic components and distortions
- Part 2: Elastic analyses with thermal strains, which are equivalent to the cumulative plastic strains obtained from the EPA to predict the individual distortions that are associated with only one cumulative plastic strain component
- Part 3: Postprocessing to check the accuracy of the predicted distortion. If the accuracy does not satisfy the required accuracy, update a finite element model and repeat Parts 1, 2, and 3.

Thermal-Elastic-Plastic Analysis

The 3-D uncoupled thermal-elastic-

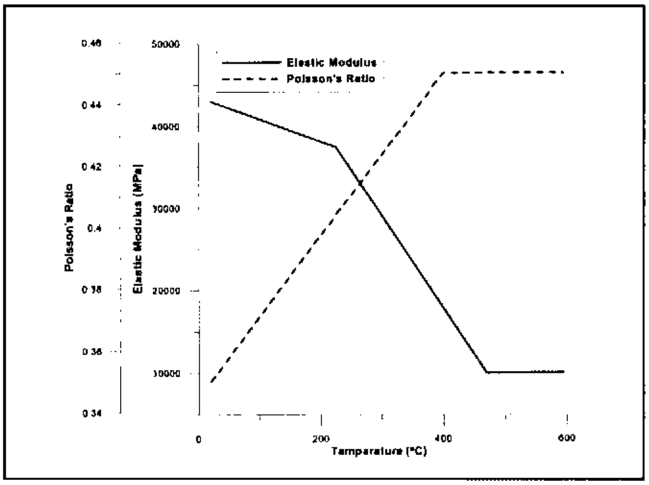


Fig. 5 — Temperature-dependent elastic modulus and Poisson's ratio of magnesium alloy.

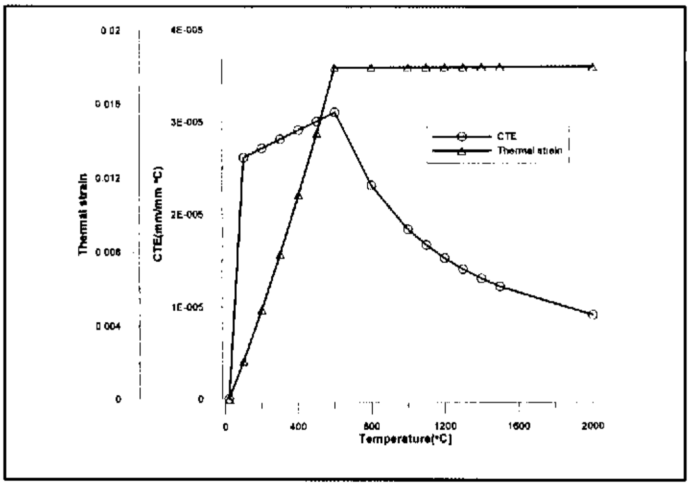


Fig. 6 — Temperature-dependent CTE and corresponding thermal strain of magnesium alloy.

Table 1 — Comparison of the Averaged Displacements Obtained from EPA, PDA, and Simultaneous Mapping Analysis for a T–Joint

Type of Analysis		Displacement (mm) U_X	U_Y	U_Z
EPA		–2.090E–01	1.042E+00	1.328E–01
	$\Sigma\varepsilon^p_{xx}$	1.694E–01	–1.143E+00	1.028E–01
	$\Sigma\varepsilon^p_{yy}$	1.202E–02	–7.656E–01	5.590E–04
	$\Sigma\varepsilon^p_{zz}$	–2.263E–04	8.392E–02	5.364E–03
PDA	$\Sigma\varepsilon^p_{xy}$	–4.991E–02	2.805E+00	1.088E–03
	$\Sigma\varepsilon^p_{xz}$	–3.316E–04	9.435E–03	1.627E–01
	$\Sigma\varepsilon^p_{yz}$	–4.742E–04	1.995E–02	–1.399E–01
	SUM	–2.084E–01	1.009E+00	1.327E–01
Simultaneous Mapping		–2.084E–01	1.009E+00	1.327E–01

plastic analysis for fillet welded T-joints without any external restraints and thermal management techniques was performed to obtain the baseline information, such as the characteristic distribution patterns of cumulative plastic strains and the corresponding angular distortion, using *ABAQUS* 5.8-14.

The material is magnesium Alloy AZ91 C, which application has been expanded because of its relatively lower density. In this study, weld tests were not performed; only numerical simulations were performed. It is assumed that the present analysis procedure provides the reasonable distribution patterns of the cumulative plastic strains and the corresponding angular distortion in fillet welded T-joints. The validity of the present EPA procedure was evaluated by comparing the angular distortions obtained from the EPA and experiments for aluminum fillet welded T-joints (Ref.10).

Two fillet welds running simultaneously at two sides constructed the T-joint. The given gas metal arc welding parameters were voltage = 13 V, current = 110 A, weld speed = 10 mm/s for 3.2-mm- thick plates (Ref. 13).

Figure 1 shows a symmetric half finite element model used in the EPA for a fillet welded T-joint, with a flange, 100 × 200 × 3.2 mm, and a web erected on the flange plate, 100 × 100 × 3.2 mm. Quadratic brick elements with 20 nodes, DC3D20 (thermal analysis), and C3D20R(elastic-plastic analysis) in *ABAQUS* (Ref. 14) were used. The total number of elements and nodes used were 6100 and 30,068, respectively.

Figure 2 shows the temperature-dependent thermal properties (Ref. 15). The latent heat, solidus, and liquidus temperature are 3.73E5 J/(kg°C), 470°C, and 595°C, respectively. Natural convection boundaries shown in Fig. 3 were described on the entire free surfaces of the joint except for a symmetric plane. Figures 4–6 show mechanical properties depending on temperature. Nonlinear kinematic strain hardening proposed by Chabochi (Ref. 14, 17) was used.

The effect of a moving heat source was incorporated by the user-subroutine in *ABAQUS, DFLUX* (Ref. 14). Body flux had a double ellipsoidal distribution proposed by Goldak (Ref. 16). Heat input calibration was carried out by matching the boundary of the molten pool with the predesigned fillet size. UVARM (Ref. 14) was developed to calculate the maximum peak temperature overall nodes. Figure 7 shows a map of the maximum peak temperature with a calibration factor of 0.6 including the arc efficiency. During the elastic-plastic analysis, symmetric boundary conditions were described on the YZ plane in Fig. 1, and the top free edge of the web plate was fixed. The effects of the filler metal deposition, the stress and strain relaxation at melting temperature, and metallurgical transformation were not considered in the present EPA.

The characteristic cumulative plastic strain distribution patterns and the associated angular distortion for fillet welded thin plate T-joints were obtained from the EPA. The angular distortion was defined by the displacement in the Y-direction (Fig. 1) at the free edge of the flange plate (at X=100 mm). The obtained averaged angular distortion from the EPA was 1.04 mm.

Elastic Analysis

The finite element model and mechanical boundary conditions used in the elastic analysis are the same as those of the EPA. The cumulative plastic strains obtained from the EPA were mapped into elastic models with the same nodes and elements, elastic modulus (4.3E4 [MPa]) and Poisson's ratio (0.35) at room temperature using the equivalent thermal strains.

