WELDING Journal

April 2007

Welding Education

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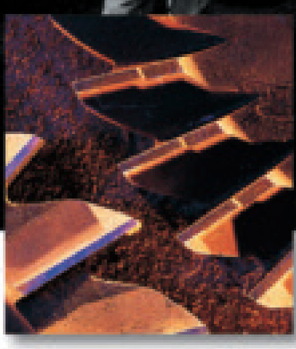
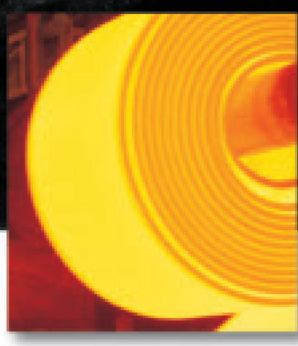
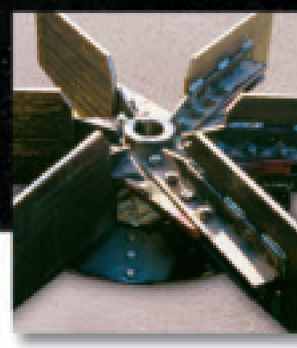
PUBLISHED BY THE AMERICAN WELDING SOCIETY TO ADVANCE THE SCIENCE, TECHNOLOGY AND APPLICATION OF WELDING AND ALLIED JOINING AND CUTTING PROCESSES, INCLUDING BRAZING, SOLDERING, AND THERMAL SPRAYING







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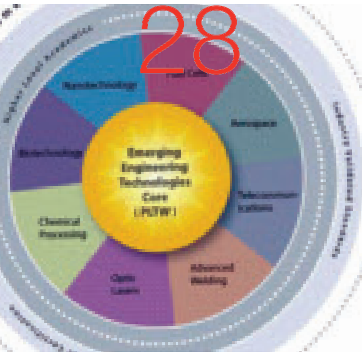

Features

The American Welder

Welding Research Supplement

Cover photo: A member of the Ironworkers Union uses the flux cored arc welding process to help build a high-rise. (Photo provided to the International Association of Bridge, Structural, Ornamental and Reinforcing Ironworkers by The Lincoln Electric Co., Cleveland, Ohio.)

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

Departments

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BY HUGH K. WEBSTER
AWS WASHINGTON GOVERNMENT AFFAIRS OFFICE

Record Set for Lobbying Expenditures

More than $1.26 billion was spent lobbying the U.S. Congress in the first half of 2006, according to disclosure reports filed under the federal Lobbying Disclosure Act. This represents a 5% increase over the previous 6-month period, and is a record amount. The top lobbying issue, in terms of money spent, was healthcare, and the largest lobbying organization was the U.S. Chamber of Commerce.

Revised Final Electrical Equipment Standard

The U.S. Occupational Safety and Health Administration has published a final rule on the design and installation of electric equipment in the workplace. The current standard, *29 CFR 1910*, had not been updated in more than 25 years. The revised rule largely reflects the 2000 edition of the National Fire Protection Association's *Electrical Safety Requirements for Employee Workplaces* (*NFPA 70E®*) and the 2002 edition of the *National Electrical Code®*.

There are several references to welding equipment in the Preamble to the rule, which is published in the Federal Register, *72 Fed. Reg. 7135-7221*.

Hexavalent Chromium Litigation Moves Slowly

The deadline for filing briefs in the lawsuits challenging the Occupational Safety and Health Administration's final hexavalent chromium rule has been extended once again, this time until mid-April. Both organized labor and industry representatives have challenged the standard's permissible exposure limit (PEL) of five micrograms per cubic meter of air, with labor arguing the PEL is too high to protect workers, and affected industries maintaining that it is too low and infeasible.

The deadline for filing briefs in the lawsuits challenging the OSHA's final hexavalent chromium rule has been extended until mid-April. Organized labor and industry representatives have challenged the standard's permissible exposure limit of five micrograms per cubic meter of air.

The rule became generally effective in November 2006, except for firms with fewer than 20 employees, which have until May 30, 2007. The engineering control provisions will not be effective until May 31, 2010.

Export Controls Considered for 'Diversion Destinations'

The U.S. Department of Commerce is considering imposing additional license requirements for exports to certain countries that have recently been involved in the redirection or transshipment of goods to terrorists and state sponsor of terrorism. Recently proposed amendments to the Export Administration Regulations would create a new "Country Group C" consisting of countries that are considered "Destinations of Diversion Concern." Exports to the countries likely to be included in this new Group C currently are not subject to burdensome licensing requirements.

As a result of being placed into Country Group C, the current, relatively relaxed licensing policy would likely change for items going to any country designated as a "Destination of Diversion Concern." Such changes could mean that more license applications might be required; more stringent license review policies might be implemented, which could result in less approvals or more conditions on licenses; authorizations may be delayed because of increased end-user checks; or authorizations may decrease because of diversion risks for such countries.

OSHA Violation Citations

The U.S. Occupational Safety and Health Administration issued more than 9000 citations to employers last year for violations of its hazard communication regulations, the most cited OSHA regulation for fiscal year 2006. Other leading areas of OSHA citations were as follows: fall protection (unprotected sides and edges); machine guarding (guarding methods); head protection (protective helmets); scaffolds; and general safe and healthful conditions.

Lawsuit Regarding Payment for Personal Protective Equipment

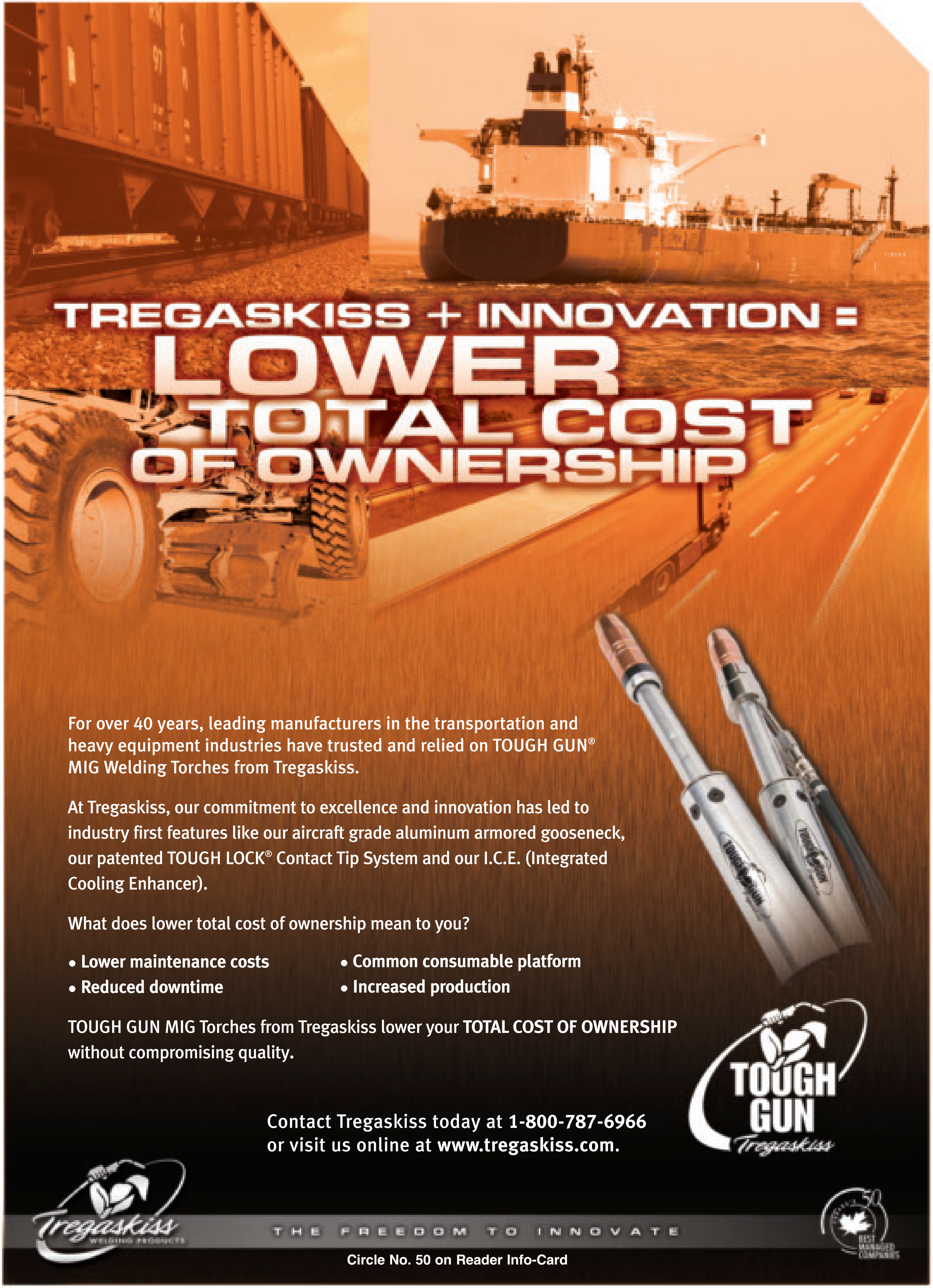
A lawsuit has been filed against the Occupational Safety and Health Administration (OSHA) based on the failure of OSHA to issue a final rule regarding responsibility for payment for personal protective equipment (PPE). A decision issued by the Occupational Safety and Health Review Commission in October 1997 determined that employers need not pay for employees' personal protective equipment, but in March 1999, OSHA formally proposed a standard requiring employers to pay for the costs of PPE (*64 Fed. Reg. 15,401*). It is that standard that the union plaintiffs are asking a court to compel OSHA to finalize. In April 2006, the agency said it planned final action on the rule by September 2006, but the most recent regulatory agenda released in December says final action is now slated for May 2007.