Each cumulative plastic strain component can be mapped independently into six elastic models. Anisotropic thermal expansion coefficients and corresponding temperature fields replace the cumulative plastic strains. For example, the transverse cumulative plastic strain, $\Sigma\varepsilon^p_{xx}(x,y,z)$ can be mapped by using the temperature field calculated by Equation 1 (Ref.14):

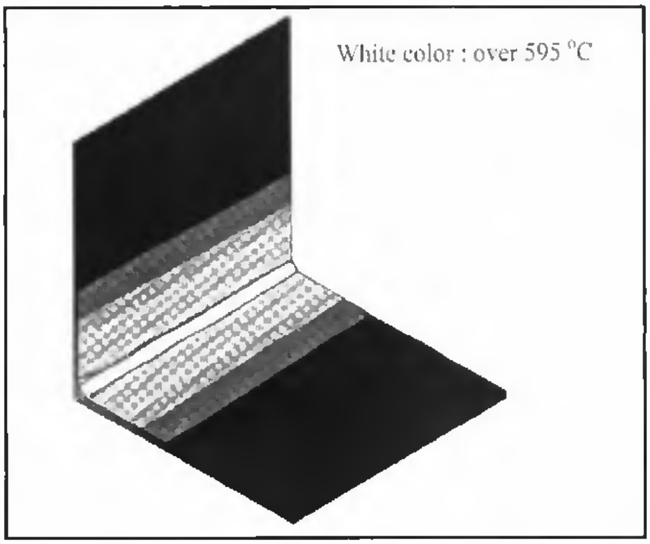


Fig. 7 — *Maximum peak temperature map in the T-joint*

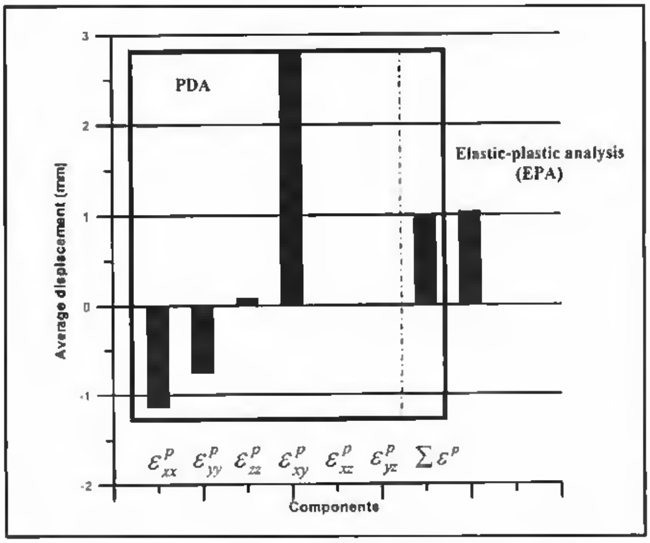


Fig. 8 — *Averaged angular distortions calculated by EPA and PDA.*

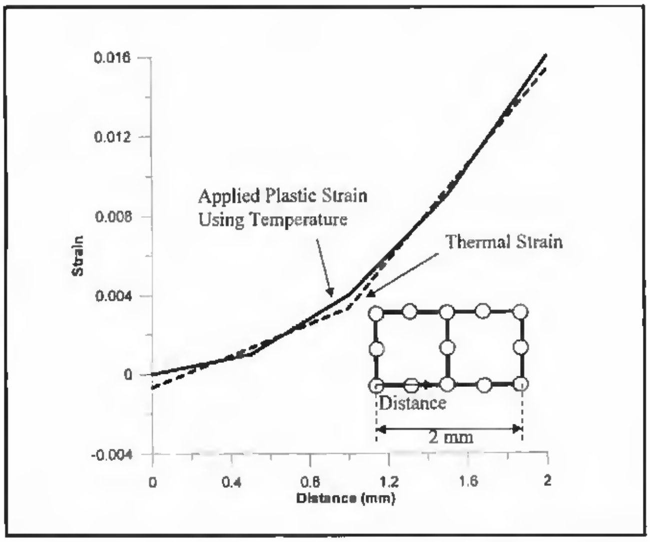


Fig. 9 — *Characteristics of thermal strain in second-order elements*

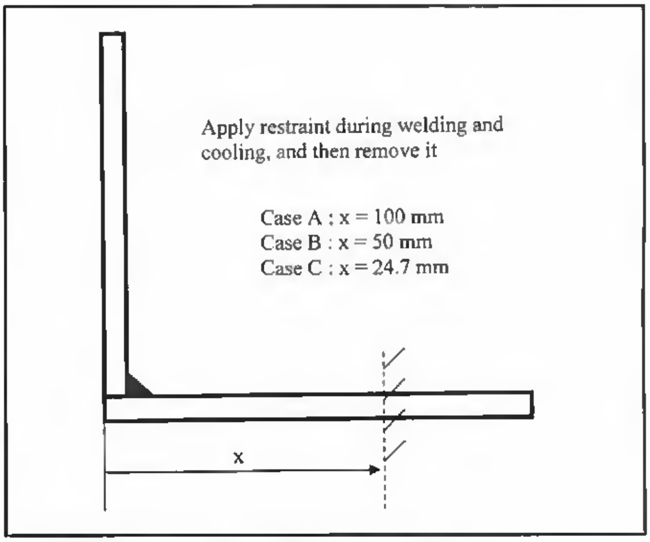


Fig. 10 — *Locations of applied external restraints*

$$\theta_{xx}(x,y,z) = \frac{\Sigma\varepsilon^p_{xx}(x,y,z)}{\alpha_{xx}} \qquad (1)$$

$$\alpha_{xx} = \text{constant}, \alpha_{yy} = \alpha_{zz} = \alpha_{xy} = \alpha_{xz} = \alpha_{yz} =$$

where $\Sigma\varepsilon^p$ = averaged cumulative plastic strain at nodes, θ = temperature, a = anisotropic thermal expansion coefficients. Other temperature fields associated with other cumulative plastic strain components can be obtained using Equation 1 as well.

Six cumulative plastic strains can also be simultaneously mapped into an elastic model using the equivalent thermal strains depending upon six field variables defined by Equation 2 (Ref.14):

$$\varepsilon^{th}_{ij} = \alpha_{ij} F_{ij}(x,y,z)$$

$$\text{where } F_{ij}(x,y,z) = \frac{\Sigma\varepsilon^p_{ij}(x,y,z)}{a_{ij}} \text{: Field Variables} \qquad (2)$$

This simultaneous mapping method was used to demonstrate the validity of the addition procedure to obtain the total distortion and the unique relationship between cumulative plastic strains and distortions.

Figure 8 also clearly shows the quantitative relationship between cumulative plastic strains and angular distortion. The transverse, $\Sigma\varepsilon^p_{xx}$, and the vertical, $\Sigma\varepsilon^p_{yy}$, cumulative plastic strain components result in the bend-down angular distortion, and the longitudinal, $\Sigma\varepsilon^p_{zz}$, and the xy-plane shear, $\Sigma\varepsilon^p_{xy}$, cumulative plastic strain components generate the bend-up angular distortion. Most bend-up angular distortion is induced by the xy-plane shear cumulative plastic strain, and the angular distortion induced by other shear, $\Sigma\varepsilon^p_{xz}$ and $\Sigma\varepsilon^p_{yz}$, cumulative plastic strains is small enough to be negligible.

Postprocessing

The total distortion induced by all cumulative plastic strains is obtained by adding the individual distortions calculated from six independent elastic analyses:

$$\delta^{total}_{PDA} = \sum_{i=1}^{6} \delta_i \qquad (3)$$

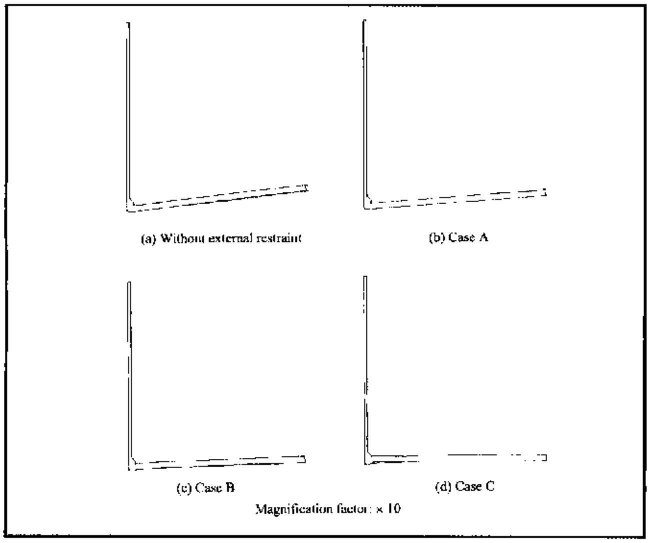


Fig. 11 — Deformed shapes after removing external restraints.