New Ethics Rules for Large Federal Contractors

The Civilian Agency Acquisition Council and the Defense Acquisition Regulations Council, which oversee the Federal Acquisition Regulation (FAR), are planning amendments to the FAR that would require federal contractors receiving awards worth more than $5 million and involving work in excess of 120 days to adopt a written "code of ethics and business conduct" and fraud hotline posters. Citing "the significant sums of federal dollars spent by agencies to acquire goods and services," the Councils expressed the view that a "clear and consistent policy regarding contractor code of ethics and business conduct [and] responsibility to avoid improper business practices" is reasonable and necessary.

The use of federal contractors has increased significantly in recent years, with the amount spent by the government having doubled since 2000, from $207 to $400 billion. ♦

Contact the AWS Washington Government Affairs Office at 1747 Pennsylvania Ave. NW, Washington, DC 20006; e-mail hwebster@wc-b.com*; FAX (202) 835-0243.*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Orders for Robots Fell in 2006

According to statistics from the Robotic Industries Association (RIA), Ann Arbor, Mich., North American robotics companies experienced a record year for orders from nonautomotive users in 2006, but it was not enough to offset the steep decline in robot sales to automotive companies. As a result, new orders to North American companies fell 30% for the year.

In 2006, a total of 12,765 robots valued at $904.2 million were sold to North American companies, a decline of 30% in units and 22% in revenue from 2005. When sales to companies outside North America are added in, North American robotics companies total sales were 13,791 robots valued at $958.4 million, down 29% in units and 22% in revenue.

"The most interesting result from 2006 is that nonautomotive orders reached the highest mark since we've been tracking the data this way," said Donald A. Vincent, executive vice president of RIA. Nonautomotive orders accounted for 44% of total orders last year, compared with just 30% in 2005.

"Our members understand that while the automotive industry has traditionally been and remains the largest customer for robotics, changes are occurring in the auto industry that may negatively impact future robot sales to automotive OEMs and their suppliers," said Vincent. "Therefore, it becomes more important than ever to find new markets, which is what we're seeing happen."

General Dynamics NASSCO Delivers Second T-AKE Ship

General Dynamics NASSCO, San Diego, Calif., a wholly owned subsidiary of General Dynamics, recently delivered USNS *Sacagawea* (T-AKE 2) to the U.S. Navy. The ship is named in honor of the Native American woman who helped guide and interpret for Meriwether Lewis and William Clark during their legendary exploration of the American West in the early 1800s.

Construction of USNS *Sacagawea* began in September 2004. The ship is the second in an expected class of 11 dry cargo-ammunition ships for the Navy. The T-AKE class incorporates international marine technologies and commercial ship-design features to minimize operating costs during its projected 40-year service life.

Sacagawea's primary mission will be to deliver food, ammunition, fuel, and other provisions from shore stations to combat ships at sea. The 689-ft-long ship has modular cargo holding and handling systems onboard and can carry more than 6600 tons of dry cargo and nearly 23,500 barrels of fuel.

Toyota to Build *Highlanders* in Mississippi

Mississippi Governor Haley Barbour recently joined Toyota officials to announce that the company has chosen a 1700-acre site in Blue Springs, Miss., to build its eighth North American vehicle assembly plant.

The facility will have the capacity to build 150,000 vehicles annually of Toyota's *Highlander* sport utility vehicle. Production is scheduled to begin by 2010.

Also, the plant represents a $1.3 billion investment by the company and is expected to create approximately 2000 new jobs for the region and indirectly create work for many more. Operations at the plant will include stamping, body weld, plastics, paint, and assembly.

BOC Gases Expands Distributor Network

BOC, Murray Hill, N.J., a member of The Linde Group, a global industrial gases and engineering company, recently signed a multiyear supply agreement with Superior Welding Supply Co. of Waterloo, Iowa.

Superior is a privately owned retailer of welding equipment, safety supplies, and industrial, medical, and specialty gases. The company has been in business since 1929, and it employs 46 people in two locations in Dubuque and Waterloo, Iowa.

In addition, Superior chose to join the Airco Distributor Association, the buying group exclusively available to BOC distributors.

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Learn All You Can

Most American Welding Society officers have special concerns or causes that are important to them as they serve the Society. Those concerns or causes usually reflect the portion of the welding industry we are involved in and does not mean we are single minded — they are in addition to the general good of the Society. For instance, my background mostly has been related to sales and working directly with people (customers) to help solve problems and promote the products I represent. The term "salesman" sometimes seems to be a throwaway — think used-car salesman or door-to-door salesman — rather than denoting a profession. That's why I'm standing up for the "welding products salesman."

We sell to the smartest customers in industry, who are welding ships, buildings, bridges, refineries …well the list just gets too long. The sales part doesn't just happen, it requires training, practice, and, most of all, preparation. Recently, a territory sales manager in the Northwest, who has been in the industry for more than 25 years, wanted to bring more to the table for his customers. Therefore, he took the AWS Certified Welding Inspector prep course and the CWI test. (I'd like to send my congratulations to him because he passed and now is a CWI.) His motivation was not to work as an inspector, but about bringing more credentials to the job and knowing that this additional knowledge may come in handy when helping customers.

More of us in sales need to take whatever training we can. I realize much of the training available to salespeople is vendor related as to the company they work for or, if you're a salesperson for a welding distributor, through the vendor your company sends you to. This training can be excellent, so take as many classes as you can as often as you can. I have a wall full of certificates for courses taken over my 34 years in the industry. I did take the CWI training class 20 years ago, but didn't take the test. Why not you ask? Well, I was in sales and figured it wasn't my job, but I wish I had paid the money to test because I respect the title of CWI.

I believe there are many salespeople out there who think "certifications" are only for the engineers or production managers. My thought today is that they are mistaken. You'll do yourself a great service if you get training from the AWS in the form of certifications or through the technical sessions that are a big part of the FABTECH International & AWS Welding Show. I realize doing so is not easy, but it is rewarding if you can pull it off.

I hope the American Welding Society can soon offer a certification aimed at "salesmen." Work is being done to create a Certified Welding Salesman (CWS) program that would provide salespeople who passed the test with a card to carry that would serve as a record of their knowledge and accomplishments. I think any certification program regarding sales should look at all aspects of a job, for instance, gases, electricity, metallurgy, welding, cutting, and removal. To be of value, the test would have to be difficult like the one for Certified Welding Inspectors. If developed properly, I believe employers and customers would appreciate and respect the certification. I just want "us" salespeople to be the best we can be. Programs like this are put together by volunteer committees of people such as yourself. You can easily provide your input by becoming a volunteer. Believe me, there are plenty of committees that could benefit from your knowledge.

Currently, there are about 600,000 welders in the United States, with another 200,000 needed. There are also at least 80,000 people involved in management and sales that make the connection to the market. We must be the best we can be to help make sure the right products get to the right people and that those same people have confidence in those of us who are in the supply chain.