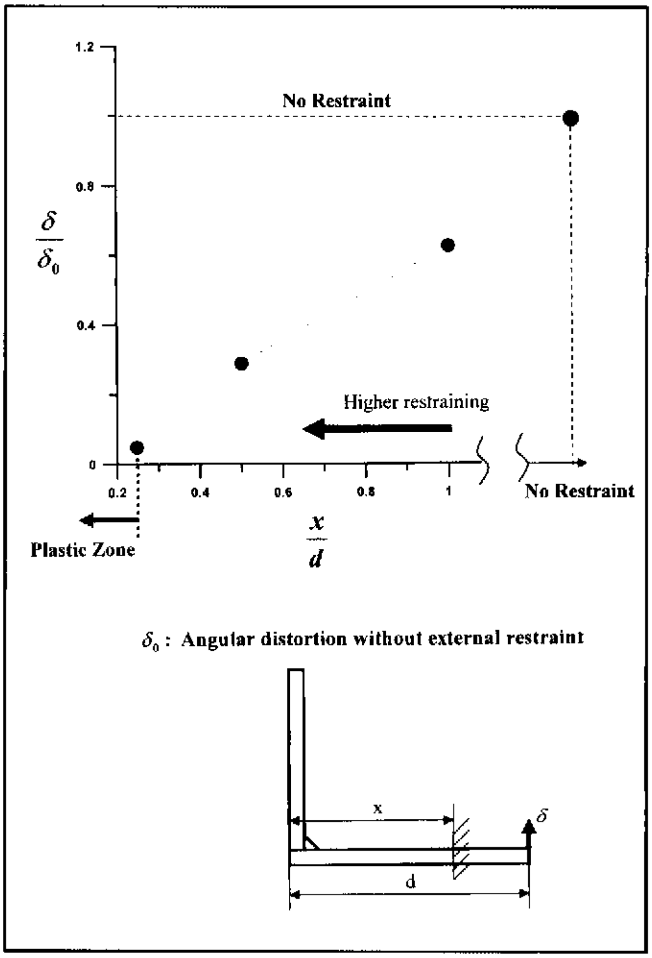


Fig. 12 — Comparison of averaged angular distortion for the cases with differing degrees of external restraint.

where δ^{total}_{PDA} = the total distortion, δ_i = the individual distortion with only i^{th} component of cumulative plastic strains. The accuracy of the PDA procedure can be determined by comparing the distortions from the EPA with the total distortions obtained from the PDA using Equation 3.

$$Error = \left| \frac{\delta_{EPA} - \delta^{total}_{PDA}}{\delta_{EPA}} \right| \times 100(\%) \qquad (4)$$

This accuracy of the PDA procedure may be affected by some factors such as the nonlinearity of material and the mapping accuracy.

One factor is material nonlinearity, which does not allow the linear suppositions if the effect of nonlinearity is dominant. Material nonlinearity comes from the plastic deformation and the temperature dependency of material properties in the welding situation. In the PDA, material nonlinearity due to temperature dependency does not exist anymore because temperature is constant (room temperature) after completing welding. Nonlinearity due to the plastic deformation can also be negligible because the PDA is somewhat elastic, reloading analysis up to the final plastic deformation after welding.

The mapping accuracy may also affect the accuracy of the PDA procedure. The mapping accuracy is strongly dependent upon the number of elements/nodes and the order of shape function of element. Figure 9 shows the applied cumulative plastic strain using temperature and the calculated thermal strain within two second-order elements in which the thermal strain is linear. Unless the cumulative plastic strains are distributed uniformly or linearly within an element, the mapping error is unavoidable even though second-order elements are used. The averaged cumulative plastic strains at nodes may also result in the error when significant discontinuity of the cumulative plastic strains at the integration points between the adjacent elements is present. In order to reduce the error induced by mapping, a finer-meshed model with second-order elements is recommended.

In this study, it was assumed that the acceptable error range of the PDA procedure was 0 to 10% in view of the engineering application. Since most error comes from the mapping, the finite element model should be updated until the required accuracy is achieved. The averaged total angular distortion obtained from the PDA was 1.01 mm, which had 3% error compared with 1.04 mm obtained from the EPA. This accuracy is acceptable.

In order to evaluate the PDA application to fillet welded T-joints and demonstrate the unique relationship between cumulative plastics and distortion, the simultaneous mapping analysis was performed under the combined cumulative plastic strains. Table 1 shows that the displacements obtained from the simultaneous mapping analysis are equal to those calculated by the PDA, which satisfies the linear superposition requirement described in Equation 5. Therefore, the PDA procedure is valid and each individual distortion can be uniquely determined by the associated cumulative plastic strain.

$$\begin{aligned} & L\left(\Sigma\varepsilon^p_{xx}, \Sigma\varepsilon^p_{yy}, \Sigma\varepsilon^p_{zz}, \Sigma\varepsilon^p_{xy}, \Sigma\varepsilon^p_{xz}, \Sigma\varepsilon^p_{yz}, \right) \\ & = L_i\left(\Sigma\varepsilon^p_{xx} \right) + L_2\left(\Sigma\varepsilon^p_{yy} \right) + L_3\left(\Sigma\varepsilon^p_{zz} \right) \\ & + L_4\left(\Sigma\varepsilon^p_{xy} \right) + L_5\left(\Sigma\varepsilon^p_{xz} \right) + L_6\left(\Sigma\varepsilon^p_{yz} \right) \qquad (5) \end{aligned}$$

Effect of External Restraints on Angular Distortion in T-Joints

The external restraining techniques have been widely known as useful techniques for reducing the angular distortion in welded structures. For pressure vessels or large-scale pipes, pre-expanding has been adopted to reduce the radial shrinkage. In the case of T-joints, it has been reported that restraining and back-bending of the flange plates are effective means for reducing angular distortion (Ref. 3).

In this study, the PDA investigates the effect of external restraints on the characteristic relationship between cumulative