Gene E. Lawson
AWS vice president

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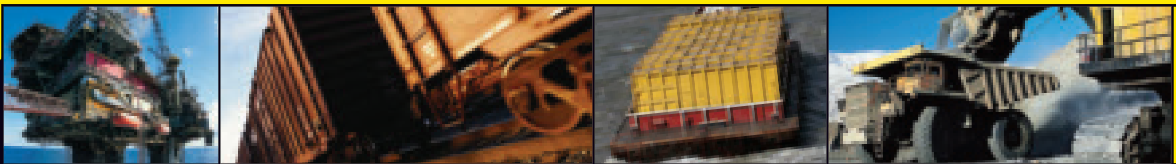

X·SERIES

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Lincoln Electric Forms Agreement with Robert Yates Racing

Lincoln Electric recently formed a team-supplier agreement with Robert Yates Racing, home of three NASCAR teams, including David Gilliland of the #38 M&M's car.

With this year's NASCAR racing season ramping up, Lincoln Electric, Cleveland, Ohio, has formed a team-supplier agreement with Robert Yates Racing.

The partnership begins immediately with the company supplying the team with a full range of welding and cutting equipment, technical training, and welding application support.

In addition, the program will help ensure the team maintains a high standard of safety, weld integrity, and performance on the track and in the shop.

Robert Yates Racing is owned by industry veteran Robert Yates, who is also considered one of the sport's premier engine builders. He runs the business with his son, Doug Yates.

"This relationship guarantees that our guys have access to the latest welding and cutting technology and equipment, a vital link to our teams' success," said Robert Yates.

Aluminum Stretch Former to Manufacture Aircraft Components in China

Erie Press Systems, Erie, Pa., has shipped a 440-ton aluminum sheet stretch forming machine to Changhe Aircraft Industries in Jiangxi Province, China. The press will be used to form fuselage sections for the company's new series helicopters. The sheet stretch former is a combination longitudinal/transverse type press with "curving jaws" used to stretch-form sheet metal panels and large extrusions. The base machine, STC400M – 3200-6000 CNC, includes independent jaw rotation for flexibility, and a full floor-plate with coverage between the forming jaws to protect workers and provide convenient die changes. The system also includes spare parts, a fully automatic powered die table rotation, a 1200 KN ton gantry-type bulldozer, and 1600-mm-long and 100-metric-ton-capacity accessory jaws.

Asian Welding Show Celebrating 20th Anniversary in China

The Beijing Essen Welding & Cutting Fair is celebrating its 20th anniversary in Shanghai, China.

Debuting in 1987, the show has grown steadily at the same pace as the Chinese economy. Now a yearly event, alternately held in Beijing and Shanghai, it ranks as the second-largest welding show worldwide, trailing its sister show Schweissen & Schneiden in Essen, Germany.

The 12th Beijing Essen Welding & Cutting Fair will be held this year at the Shanghai New International Expo Center from June 19 to 22. A 17% increase in exhibition space with about 700 exhibitors from 20 countries and about 30,000 visitors from more than 70 countries and regions are expected.

This show is sponsored by the Chinese Mechanical Engineering Society (CMES); Welding Institution of CMES; China Welding Association; Electric Welding Machine Committee of CEEIA; German Welding Society; and Messe Essen GmbH; and cosponsored by the American Welding Society; Korea Welding Industry Cooperative; and The Japan Welding Engineering Society.

For more information, visit *http://essen.cmes.org*.

College of DuPage and Caterpillar Team to Offer Students Practical Experience

College of DuPage (C.O.D.), Glen Ellyn, Ill., recently joined forces with Caterpillar Inc.'s Education to Careers (ETC) program to offer high school seniors and first-semester college students a chance to work at the Aurora, Ill., plant while obtaining a degree from the college in the technical/manufacturing field.

The internship program pays for two years of tuition and fees, as students work part time at Caterpillar and earn their associate's degree. Additionally, the students take part in a paid, full-time summer internship to round out their hands-on training and incorporate the variety of skills they have learned during the program.

"This is a great opportunity for students who are interested in having a hands-on career in a technical field of some sort, but aren't exactly sure which area would be best for them," said Mark Meyer, who coordinates the ETC Caterpillar internship program for C.O.D. "During the internship, students are rotated through different jobs, positions and departments at Caterpillar so they can experience first-hand the types of opportunities that exist within a world-class manufacturing environment."

The company's 350-acre Aurora site is the largest of the more than 100 Caterpillar facilities located in the United States and 22 countries worldwide. The 4500-sq-ft plant mainly manufactures wheel loaders and excavators.

Currently, the need for employees in the technical/manufacturing field at Caterpillar Inc. is "at an all-time high," said Nev Milanovic, Education to Careers coordinator at the Aurora, Inc., manufacturing facility.

KUKA to Provide Robotics for Center at Ohio Northern University

Dr. Kendall L. Baker, president of Ohio Northern University, cuts the ribbon at the university's new robotics technology center with the help of Leroy Rodgers, president of KUKA Robotics. The center, powered by KUKA Robotics technology, provides hands-on automation design and programming experience.

KUKA Robotics Corp., Clinton Township, Mich., has been selected by Ohio Northern University (ONU) to provide robotics for its newly remodeled and expanded robotics technology center.

The center — to be named the "ONU Robotics Technology Center of Excellence, powered by KUKA Robotics Corporation" — will provide students with hands-on design and programming experience using the company's robots, controllers, and software. The university opened the center located in Taft Memorial Hall on South Union Street in Ada, Ohio, on January 26.

The ONU center is a part of its Department of Technological Studies, and is in the College of Arts and Sciences. Currently, it has seven KR3 robots. Five of the robots are being interfaced to PLCs and CNC machines in a simulated manufacturing environment; performing loading, unloading, and part-transfer functions. Two are slated to be used by ONU's award-winning competitive traveling robotics team for competitions.

Industry Notes

- The National Center for Construction Education and Research, Gainesville, Fla., and FMI have partnered to develop a comprehensive career development map with joint credentialing for the construction industry. The map will outline recommended training, education, and development programs from entry-level craft professionals to executive leadership. This industry tool will also help employers and employees with making decisions about investing in training and informed career choices.

- ATI Industrial Automation, Apex, N.C., an engineering-based developer of robotic peripheral equipment, is breaking ground on a new plant expansion. "High demand for our robotic end-effector products dictated the need for additional engineering, manufacturing, and inventory capacity," said Keith Morris, the company's president. "Our new facility will double our space with a provision to triple our space in the future."

- Mid-State Chemical Supply Corp., Indianapolis, Ind., has changed its name to MS Fluid Technologies, an initiative complemented with a revised logo and new tagline 'Solutions for Manufacturing.' The company continues to be led by CEO Paul Bosler Jr. and owned by Bosler and his three brothers.

- Fronius USA LLC, an Austrian-established company, a supplier of welding technology equipment, has moved to larger facilities in Brighton, Mich.

- Abbott Furnace Co., St. Marys, Pa., a manufacturer of continuous belt industrial furnaces, has launched an upgrade and expansion of its Web site at *www.abbottfurnace.com*. Among the site's features are the following: updated and expanded product pages covering the range of the company's products; a full suite of downloadable brochures; and easier, more direct navigation with pull-down menus.

- AK Steel Corp. will move its corporate headquarters into a new, technology-ready building totaling 136,000 sq ft currently under construction at Centre Pointe in Union Centre, West Chester, Ohio. The company will relocate about 300 corporate office positions housed in Middletown, Ohio, to the new building in the third quarter of 2007.

- August Mack Environmental, Inc., a full-service environmental, health, and safety consulting firm, has opened a new office in St. Louis, Mo. It is targeted to serve Missouri, southern Illinois, and eastern Kansas. Environmental Engineer and Project Manager Eric Emmett, P.E., has been named manager of the office.

Author Corrects Article on Gas Purging

M. Fletcher submits the following correction to his article, Gas Purging Optimizes Root Welds, published in the December 2006 *Welding Journal* pp. 38–40.

Further to communications received from the AWS Welding Journal, *I agree that for successful welding of most stainless steels, an oxygen content in the purge gas of less than 0.1% is desirable. To clarify the situation on page 40 (bottom of second column), I offer the following amended text: While 1% residual oxygen is a suitable working level for some ferrous materials, most stainless steels can only be successfully welded with a purge gas oxygen level below 0.1%. The level needs to be as low as 20 ppm when welding the more sensitive alloys based on titanium and other reactive metals.*

BY TONY ANDERSON

Q: Recently, I moved into the aluminum fabrication industry. I have worked with steel fabrication for many years, and I am very familiar with the common structural steel alloys; however, I do not know the alloy numbering system for aluminum. Can you please explain how the aluminum material numbering system works and advise me on where I can find detailed information about the aluminum alloys?

A: In North America, The Aluminum Association, Inc., is responsible for the allocation and registration of aluminum alloys. Currently, there are more than 400 wrought aluminum and wrought aluminum alloys and more than 200 aluminum alloys in the form of castings and ingots registered with the Aluminum Association. The alloy chemical composition limits for all of these registered alloys are contained in The Aluminum Association's *Teal Sheets — International Alloy Designations and Chemical Composition Limits for Wrought Aluminum and Wrought Aluminum Alloys,* and in its *Pink Sheets — Designations and Chemical Composition Limits for Aluminum Alloys in the Form of Castings and Ingot*. These publications can be extremely useful to the welding engineer when developing welding procedures and when considering chemistry for crack sensitivity purposes.

Table 1 — Wrought Aluminum Alloy Designation System

Alloy Series	Principal Alloying Element
1xxx	99.000% Minimum Aluminum
2xxx	Copper
3xxx	Manganese
4xxx	Silicon
5xxx	Magnesium
6xxx	Magnesium + Silicon
7xxx	Zinc
8xxx	Other Elements

Table 2 — Cast Aluminum Alloy Designation System

Alloy Series	Principal Alloying Element
1xx.x	99.000% Minimum Aluminum
2xx.x	Copper
3xx.x	Silicon + Copper and/or Magnesium
4xx.x	Silicon
5xx.x	Magnesium
6xx.x	Unused Series
7xx.x	Zinc
8xx.x	Tin
9xx.x	Other Elements

The Aluminum Association categorizes aluminum alloys into a number of groups based on the particular material's characteristics, such as its ability to respond to thermal and mechanical treatment, and the primary alloying element added to the aluminum alloy. The numbering/identification system used for aluminum alloys recognizes the above characteristics. The wrought and cast aluminums have different systems of identification — the wrought having a 4-digit system, and the castings having a 3-digit and 1-decimal place system.

Wrought Alloy Designation System

In the 4 digit wrought aluminum alloy identification system, the first digit (Xxxx) indicates the principal alloying element, which has been added to the aluminum alloy and is often used to describe the alu-

Table 3 — The Basic Temper Designations

Letter	Meaning
F	As fabricated — Applies to products of a forming process in which no special control over thermal or strain-hardening conditions is employed.
O	Annealed — Applies to product that has been heated to produce the lowest strength condition to improve ductility and dimensional stability.
H	Strain Hardened — Applies to products that are strengthened through cold working. The strain hardening may be followed by supplementary thermal treatment, which produces some reduction in strength. The "H" is always followed by two or more digits (see Table 4).
W	Solution Heat Treated — An unstable temper applicable only to alloys that age spontaneously at room temperature after solution heat treatment.
T	Thermally Treated — To produce stable tempers other than F, O, or H. Applies to product that has been heat treated, sometimes with supplementary strain hardening, to produce a stable temper. The "T" is always followed by one or more digits (see Table 5).

minum alloy series, i.e., 1000 series, 2000 series, 3000 series, up to 8000 series (Table 1).

The second single digit (xXxx), if different from 0, indicates a modification of the specific alloy, and the third and fourth digits (xxXX) are arbitrary numbers given to identify a specific alloy in the series. For example: In Alloy 5183, the number 5 indicates that it is of the magnesium alloy series, the 1 indicates that it is the 1st modification to the original Alloy 5083, and the 83 is the materials number within the 5xxx series alloys.

The only exception to this alloy numbering system is with the 1xxx series aluminum alloys (pure aluminums), in which case, the last 2 digits provide the minimum aluminum percentage above 99%, i.e., Alloy 1350 (99.50% minimum aluminum).

Cast Alloy Designation

The cast alloy designation system is based on a 3 digit-plus decimal designation xxx.x (i.e., 356.0). The first digit (Xxx.x) indicates the principal alloying element, which has been added to the aluminum alloy (Table 2).

The second and third digits (xXX.x) are arbitrary numbers given to identify a specific alloy in the series. The number following the decimal point indicates whether the alloy is a casting (.0) or an ingot (.1 or .2). A capital letter prefix indicates a modification to a specific alloy.

For example, in Alloy A356.0, the capital A (Axxx.x) indicates a modification of Alloy 356.0. The number 3 (A3xx.x) indicates that it is of the silicon plus copper and/or magnesium series. The 56 (Ax56.0) identifies the alloy within the 3xx.x series, and the .0 (Axxx.0) indicates that it is a final shape casting and not an ingot.

The Aluminum Temper Designation System

Considering the different series of aluminum alloys, there are significant differences in their characteristics and consequent applications. After understanding the identification system, recognize there are two distinctly different types of aluminum within the series mentioned above. These are the *heat-treatable aluminum alloys* (those which can gain strength through the addition of thermal treatment) and the *nonheat-treatable aluminum alloys*. This distinction is particularly important when considering the effects of arc welding on these two types of materials.

The 1xxx, 3xxx, and 5xxx series wrought

Table 4A — Subdivisions of H Temper — Strain Hardened[(a)]

Number	Meaning
H1	Strain Hardened Only
H2	Strain Hardened and Partially Annealed
H3	Strain Hardened and Stabilized
H4	Strain Hardened and Lacquered or Painted

(a) The first digit after the H indicates a basic operation.

Table 4B — Subdivisions of H Temper — Strain Hardened[(a)]

Number	Meaning
HX2	Quarter Hard
HX4	Half Hard
HX6	Three-Quarters Hard
HX8	Full Hard
HX9	Extra Hard

(a) The second digit after the H indicates the degree of strain hardening.

Table 5A — Subdivisions of T Temper — Thermally Treated[(a)]

Number	Meaning
T1	Naturally aged after cooling from an elevated temperature shaping process, such as extruding
T2	Worked after cooling from an elevated temperature shaping process and then naturally aged cold
T3	Solution heat treated, cold worked, and naturally aged
T4	Solution heat treated and naturally aged
T5	Artificially aged after cooling from an elevated temperature shaping process
T6	Solution heat treated and artificially aged
T7	Solution heat treated and stabilized (overaged)
T8	Solution heat treated, cold worked, and artificially aged
T9	Solution heat treated, artificially aged and cold worked
T10	Cold worked after cooling from an elevated temperature shaping process and then artificially aged

(a) The first digit after the T indicates the operations used during heat treatment.

Table 5B — Subdivisions of T Temper — Thermally Treated[(a)]

Numbers	Meaning
TX51 or TXX51	Stress relieved by stretching
TX52 or TXX52	Stress relieved by compressing

(a) Additional digits after the T indicate stress relief.

aluminum alloys are nonheat treatable and are strain hardenable only. The 2xxx, 6xxx, and 7xxx series wrought aluminum alloys are heat treatable and the 4xxx series consist primarily of nonheat-treatable alloys but contain some alloys that are heat treatable. The 2xx.x, 3xx.x, 4xx.x, and 7xx.x series cast alloys are heat treatable. Strain hardening is not generally applied to castings.

The heat-treatable alloys acquire their optimum mechanical properties through a process of thermal treatment. The most common thermal treatments are solution heat treatment and artificial aging.

Solution heat treatment is the process of heating the alloy to an elevated temperature (around 990°F) in order to put the alloying elements or compounds into solution. This is followed by quenching, usually in water, to produce a supersaturated solution at room temperature. Solution heat treatment is usually followed by aging. Aging involves the precipitation of a portion of the elements or compounds from a supersaturated solution in order to yield desirable properties. The aging process is divided into two types: aging at room temperature, which is termed natural aging, and aging at elevated temperatures termed artificial aging. Artificial aging temperatures are typically about 320°F. Many heat-treatable aluminum alloys are used for welding fabrication in their solution heat treated and artificially aged condition.

The nonheat-treatable alloys acquire their optimum mechanical properties through strain hardening. Strain hardening is the method of increasing strength through the application of cold working.

The temper designation system addresses the material conditions called tempers. This is an extension of the alloy numbering system and consists of a series of letters and numbers, which follow the alloy designation number and are connected by a hyphen. Examples are as follows: 6061-T6, 6063-T4, 5052-H32, 5083-H112, 4043-F, and 6063-O. The basic temper designations are F, O, H, W, and T, and are described in Table 3.