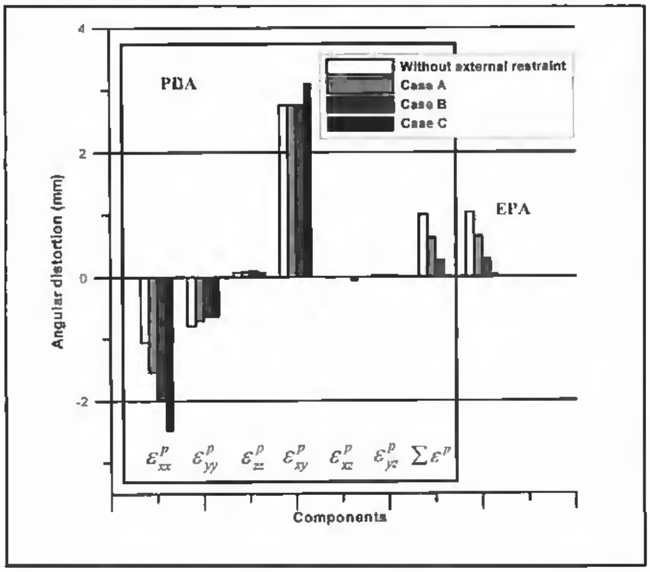
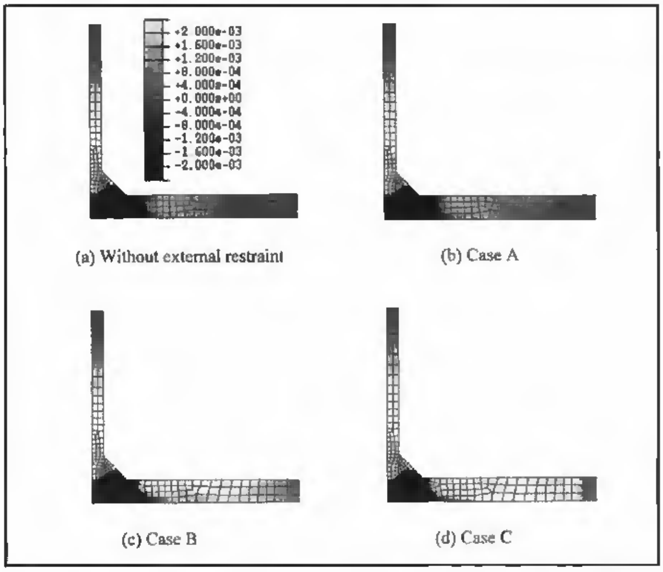


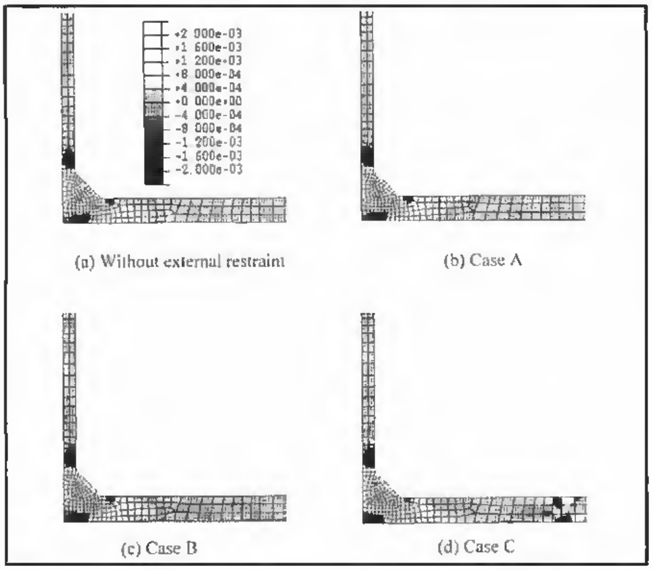
Fig. 13 — Comparison of averaged angular distortions calculated by EPA and PDA for the cases with differing degrees of external restraint.



(a) Without external restraint (b) Case A

(c) Case B (d) Case C

Fig. 14 — Transverse cumulative plastic strain maps for the cases with differing degrees of external restraint.



(a) Without external restraint (b) Case A

(c) Case B (d) Case C

Fig. 15 — xy-plane shear cumulative plastic strain maps for the cases with differing degrees of external restraint.

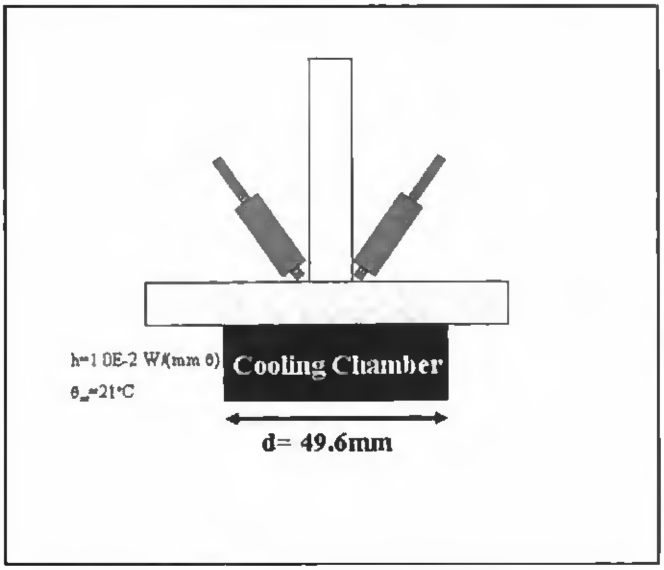


Fig. 16 — Scheme of heat sinking applied to the T-joint.

plastic strains and angular distortion in fillet welded T-joints.

Thermal Analysis (Part 1)

Some amount of heat loss through the contact surfaces between the fixtures and the flange may occur, but it was assumed that heat loss through the contact surfaces would be negligible. Therefore, the same temperature evolution obtained from the previous thermal analysis was used in the following elastic-plastic analyses for the three cases with differing degrees of external restraining.

Elastic-Plastic Analysis (Part 1)

It has been reported that the angular distortion is affected by the degree of external restraining (Refs. 1, 18); the higher degree of restraining, the less angular distortion. In this study, external restraints were applied along the flange plate with fixed boundary conditions. The degree of restraining is inversely proportional to the distance between the weld interface and the line of the fixed boundaries.

Figure 10 shows the locations of external restraints. Three cases designated as Case A, Case B, and Case C have differing degrees of external restraining. The locations applying the fixed boundary conditions for Case A, Case B, and Case C were x = 100 mm, 50 mm, and 24.7 mm, respectively. Case C has the highest restraining of the three cases. These fixed boundary conditions were applied during heating and cooling, and then removed after cooling was completed. The final angular distortion was obtained after removing external restraints. From these simulations, we can obtain the characteristic cumulative plastic strain distribution patterns and the angular distortion associated with differing degrees of external restraining, both of which can be used in the PDA to investigate the effect of the external restraints on the angular distortion in T-joints.

Figure 11 shows the deformed shapes after removing the external restraints with the same scaling factor. The averaged angular distortions for Cases A, B, and C are 0.65, 0.30, and 0.05 mm, respectively. They are plotted in Fig. 12 with dimensionless parameters. Figures 11 and 12 show that less angular distortion is expected at a higher degree of restraining. A minute angular distortion is produced in Case C with external restraints at x = 24.7 mm where it is close to the boundary of the plastic zone (x = 21.58 mm) produced in the case without external restraints.

These differences among the three cases may result from the change in the cumulative plastic strain distributions due to the external restraints. The effects of the external restraints on the distribution patterns of the cumulative plastic strains can be observed by plotting the cumulative plastic strains. However, this observation may not give the right and quantitative interpretation of the relationship because the cumulative plastic strains have complicated distribution on the welded region. Therefore, the PDA was carried out to study the effect of the external restraints on the characteristic relationship between cumulative plastic strains and angular distortion.

Elastic Analysis and Postprocessing (Parts 2, 3)

The cumulative plastic strains obtained from the three cases with differing degrees of external restraining were mapped into elastic models using the equivalent thermal strains.

In order to investigate the effect of external restraints on the relationship between cumulative plastic strains and angular distortion, the individual and the total angular distortions for the three cases and a case without external restraints are plotted together in Fig. 13. Reasonable accuracy of the PDA is shown for all cases.

No change of the basic relationship between cumulative plastic strains and angular distortion is observed: bend-down angular distortion is due to transverse/vertical cumulative plastic strains, bend-up angular distortion is due to longitudinal/xy-plane shear cumulative plastic strains, and no angular distortion is caused by other shear cumulative plastic strains.