In addition to the basic temper designation, there are two subdivision categories — one addressing the "H" temper — strain hardening (as shown in Tables 4A and 4B) and the other addressing the "T" temper — thermally treated designation (as shown in Tables 5A and 5B).

Summary

Today's aluminum alloys, together with their various tempers, comprise a wide and versatile range of manufacturing materials. For optimum product design and successful welding procedure development, it is important to understand the differences between the many alloys available and their various performance and weldability characteristics. When developing arc welding procedures for these different alloys, give consideration to the specific alloy being welded. It is often said that arc welding of aluminum is not difficult, "it's just different." I believe that an important part of understanding these differences is to become familiar with the various alloys, their characteristics, and their identification system.

Where to Find Information about the Aluminum Alloys

There are a number of excellent reference sources available exclusively addressing aluminum and aluminum welding. The Aluminum Association's *Welding Aluminum: Theory and Practice* provides a broad selection of aluminum welding topics. Another source is the American Welding Society's (AWS) D1.2, *Structural Welding Code — Aluminum*. This document provides information related to welding procedure and welder performance qualification and inspection and testing for aluminum welding. Other documents available from The Aluminum Association that assist with the design of aluminum structures are the *Aluminum Design Manual* and *Aluminum Standards and Data*. These documents along with the alloy designation documents mentioned earlier in the article can be obtained directly from the AWS through WEX Ltd. at (888) 935-3464, *www.awspubs.com*, or The Aluminum Association at (703) 358-2977, *www.aluminum.org*, as appropriate.

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

BY R. L. PEASLEE

Q: When brazing assemblies for the nuclear industry, we are having a problem with the yield strength dropping below the required 30,000 lb/in.^{2} (206.8 MPa). Our customer purchased material with the proper yield strength, but after brazing, the yield strength drops by varying amounts. What would be the cause of the drop in yield strength?

A: This has been a perplexing problem. We have experienced the same drop in yield strength after brazing. In one brazement the yield strength reported by the supplier was 33,000 lb/in.^{2} (227.5 MPa) and after brazing at 1950°F (1066°C) the yield strength had dropped to 22,000 lb/in.^{2} (151.7 MPa).

In another brazement the yield strength was reported to be 35,000 lb/in.^{2} (241.3 MPa) and after brazing at 2150°F (1121°C) it dropped to 25,000 lb/in.^{2} (172.4 MPa). Other brazements had varying drops in the yield strength after brazing that appeared to make no sense.

We talked to many manufacturers of the stainless steel and nickel-based metals before getting a clue to the problem. We found that during processing, the mills hot worked and cold worked the base metal and that increased the tensile strength and the yield strength of the base metal. At the end of the processing, the base metal was given an in-process anneal to bring the material to the required physical properties. This worked very well when the base metal was fabricated by machining, or other processes, where the parts did not see high temperatures later during processing.

It was found that the in-process annealing temperature varied from heat to heat, and when some heats were in-process annealed, the annealing temperature could be below the brazing temperature. When brazements were made from these lots of base metal, the higher brazing temperature annealed the base metal more, and therefore the yield strength dropped. While these brazements were accepted, it was necessary to assure that the yield strength did not drop below the specified 30,000 lb/in.^{2} (206.8 MPa) yield minimum, on assemblies that were brazed. Therefore, it became standard to stipulate on any purchase order to a supplier that the in-process annealing temperature be above the required brazing temperature, when the assembly was to be brazed.♦

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

Wel-Handy Multi Stitch units (with optional WU-1 weaving) are shown welding up a "stiffener" for shipbuilding using a fillet weld. These units can be used in horizontal, vertical or incline positions.

AWS Joining Dissimilar Metals Conference
Orlando, Florida • Grosvenor Resort
May 22–23, 2007

One of the most discussed topics and sources of misunderstanding involves joining dissimilar materials by welding. Vendors probably receive more phone calls with questions on this subject than any other. The traditional codes are nearly silent on the issue. Many design, shop, or field organizations do not have—or have lost—expertise in this area.

This conference will address issues including material properties, weld properties, preheat/post-weld heat treatment, corrosion, the use of transition joints, service conditions, and practical considerations.

Even the most difficult-to-weld of all material combinations—steel to aluminum—has been welded satisfactorily using such techniques as explosion welding and magnetic pulse welding. New chemistries are coming to the aid of existing filler metals, making them more amenable to dissimilar metals welding. Filler metals based on nickel-base superalloy chemistries are also meeting the challenge. Advances in brazing technology are taking care of a host of metallurgical problems as well.

The problems are there, but so are the solutions.

The conference keynote address will be presented by Dr. Thomas Eagar from MIT, a noted expert in this most difficult area of welding.

Keynote address:
Dealing with Diversity in the Joining of Dissimilar Metals
Thomas W. Eagar, Professor, MIT, Cambridge, MA

"As product life cycles increase, and the need for fuel-efficient lightweight structures increases, designers are specifying both higher strength metals, as well as a greater diversity of metals. Fabrication of these structures in an economically efficient manner poses significant challenges, as our favored fusion welding processes are simply not practical (or possible) for many of these combinations of metals. Meeting these challenges requires both greater expertise of the fabrication engineer but also earlier involvement in the product design process."

Dissimilar Metal Weld Failures Involving Grade 91 Steel
Jeff Henry, Structural Integrity Associates, Inc., Chattanooga, TN

Advances in Friction Stir Welding and Application to Dissimilar Metal Joining
William J. Arbegast, NSAF Center for Friction Stir Processing, and Advanced Materials Processing and Joining Center, Rapid City, SD

Large-Area Soldering and Brazing of Dissimilar Materials with a Novel Heat Source
Dr. Timothy P. Weihs, Reactive NanoTechnologies, Inc., Hunt Valley, MD

CSC-Controlled Short Circuit Transfer – A New GMAW Process That Solves Old Weld Problems
Tom Rankin, ITW Jetline Engineering, Irvine, CA

Tensile Properties Evaluation of Dissimilar Welds in AL-6XN, DH-36, and A514 Gr. 2 Plate
Kim Tran, Surface Warfare Center Carderock Division (NSWC-CD), West Bethesda, MD

Magnetic Pulse Welding: Design and Analysis
Dr. James R. Dydo, Advanced Computational and Engineering Services, LCC (ACES), Gahanna, OH

Prediction of DMW Microsturctures
Dr. Damian J. Kotecki, The Lincoln Electric Company, Cleveland, OH

Explosion Welding – A Highly Versatile Welding Technology
John G. Banker, DMC Clad Metal, Boulder, CO

Alternative Filler Materials for DMWs Involving P91 Materials
Kent Coleman, Electric Power Research Institute, Charlotte, NC

Ultrasonic Welding of Dissimilar Metals
Dr. Karl Graff, Edison Welding Institute, Columbus, OH

The Way We Were – NDE from the Beginning
Mike Turnbow, Tennessee Valley Authority, Chattanooga, TN

Applications of Dissimilar Joint Metallurgy in the Chemical Process Industry
David Oulton, NOVA Chemicals (Canada) Ltd, Ontario, Canada

Inertia Friction Welding
Al Wadleigh, Interface Welding, Carson, CA

Conference price is $550 for AWS members, $680 for nonmembers. To register or to receive a descriptive brochure, call (800) 443-9353 ext. 223, (outside North America, call 305-443-9353), or visit www.aws.org/conferences

GMAW Shielding Gas Flow Control Systems

BY GERALD D. UTTRACHI

Typical changes in shielding gas flow restrictions caused by spatter in the welding gun nozzle, spatter clogging some of the welding gun gas diffuser ports, bends in the welding cable, or debris in the welding gun gas hose passages can be automatically compensated to maintain a preset flow. From the time the GMAW process was introduced, typical shielding gas flow systems utilize a minimum pressure of 170 kPa (25 lb/in.^{2}) as the output of regulator/flowmeters and flow gauge regulators for cylinder use or in pipeline gas supply. This pressure provides automatic flow compensation for the inevitable gas restrictions that occur in production.

Automatic Gas Flow Control

Self-compensating or automatic flow control is achieved by employing a minimum gas delivery pressure upstream of the shielding gas control orifice or valve. The phenomenon that creates this automatic flow compensation is referred to as critical orifice flow. In general, flow though an orifice is dependent on the upstream and downstream pressures. That is until the gas velocity in the orifice reaches the speed of sound. Once this flow velocity is reached, for a given upstream pressure, the flow rate stays the same regardless of the downstream pressure changes. When critical orifice flow is maintained, typical changes in flow restrictions caused by spatter in welding gun parts, gas hose bends, etc., have no effect on shielding gas flow. The downstream pressure automatically increases to compensate. No interaction by the welder is required.

Defining the pressure needed to have automatic flow compensation for restrictions that occur in production; the pressure upstream of the orifice or flow control valve must be more than 2.1 times (approximately twice) the downstream pressure. Both are measured as absolute pressure, which adds atmospheric pressure to the normal gauge reading — Fig. 1. The typical pressure needed to flow shielding gas at normal rates through a gas solenoid, plumbing, and welding gun is about 35 kPa (5 lb/in.^{2}) or stated as absolute pressure 135 kPa (20 lb/in.^{2} atm). Therefore, the pressure upstream of the flow control device should be about twice that amount or an absolute pressure of 270 kPa (40 lb/in.^{2} atm). When stated as normal gauge pressure, that is a minimum upstream pressure of 170 kPa (25 lb/in.^{2}).

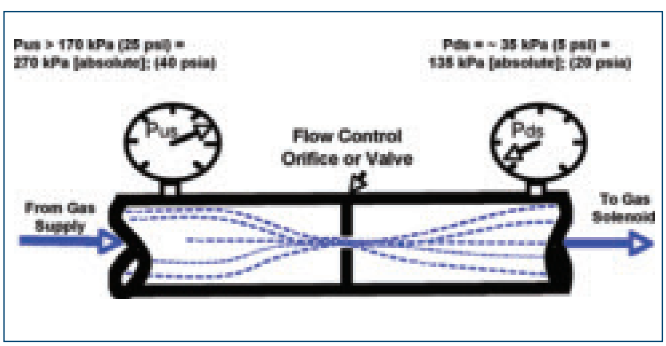


Fig. 1 — Automatic flow compensation requires the pressure upstream of the orifice or flow control valve to be greater than (approximately twice) the downstream pressure. Measured as absolute pressure = gauge reading + atmospheric pressure.

In flow tests reported by WA Technology with a typical system having a delivery pressure of 170 kPa (25 lb/in.^{2}), the flows remained consistent and at a preset level when the solenoid through gun restrictions were varied from 21 to 55 kPa (3 to 8 lb/in.^{2}). In similar tests conducted with a low-pressure system over the same restriction range, there was more than a 65% flow change with no manual change in the flow setting. When restrictions with the low-pressure system were varied over a smaller range of 24 to 48 kPa (4 to 7 lb/in.^{2}) the flow changed more than 35%.

Extra Shielding Gas Needed at Weld Start

It is important to have some extra shielding gas supplied at the weld start to quickly purge the welding gun nozzle and weld start area of moisture-ladened air. Stauffer, in a U.S. Patent in 1982 (Ref. 1), described the need, stating "... air leaks back into the torch and lines when welding is stopped. The air must be quickly purged and replaced with inert gas to produce high-quality welds. Also, it is critical to displace the air at the weld zone of the workpiece upon initiating the weld."

In normal gas delivery systems, extra gas flow is created by the higher delivery pressure building in the gas delivery hose when welding stops. Unfortunately, this excess gas exits the welding gun at a high velocity that creates turbulence in the shielding stream. This turbulence defeats the objective by pulling moisture-ladened air into the gas stream. Once started, the turbulent flow will continue for a short time even after the flow returns to the proper preset level. This entrained moist air creates inferior starts with excess spatter and possibly internal or even visible porosity. The high surge flow also wastes significant shielding gas (Ref. 2). The volume of excess gas in the delivery hose, measured at standard temperature and pressure, is much more than the physical hose volume due to the higher pressure developed in the hose when welding stops. Much of this excess volume exits at high velocity and is wasted on each weld start. The extra gas should exit the welding gun at a flow rate that produces laminar flow. To achieve this objective, the maximum flow rate is only somewhat higher than that typically employed during welding. Preflow can be utilized to accomplish the objective of having a gas purge. However, it must be set sufficiently long to overcome the time it takes for the surge flow to reduce below a turbulent flow rate. Depending on the delivery hose length, this has been measured to be up to several seconds. Preflow is often an irritant to a welder, particularly for tack or short welds, and may

GERALD D. UTTRACHI (guttrachi@aol.com) *is president, WA Technology LLC, Florence, S.C., and president, American Welding Society.*

be circumvented since there is a delay when the welding gun switch is pulled.

Methods of achieving a controlled amount of extra shielding gas at the start are defined in the Stauffer patent. Other more recent patents describe devices to control the volume and velocity of this extra gas while maintaining the pressure needed for automatic flow compensation (Ref. 3). For details of products that eliminate gas waste at the weld start while maintaining the minimum pressure needed for automatic flow compensation see *www.NetWelding.com.* Examples are presented of users of GMAW who reduced their total shielding gas use (waste) by up to 63% with improved weld starts.♦

References

1. Stauffer, H. R. 1982. Application and Method for Reducing the Waste of Shielding Gas. U.S. Patent Number 4,341,237.

2. Standifer, L. R. 2000. Shielding gas consumption efficiency. *Fabricator* 30(6).

3. Uttrachi, G. D. Welding Shielding Gas Flow Control Devices. U.S. Patent Numbers 6,610,957, 7,015,412, and 7,019,248. Also refer to *www.NetWelding.com*

Dear Readers:

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

Wire Minimizes Cleanup, Maximizes Portability

The Fabshield® 21B self-shielded flux cored wire eases postweld cleanup and increases portability. Designed for general-purpose welding, light fabrication, and for use on noncritical applications, the wire provides performance on fillet and lap welds on galvanized or mild steels measuring up to ¾ in. thick. In addition, it works on lightly primered steels. The wire requires no external shielding gas. It also produces a smooth spraylike transfer that produces low spatter levels with good bead appearances in all welding positions and can be used with a variety of power sources and using DCEN. The wire is offered in 0.045, 1⁄16, 0.068, 5⁄64, and 3⁄32 in. diameters on 10- or 33-lb spools. For higher-volume applications, the 1⁄16-in.-diameter wire on 50-lb coils is offered.

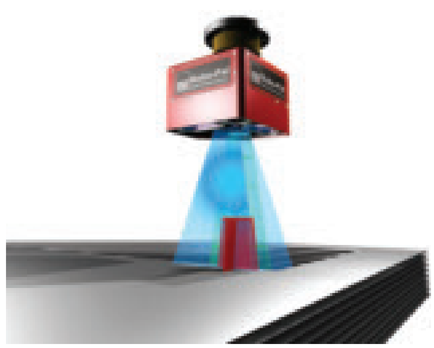
Hobart Brothers Co. 100
101 Trade Square East, Troy, OH, 45373

Gas Apparatus Toolbox Outfits Include Torches

The company's two toolbox outfits are designed for use with its hand-held, oxyacetylene welding and cutting product line. The PUROX® GT-510 outfit offers a combination of welding and cutting components, featuring PUROX® cutting tips. It includes the W-300 torch suitable for welding thin-gauge to ⅜-in. material; the Rosebud Jr. heating head with a heating range up to 30 ft^3/h acetylene (44,000 Btu/h); a CW-300 cutting attachment for cutting up to 1½-in. steel; 4200 series nozzle; and R-72 oxygen and acetylene regulators. The OXWELD® GT-510 outfit offers a combination of heavy-duty components. This kit includes the W-400 torch; CW-400 cutting attachment; 1500 series tip; the Rosebud Jr. heating head; and Trimline® R-76 oxygen and acetylene regulators. It offers a welding range up to ¼ in. and a cutting range up to 1½ in.

ESAB Welding & Cutting Products 101
PO Box 100545, 411 S. Ebenezer Rd., Florence, SC 29501-0545

Sensing System Increases Productivity of Robotic Material Handling



The ROBO-PAL smart hybrid sensing system is a noncontact digital part locator and measurement tool designed to increase the productivity and reliability of robotic material handling. The sensor system control is embedded and communicates with the process engineering control platform where integrators can benefit from preengineered function libraries to develop the application. This sensor head also includes an ultrasonic long-range device, a dual 3D laser vision system for medium-range precision measurements, and a smart camera module for audio and video monitoring of the work cell.