The major change due to the external restraints is observed in the individual angular distortion induced by the transverse cumulative plastic, $\Sigma\varepsilon^p_{xx}$. A higher degree of restraining produces a more bend-down angular distortion induced by the transverse cumulative plastic strain. Figure 14 shows the change in the transverse cumulative plastic strain distributed on the flange plate. There is no change in the distribution on the web plate, but the area with the positive plastic strain on the top surface of the flange expands with an increase in the degree of restraining. The positive transverse plastic strain presents within the plastic zone where the compressive longitudinal plastic strain exists. Some parts of the positive transverse plastic strain may originate to satisfy the incompressibility under the plastic deformation. However, the applied external restraints (transverse and bending restraining) may not significantly affect the distribution of the longitudinal cumulative plastic strain because the longitudinal stress is mostly governed by the longitudinal restraint or the rigidity in the longitudinal direction. Therefore, considering the distribution pattern of the positive transverse plastic strain, yielding may occur due to the high tensile transverse stress, which is generated by the external restraints that are present from the bend-up bending and the transverse shrinkage during cooling. In general, higher restraining produces more cumulative plastic strains because higher stress resulting from higher restraining causes an earlier yielding. As higher external restraining is applied, higher and wider positive transverse cumulative plastic strain is produced and more bend-down angular distortion occurs because the role of the positive transverse cumulative plastic strain on the top surface of the flange bends down the flange plate.

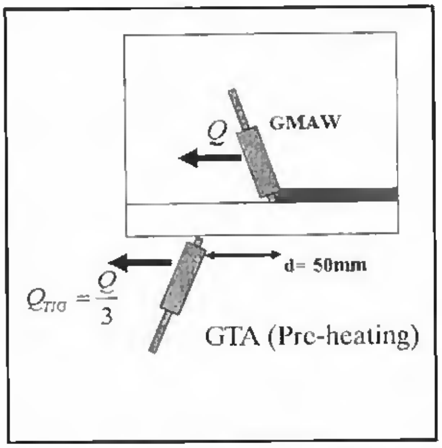
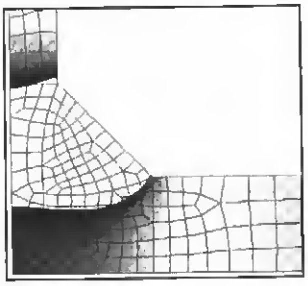


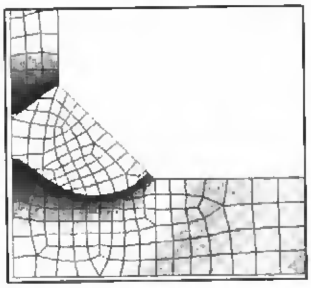
Fig. 17 — Scheme of GTA preheating applied to the T-joint.

For the vertical cumulative plastic strains, $\Sigma\varepsilon^p_{yy}$, only a slight change in the angular distortion is shown. In general, less bend-down angular distortion is induced by higher external restraining. No change in the angular distortion induced by the longitudinal cumulative plastic strain occurs. This may imply that the external restraints applied on the flange would not affect the distribution patterns of the longitudinal cumulative plastic strain.

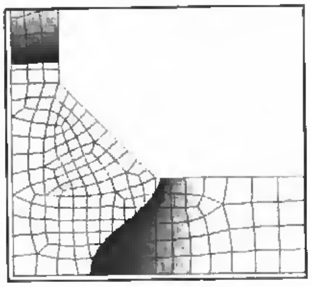
For the angular distortion induced by the xy-plane shear cumulative plastic strain, $\Sigma\varepsilon^p_{xy}$, no change in the individual angular distortion is shown except Case C with the external restraint close to the boundary of the plastic zone. Figure 15 clearly shows how the external restraints affect the distribution of the xy-plane shear cumulative plastic strain. There is no change in the distribution pattern for Case A, Case B, and the case without external restraints. For Case C, the external restraint close to the boundary of the plastic zone disturbs the distribution of the xy-plane shear cumulative plastic strain. The change in the individual angular distortions induced by other shear components is negligible.



(a) Without thermal managements



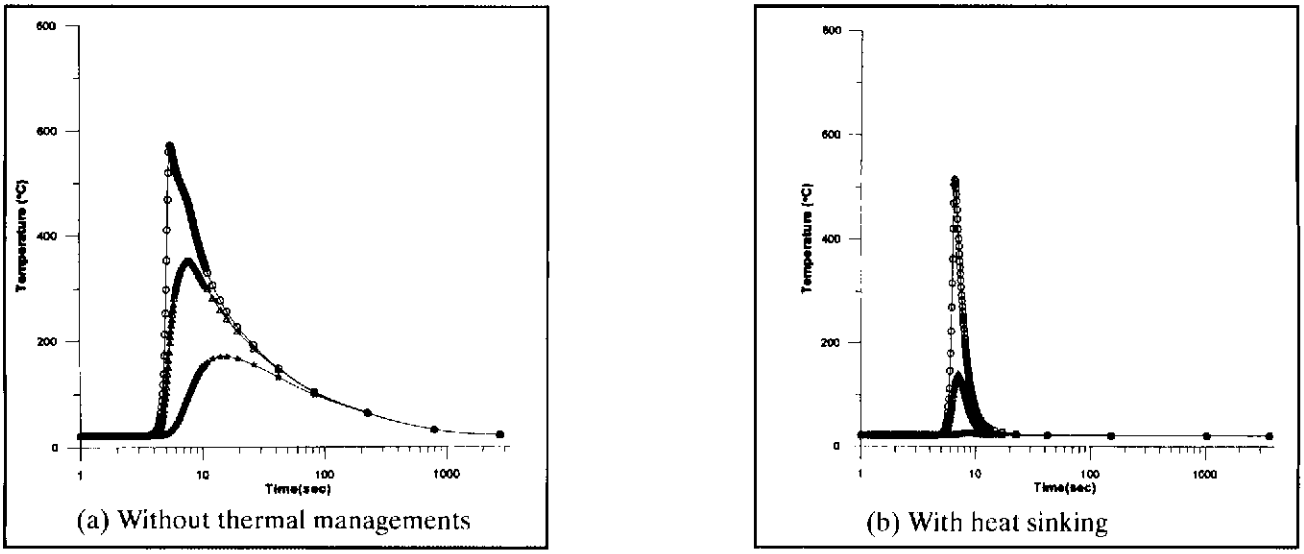
(b) With heat sinking



(c) With GTA pre-heating

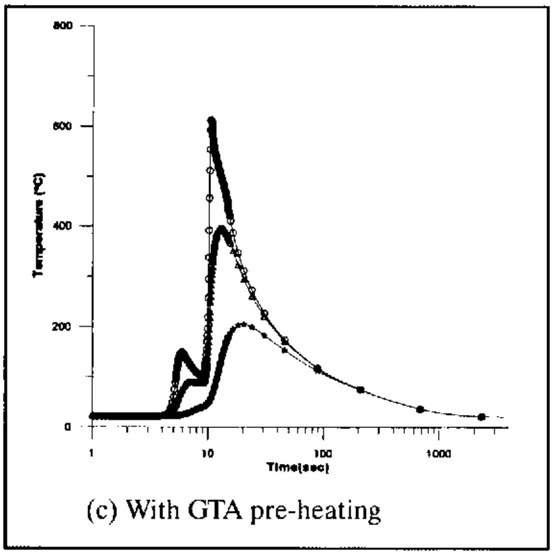
Fig. 18 — Comparison of nugget shapes obtained from thermal analyses with different thermal management techniques.

Based on results of the PDA, it can be concluded that the reduction of the angular distortion by the external restraints applied on the flange results from an increase of the bend-down angular distortion induced by the transverse cumulative plastic strain. The region where the positive transverse cumulative plastic strain exists is expanded by increasing the degree of external restraining.