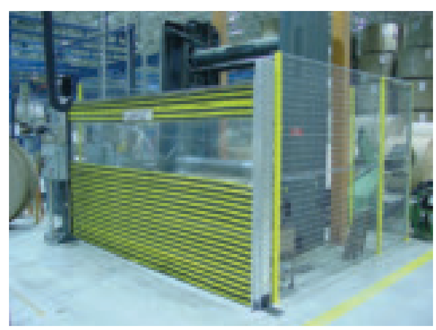
Servo-Robot, Inc. 102
1370 rue Hocquart, St-Bruno, QC, Canada J3V 6E1

Ceramic Weld Backing Eliminates Grinding

The KATBAK® ceramic weld backing lets users produce x-ray quality back beads on their root pass while welding from one side only. More metal is deposited while defects and rework are reduced, eliminating gouging and grinding. Ceramic tiles are available in a variety of sizes and configurations and are mounted on wide heat-receptive, pressure-sensitive adhesive foil for easy, accurate application to the workpiece. The product can be used on flat or curved surfaces as well.

Gullco International, Inc. 103
21568 Alexander Rd., Cleveland, OH 44146

Barrier Door Features Safety Interlock Switch



The Flash-Fold™, a safety barrier door system, protects personnel from machinery operations, but also recesses into a subgrade pit for forklift and crane loading access. Its compatible operating system is interfaceable with most machinery integration. A safety interlock switch automatically shuts down or idles a potentially dangerous cutting, forming, stamping, or welding application when breached by unauthorized personnel or impacted by machinery or flying debris. In addition, its NFPA-701-rated, high-speed fabric door's cycling speed is 36 in./s. The product comes in standard sizes ranging from 6 to 18 ft wide and can protect areas up to 12 ft high.

Frommelt Safety Products 104
4343 Chavenelle Rd., Dubuque, IA 52002

Stackers Come in Two Configurations

The company's stackers allow workers to lift, transport, and position up to 3000 lb at a time. Available with manual or electric drive, they feature battery-powered electric lift with lifting heights of up to 80 in. The stackers are available in two basic configurations — the fork-over design works with any type of open-bottom pallet or skid, and the straddle style accommodates any pallet or skid. Standard fork lengths are 45 in. for fork-over models and 42 in. for straddle units. They are maneuverable and feature an ergonomically contoured pallet-truck-style handle, a high-visibility mast, and dual-wheel casters with toe guards for easy, safe positioning. A short overall length (63–66 in.) and large turning angle make it possible to lift and stack in confined areas.

Southworth Products Corp. 105
PO Box 1380, Portland, ME 04104-1380

Plasma, Oxyfuel Cutting Machines Upgraded

The company has upgraded the EdgeMate® and EdgeMaster® plasma and oxyfuel cutting machines with its CNC control, the Global Control S. This control is based on the technology of the original MG Global Control, the Global Control Plus. The product provides an easy-to-use touch screen interface and the Win-

dows® screen layout. Also, it features the remote diagnostic software, *Virtual Service*, to allow advanced troubleshooting capability to minimize downtime. Additional upgrades to the plasma and oxyfuel cutting machines include powerful drives and faster lifters.

MG Systems and Welding, Inc. **106**
W141 N9427 Fountain Blvd., Menomonee Falls, WI 53051

Conductor Tube Provides Heavy-Duty Performance

The design of the company's conductor tube is a reliable, flexible, durable patent-pending mechanical ball and socket joint that enables the user to achieve virtually infinite adjustment and firm positioning. It does not suffer from early fatigue-related failure after repeated

readjustment to new positions. Each conductor tube is a series of mechanical connections that allow gradual bending of the tube to any angle from straight out of a GMAW gun to a maximum of 80 deg. The conductor tube has been engineered to allow bending while minimizing restriction on wire feeding. Each of the three connector designs allows a maximum of 60 deg of bend, and four connector tubes are suitable for a maximum 80-deg bend.

Tweco **107**
2800 Airport Rd., Denton, TX 76207

Punch Stripper Pierces a Variety of Materials

The True Strip die-spring-actuated me-

chanical stripper for punches effectively and cleanly strips the workpiece to prolong tool life and avoid double hits or parts stacked in the die. It is a precision-machined device that is compact, interchangeable, and fits directly onto industry standard retainers with one screw. The product is used with a single punch design or custom multihole pierce punch applications. The unit's design has a stripper guided not only by the land of the steel can, but also by the stripper head. It can pierce and strip a variety of materials to 2 mm thick with unlimited production requirements. By changing the spring, stripping force is adjustable.

Moeller Mfg. Co. **108**
43938 Plymouth Oaks Blvd., Plymouth, MI 48170-2584

Gas Detector Useful for Industrial Applications

The Series 3000 XPIS (Explosion Proof, Intrinsically Safe) gas detector utilizes existing two-wire systems to monitor for toxic and oxygen gas hazards in potentially flammable environments. Operating on a standard two-wire 4–20 mA loop that makes it suitable for new and retrofit applications, the product serves a variety of industrial environments. It requires minimal sensor replacement/downtime. The gas sensors available for the product include oxygen, hydrogen sulfide, carbon monoxide, ammonia, and sulfur dioxide. It uses smart gas sensors that configure automatically when they are plugged into the device. Additionally, onboard diagnostics provide useful information during operation and fault finding routines, plus the patented “Reflex” sensors test algorithms.

Honeywell Analytics **109**
553 N. North Ct., Ste. 110, Palatine, IL 60067

Valve Available in Brass, Stainless Steel

The KFPV050 Series proportional control valves provide stepless variable control of gases and liquids. The valve is a direct acting two-port plunger type with a body available in brass or stainless steel. The solenoid can be oriented 360 deg, and its elbow electrical terminal can be positioned every 90 deg top to bottom and left to right for maximum wiring versatility. The valves are designed for use with the KFPC1 controller; this accepts standard input signals of 4–20 mA or 0–10 V. Onboard support circuits make initial setting possible without any external input.

Humphrey Products Co. **110**
PO Box 2008, Kalamazoo, MI 49003

Wire Dispensing System Optimizes Production Time

The Non-Stop™ wire dispensing system, constructed with heavy-duty extruded aluminum, utilizes a process that joins the end wire from an empty drum with the start wire of the next full drum, eliminating downtime for wire changeover and optimizing production time. A smooth operating wire guide arm handles the wire transfer during the automatic change, with no manual operator action required. The system works with either one or two station robotic cells (two or four drums), and it is available for both 500- and 1000-lb Accu-Pak drums.

ELCo Enterprises, Inc. **111**
5750 Marathon Dr., Jackson, MI 49201

‘Project Lead the Way’ Attracts Students to Engineering Careers

A nationwide initiative enhances high school curricula with technical courses expressly designed to lead students to pursue careers in engineering

BY DAVID W. DICKINSON

There has been a shortage of engineers in the United States for more than a decade. To help encourage middle and high school students to consider careers in engineering, a national initiative called Project Lead the Way (PLTW) has been adopted by more than 40 states. The PLTW curriculum engages students in scientific study coupled with hands-on experience and teamwork with other students and mentors from industry. The success of this program is gaining international attention.

The high school core consists of five courses in emerging engineering technologies traditionally taken over the four years of high school, together with a series of high school senior-level technical electives available for each state. These technical electives augment the basic engineering curricula in PLTW. The elective courses 1) build on the entire PLTW curriculum knowledge base, 2) tie topics together for better student comprehension, and 3) offer real-world applications for the concepts. The advanced welding technical elective described more fully below is one of these advanced technologies.

Project Lead the Way Core Courses

In the typical four-year high school track, as illustrated in Fig. 1, freshman students take the usual English, algebra, physical science, world history, and physical education or health classes, but also enroll in the first PLTW course, Principles of Engineering.

Sophomore students take an Introduction to Engineering Design class in addition to their regular courses.

Junior year students take two additional PLTW classes: Digital Electronics and Computer Integrated Manufacturing.

Senior year students attend Engineering Design and Development, a research-oriented class, and an Emerging Technology technical elective class.

The benefits of such a sound core program in engineering include the fact that this is a nationally recognized preengineering program taught in more than 40 states with the curricula updated annually by PLTW. The programs feature hands-on, team-oriented classes that stimulate continued career development. In addition, students can receive up to 15 hours of college credit from many accredited universities.

The following presents a closer look at each of the basic courses in the PLTW Core.

Each of the five PLTW courses builds on the others, as illustrated in Fig. 2 and described in the following, giving a sound background in engineering.