(a) Without thermal managements

(b) With heat sinking



(c) With GTA pre-heating

Fig. 19 — Comparison of temperature evolutions for the cases with different thermal management techniques.

Effect of Thermal Management Techniques on Angular Distortion in T-Joints

Two thermal management techniques were selected: heat sinking and GTA preheating. They are inherently different in terms of heat control. Heat sinking reduces the heat-affected zone by applying a cooling chamber beneath the bottom of the flange. On the other hand, GTA preheating increases the heat-affected zone by preheating, which is carried out by running a gas tungsten arc ahead of gas metal arc welding (GMAW) on the bottom surface of the flange.

It has been reported that heat sinking is an effective way to reduce buckling (Ref. 7), and GTA preheating reduces the angular distortion in T-joints (Ref. 5). Most research has been focused on showing their effectiveness using weld tests and numerical simulations. Recently, Han (Ref. 9) investigated the relationship between cumulative plastic strains and buckling for butt joints. However, it is still unknown how thermal management techniques affect the relationship between cumulative plastic strains and angular distortion in T-joints. Therefore, the effect of thermal management techniques on the relationship between cumulative plastic strains and angular distortion was investigated using the PDA.

Thermal Analysis (Part 1)

The effect of heat sinking was simulated by applying the relatively low film coefficient, 1.0E-2 W/(mm^2 °C) with temperature 21°C, on the bottom surface of the flange within x = 0~24.8 mm as shown in Fig. 16. Gas tungsten arc preheating was modeled by running a gas tungsten arc 50 mm ahead of GMAW at the same speed as GMAW on the bottom surface of the flange as shown in Fig. 17. The GTA heat was one-third of that of GMAW, 477 W(= 110 V × 13 A × ⅓) with a heat input calibration factor of 0.6.

A nugget with heat sinking will be smaller than that with GTA preheating because preheating raises the temperature in and around the weld region. Figure 18 shows the maximum peak temperature maps calculated by the user-subroutine, UVARM. Compared to the nugget without thermal management, heat sinking generates a smaller nugget and GTA preheating gives a larger nugget.

Heat management techniques affect not only the size of the heat-affected zone, but also the rate of heating and cooling, which can be related to the instantaneous gradient of temperature in the plates. In general, heat sinking results in a higher temperature gradient due to a higher cooling rate, and facilitates achieving a uniform temperature in the plates compared to the case without thermal management. Contrarily, GTA preheating increases the maximum peak temperature and reduces the temperature gradient.

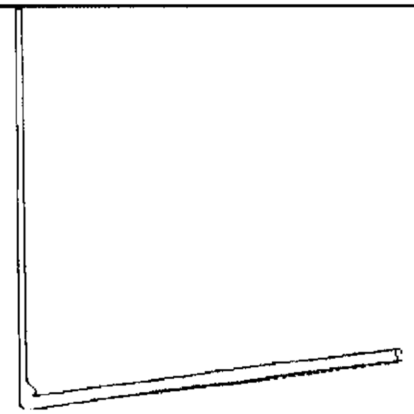
Figure 19 compares temperature evolutions on three points located on the top surface of the flange, x = 4.8, 9.8, and 24.8 mm. The distance between the curves represents the temperature gradient and their slopes show the heating and cooling rate. For heat sinking, a significant change of the magnitude of the maximum peak temperature, the temperature gradient, and the rate of cooling are observed. Gas tungsten arc preheating does not give significant changes in the temperature gradient and the cooling rate compared with the case without thermal management. During heating, two spikes on each curve show the effect of GTA preheating. Preheating also increases the maximum peak temperatures of each curve, which results in a wider nugget and heat-affected zone.

Based on the results of the thermal analysis, the two thermal management techniques, heat sinking and GTA preheating, may give the opposite impact on not only the temperature evolution and profile, but also the angular distortion.

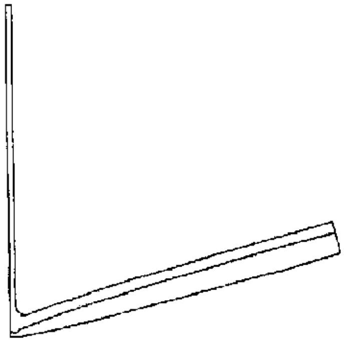
Elastic-Plastic Analysis (Part 1)

All boundary conditions for the two cases were the same as those of the case without the external restraints described in the previous section. The temperature evolutions for the two cases calculated by the thermal analyses were retrieved and applied to the elastic-plastic analysis.

Figure 20 shows the deformed shapes for the three cases with the same magnification scale factor: Case 1 = without ther-



(a) Without thermal managements



(b) With heat sinking

(c) With GTA pre-heating

Fig. 20 — Comparison of deformed shapes for the cases with different thermal management techniques.

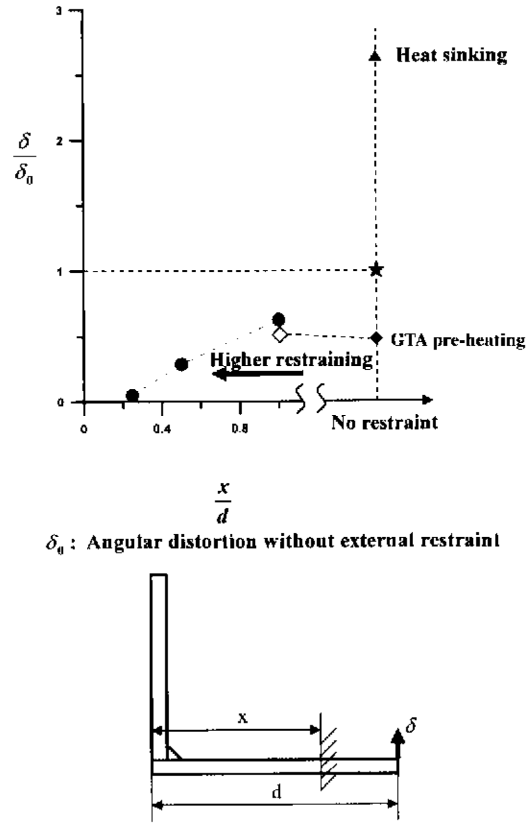


Fig. 21 — Comparison of averaged angular distortions for the cases with different distortion control plans.

mal management, Case 2 = heat sinking, Case 3 = GTA preheating. The average angular distortions calculated for Cases 1, 2, and 3 are 1.04, 2.75, and 0.5 mm, respectively, and are plotted with dimensionless parameters in Fig. 21. It shows that heat sinking increases angular distortion, but GTA preheating reduces angular distortion. This opposite effect between the two thermal management techniques on the angular distortion was expected after observing the results of the thermal analysis. Figure 21 shows that external restraining and GTA preheating effectively reduces the angular distortion. The effect of the combination of GTA preheating and external restraining (Case A, restrained at X = 100 mm) was also tested, but a slight increase in the angular distortion was obtained compared to the case with only GTA preheating.

To investigate the causes of these differences, cumulative plastic strain maps for the three cases are plotted in Fig. 22. For Cases 1 and 3, a similar distribution pattern of the cumulative plastic strains is shown. On the other hand, a significant reduction of the size of the plastic zone is obtained by heat sinking. The distribution pattern of the transverse cumulative plastic strain for Case 2 is different from those of Cases 1 and 3. For Case 2, the transverse cumulative plastic strain on the top surface of the flange is wider than on the bottom of the flange, which may cause the bend-up angular distortion and eventually reduce the amount of the bend-down angular distortion. For the vertical cumulative plastic strain, the reduced size of the plastic strain zone in the flange may affect the angular distortion as well. Even though there is significant change in the distribution pattern of the longitudinal cumulative plastic strain, the resultant effect may be small because the longitudinal component is not as sensitive as other components on the angular distortion. For the xy-plane shear cumulative plastic strain, no significant change is shown. For Case 3, it is not clear what causes the reduction of the angular distortion because there is no significant difference of cumulative plastic strain distributions between Cases 1 and 3. Compared to other components, it is observed that the distribution of the xy-plane shear cumulative plastic strain is slightly affected by GTA preheating. Gas tungsten arc preheating increases the area of the positive shear strain region on the bottom (or corner) of the flange and the area of the negative shear strain region on the top of the flange. However, it is not clear if this observation and interpretation is right at this point.

Elastic Analysis and Postprocessing (Parts 2 and 3)

As discussed previously, it is not easy to figure out the relationship between cumu-

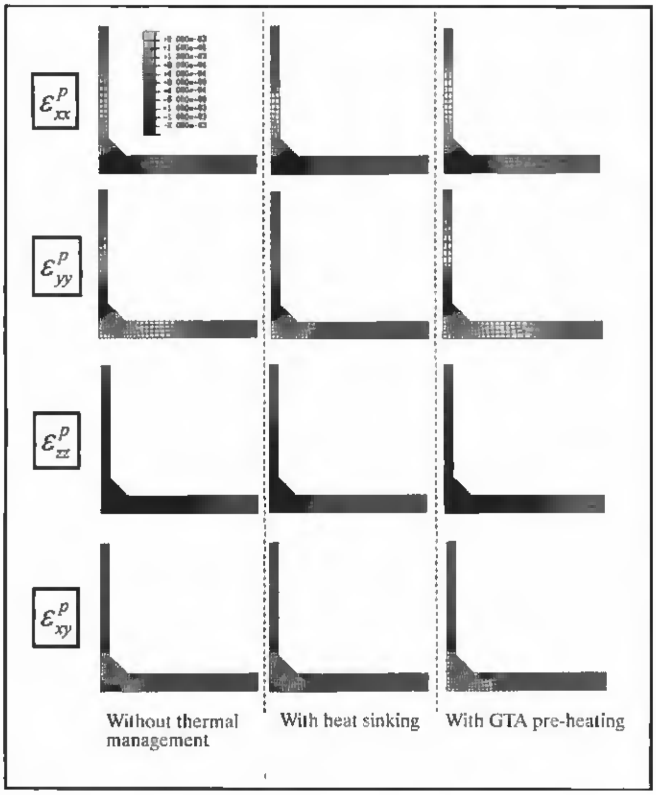


Fig. 22 — Comparison of typical cumulative plastic strain distribution patterns in the cases with different thermal management techniques.

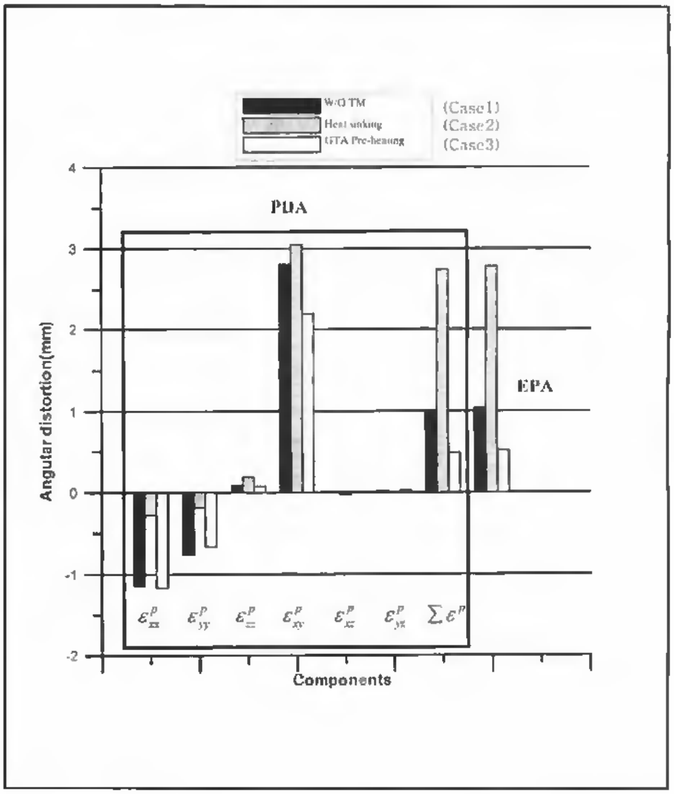


Fig. 23 — Comparison of averaged angular distortions calculated by EPA and PDA for the cases with different thermal management techniques.

lative plastic strains and angular distortion using only the results from the EPA. The PDA was performed to investigate the effect of the thermal management techniques on the relationship between cumulative plastic strains and angular distortion.

The individual and the total angular distortions are plotted and compared for Cases 1, 2, and 3 in Fig. 23. No matter what types of thermal management techniques are applied, the basic characteristic relationship between cumulative plastic strains and angular distortion is not changed: transverse and vertical cumulative plastic strains result in bend-down angular distortion, and longitudinal and xy-plane shear cumulative plastic strains generate bend-up angular distortion.

Figure 23 shows that heat sinking increases the bend-up individual angular distortion, reducing the bend-down angular distortion, and ultimately causing an increase in the total angular distortion. The main cause of the increase of the total angular distortion comes from the reduction of the bend-down angular distortion induced by the transverse and the vertical components. A relatively small increase of the angular distortion due to the longitudinal and the xy-plane shear components is shown. These results obtained from the PDA are similar to the ones discussed in the EPA based on the maps of the cumulative plastic strains, but provide more quantitative information.

On the other hand, GTA preheating does not significantly change the individual angular distortions except the one induced by the xy-plane shear cumulative plastic strain. The reduction of the total angular distortion by GTA preheating is mainly related to the reduced bend-up angular distortion induced by the xy-plane shear cumulative plastic strain only. In order to reduce the bend-up angular distortion, the negative xy-plane shear strain resulting in the bend-down angular distortion must act more dominantly to reduce the bend-up angular distortion than the positive one. Therefore, the wider region of the negative xy-plane shear cumulative plastic strain on the top surface of the flange as shown in Fig. 22, the smaller bend-up angular distortion.

Based on results from the PDA, it can be concluded that heat sinking increases the total bend-up angular distortion by reducing the bend-down angular distortions induced by the transverse and the vertical cumulative plastic strains, and GTA preheating reduces the total bend-up angular distortion by reducing the bend-up angular distortion induced by the xy-plane shear cumulative plastic strain.

In addition, in terms of optimizing the welding-induced distortion, the selection of thermal management techniques should be carefully performed. Based on this study, heat sinking can help to reduce buckling, but may result in more angular distortion. On the other hand, GTA preheating can reduce the angular distortion, but it may possibly result in buckling or a more transverse shrinkage because GTA preheating generates a wider plastic zone (Ref. 9).

Conclusions

The effect of external restraints and thermal management techniques on the relationship between cumulative plastic strains and angular distortion in fillet welded thin plate T-joints was discussed using results from the PDA. The major findings are summarized as follows.

1) The PDA successfully investigated the effect of the external restraints and the thermal management techniques on the relationship between cumulative plastic strains and angular distortion.

2) Angular distortion was reduced by increasing the degree of external restraining applied on the flange of T-joints. The PDA showed that the reduction of the angular distortion by external restraints resulted from the increase of the bend-down angular distortion induced by the transverse cumulative plastic strain. The effect of the external restraints on other cumulative plastic strains was small enough to

be negligible.

3) Heat sinking increased the angular distortion. The PDA showed that heat sinking mainly controlled nominal cumulative plastic strains, such as transverse, vertical, and longitudinal components. The bend-down angular distortion induced by the transverse and the vertical components was reduced by heat sinking, which resulted in the increase in angular distortion. For other components, the change in angular distortion was relatively small, thus negligible.

4) Preheating with a gas tungsten arc reduced the angular distortion. The PDA showed that GTA preheating mainly controlled the contribution of the xy-plane shear cumulative plastic strain existing in and around the welded region. The reduction in angular distortion resulted from the reduction of the bend-up angular distortion induced by the xy-plane shear cumulative plastic strain.

References

1. Masubuchi, K. 1980. *Analysis of Welded Structures*. Pergamon Press.

2. Papazoglou, V. J., and Masubuchi, K. 1982. Numerical analysis of thermal stresses during welding including phase transformation effects. *Transactions of the ASME, Journal of Pressure Vessel Technology*, 104: 198–203.

3. Conrardy, C., and Dull, R. 1997. Control of distortion in thin ship panels. *Journal of Ship Production* 13(2): 85–92.

4. Park, S. C. 1998. Distortion mechanisms and control methodology for welding thin-plate panel structures. Ph.D. thesis, The Ohio State University, Columbus, Ohio.

5. Ohata, M., Toda, Y., Toyoda, M., and Takeno, S. 1999. Control of welding distortion in fillet welds of aluminum alloy thin plates. *Welding International* 13(12): 967–976.

6. Michaleris, P., and Debiccari, A. 1997. Prediction of welding distortion. *Welding Journal* 76(4): 172-s to 181-s.

7. Michaleris, P., and Sun, X. 1997. Finite element analysis of thermal tension techniques mitigating weld buckling distortion. *Welding Journal* 76(11): 451-s to 457-s.

8. Ma, N. X., Ueda, Y., Murakawa, H., and Maeda, H. 1995. FEM analysis of 3-D welding residual stresses and angular distortion in T-type fillet welds. *Transactions of JWRI* 24(2): 115–122.

9. Han, M. S. 2002. Fundamental studies on welding-induced distortion in thin plate. Ph.D. dissertation, The Ohio State University, Columbus, Ohio.

10. Jung, G. H. 2003. Plasticity-based distortion analysis for fillet welded thin plate T-joints. Ph.D. dissertation, The Ohio State University, Columbus, Ohio.

11. Ueda, Y., and Yuan, M. G. 1993. Prediction of residual stresses in butt welded plates using inherent strains. *Transactions of the ASME, Journal of Engineering Materials and Technology* 115(10): 417–423.

12. Yuan, M. G., and Ueda, Y. 1996. Prediction of residual stresses in welded T- and I-joints using inherent strains. *Journal of Engineering Materials and Technology* 118(4): 229–234.

13. *ASM Handbook* Volume 6. 2000. Welding, Brazing, and Soldering. ASM International.

14. *ABAQUS User's Manual*. 1998. HKS Co., USA.

15. Mg Database. International Magnesium Association. (*http://www.intlmag.org/*)

16. Goldak, J., Charkravarti, A., and Bibby, M. 1984. New finite element model for welding heat sources. *Metallurgical Transactions B* 15B: 300–305.

17. Chabochi, J. L. 1986. Time independent constitutive theories for cyclic plasticity. *International Journal of Plasticity* 2(2): 247–302.

18. Sizemore, J. 1994. Control of residual stresses and distortion in thin section panel fabrication: Review of welding processes and procedures Revision A. Ingalls Shipbuilding.

CALL FOR PAPERS
WELDING FOR PIPELINE AND ENERGY APPLICATIONS SYMPOSIUM

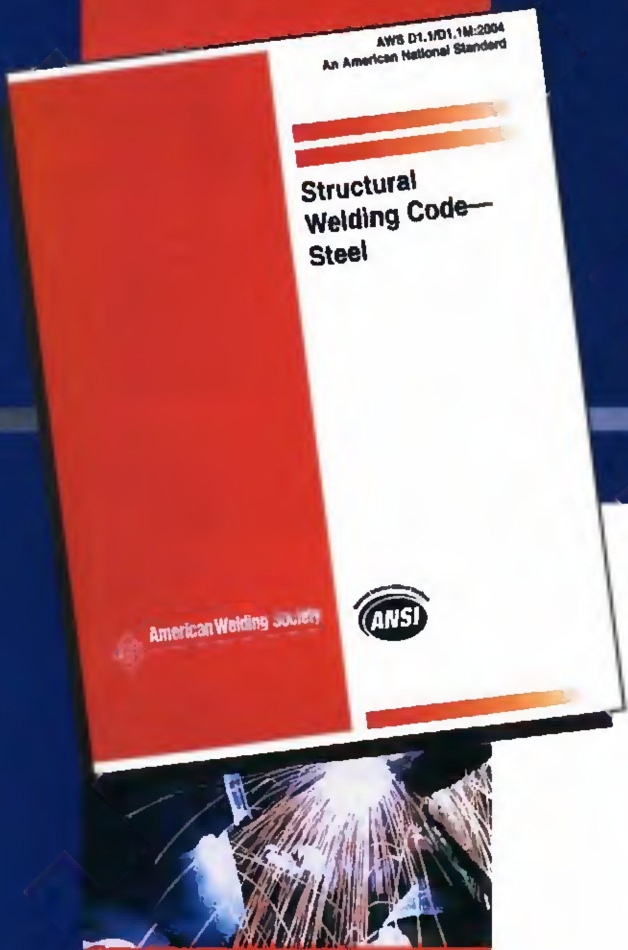
Papers are sought on the welding and joining of products and components related to pipeline and energy applications. Authors are encouraged to submit a 500 to 1,000-word abstract by July 30th, 2004, to be considered for presentation at the 2005 Symposium on Welding for Pipeline and Energy Applications. The two-day Symposium is taking place in conjunction with the 53rd annual AWS Welding Show, April 26 through April 28 at the Dallas Convention Center in Dallas, Texas.

Papers representing original experimental investigations, theoretical and statistical modeling, and applications in welding and joining for pipeline and energy applications are sought in the following areas:

- Properties and structural integrity of weldments
- Design and manufacture of welded structures
- Corrosion of weldments
- NDE of weldments
- Weldability of high-strength steel and aluminum alloy pipelines
- Weld phase transformations & microstructures
- Dissimilar welding and joining of graded materials
- Welding processes and procedures
- Innovative welding consumables
- Sensing, control and automation
- Computer modeling and simulation
- Advanced and alternative joining technologies
- Robotics and automation
- Application studies
- Others

To submit your abstract for consideration or for more information on the Symposium on Welding for Pipeline and Energy Applications, and all AWS programs and conferences, visit www.aws.org/conferences or contact Dorcas Troche, manager, conferences and seminars, via e-mail at dorcas@aws.org, or 800-443-9353, ext.313.

THE D1.1 CODE WEEK— IT CAN SHOW YOU WHAT YOU NEED TO KNOW TO USE THE CODE RIGHT.



At the D1.1 Code Week, you will learn all the information you need to keep your jobs trouble-free and up-to-code. These seminars provide the in-depth knowledge you need about the D1.1 *Structural Welding Code–Steel*, from the people who know it best—AWS.

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

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

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

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

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

AWS CODE WEEK IS COMING TO A CITY NEAR YOU:

**San Francisco, CA:
September 20-24**

**Philadelphia, PA:
October 11-15**

**Atlanta, GA:
November 8-12**

SPACE IS LIMITED SO REGISTER EARLY.

American Welding Society
550 NW LeJeune Road, Miami, FL 33126
www.aws.org

Circle No. 5 on Reader Info-Card

© American Welding Society 200[illegible] [illegible]

POWERCUT
POWERCUT
POWERCUT
DURABILITY
VALUE
PLASMARC
ESAB
POWERCUT
ESAB