Principles of Engineering is a broad-based survey course designed to help students understand the field of engineering and engineering technology and its career possibilities. The curriculum develops problem-solving skills used in postsecondary education programs and engineering careers. It explores various engineering systems and manufacturing processes. Students learn how engineers address concerns about the social and political consequences of technological changes.

Some of the specific topics covered in this course include definitions of engineering principles and descriptions of various types of engineering. The course describes the importance of accurate communication and documentation of test results. It introduces the understanding of the design process as an engineering principle, and introduces some of the more recent and emerging engineering systems. Described are static design and the importance of strength of materials in that design. The course addresses how materials can be tested to determine their fitness for purpose, and serves as an introduction to dynamics and kinematics for applications in real systems.

Introduction to Engineering Design, the second course in the core, uses a computer-based solid modeling approach using the software program *Inventor* from the *Autocad* computer-aided design package. Students are stimulated to develop problem-solving skills with an emphasis on three-dimensional solid model sketching and visualization techniques. They progress from sketching simple geometric shapes to using the solid modeling computer software package.

Moving on to assembly modeling, the students learn a problem-solving design process and how it is used in industrial manufacturing. Marketing the finished product is also considered. Each student then prepares his/her individual portfolio detailing the complete engineering design process.

Digital Electronics, the third course in the PLTW core, offers study in applied digital logic. The students study the circuitry found in digital electronic devices, such as video games, wristwatches, calculators, and digital cameras. They study the applications for digital logic and how digital devices are used to control automated equipment. Some of the specific topics covered in the digital electronics course include number systems and how they are processed by digital electronic devices. They study electronic gates and the use of Boolean algebra in digital processing. Students design control, flip-flop, and counting circuits, and investigate the use of microprocessors in manufacturing and control applications.

DAVID W. DICKINSON (dickinson.1@osu.edu) *is a professor, College of Engineering, The Ohio State University, Columbus, Ohio.*

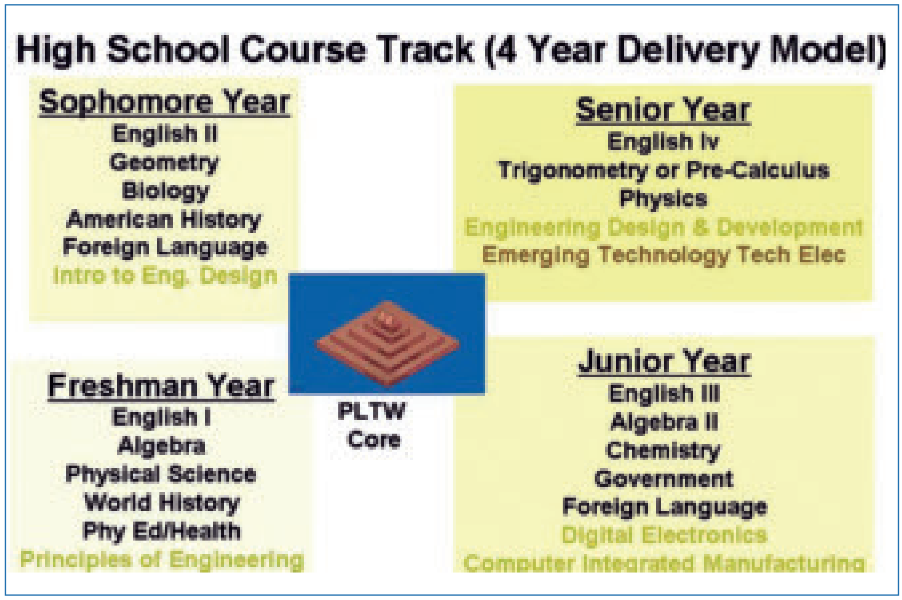


Fig. 1 — The Project Lead the Way curriculum fits into standard high school courses.

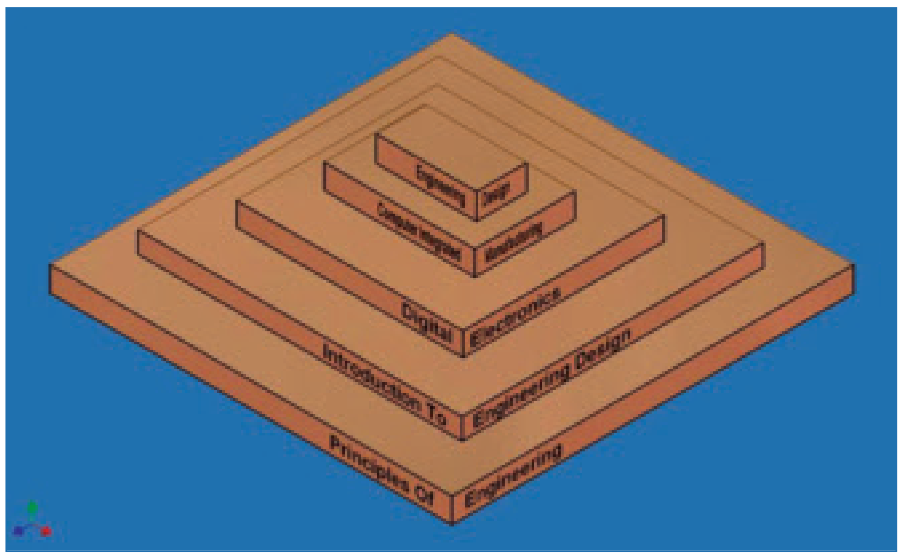


Fig. 2 — Project Lead the Way course progression.

The **Computer Integrated Manufacturing** course applies the principles of robotics and automation in manufacturing and design analysis. It builds on the computer modeling skills developed in previous PLTW curriculum classes. Students produce actual models of their three-dimensional designs.

Finally, in the **Engineering Design** course, students work in teams to research, design, and construct a solution to an open-ended engineering problem. All principles learned in the previous four PLTW courses are applied in this program. The students, guided by a community mentor, are required to submit progress reports, a final report, and defend their conclusions to reviewers.

Materials Joining Technical Elective

Following successful completion of the five core courses, each student will have the skills to take a technical elective to further develop his/her understanding of advancing technologies available in the student's resident state.

In Ohio, Project Lead the Way technical electives being developed include **Nanotechnology, Fuel Cells, Aerospace,** and **Advanced Welding** — Fig. 3. The Advanced Welding technical elective was the first of these made available for implementation in autumn 2005.

The **Advanced Welding** curriculum consists of several major areas of study, including Welding Processes, Materials, Design, and Nondestructive Evaluation (NDE).

The Welding Processes program includes topics on the science of manual arc welding, robotic arc welding, automated welding manufacture, miniature and nanofabrication, resistance welding, laser beam welding, brazing, and plastics bonding. Topics such as electrical power engineering, electrical control strategy, arc physics, heat input and heat flow, as well as other important physical concepts are presented, and the program is rich in hands-on experiences as well.

In the Materials part of the curriculum, students learn about a variety of materials including metals, plastics, ceramics, and composite materials. They learn about how the welding process affects the structure and properties of each material. Some of the topics covered include crystal structure of materials, dislocations in the crystal structure, metallographic techniques, interpretation of microstructures, weld metal solidification patterns and discontinuities that develop upon solidification, heat-affected-zone structure property modifications, and detection of weld discontinuities.

Following the completion of the Welding Processes and Materials courses, the students are required to design a weld joint. In the Design course, they study the properties of materials and how to design defect-free weld joints. They consider ways to reduce heat distortion caused by welding operations, and become proficient in using welding codes and symbols to develop complete welding procedures.

The final course content is Nondestructive Evaluation (NDE). In this curriculum topic, the various forms of NDE are reviewed including visual, dye penetrant, magnetic particle, eddy current, ultrasonic, and x-ray inspection.

As their final project, the students design a weldment, prepare a welding procedure, select the welding process and necessary materials, then make the weld. Afterward, the students perform nondestructive evaluation procedures to verify the quality of their weldments.

All of the course materials (Fig. 4) including class notes, demonstrations, videos, homework, student evaluation quizzes, and virtual hands-on laboratories, are provided to the students on a set of compact discs (CDs). This makes the course delivery very flexible through various delivery modes as described below.

How Can This New Program Recruit Welding Engineers?

The association with the internationally recognized Project Lead the Way curriculum allows this Materials Joining Technical Elective Course to be offered to high school students during their senior

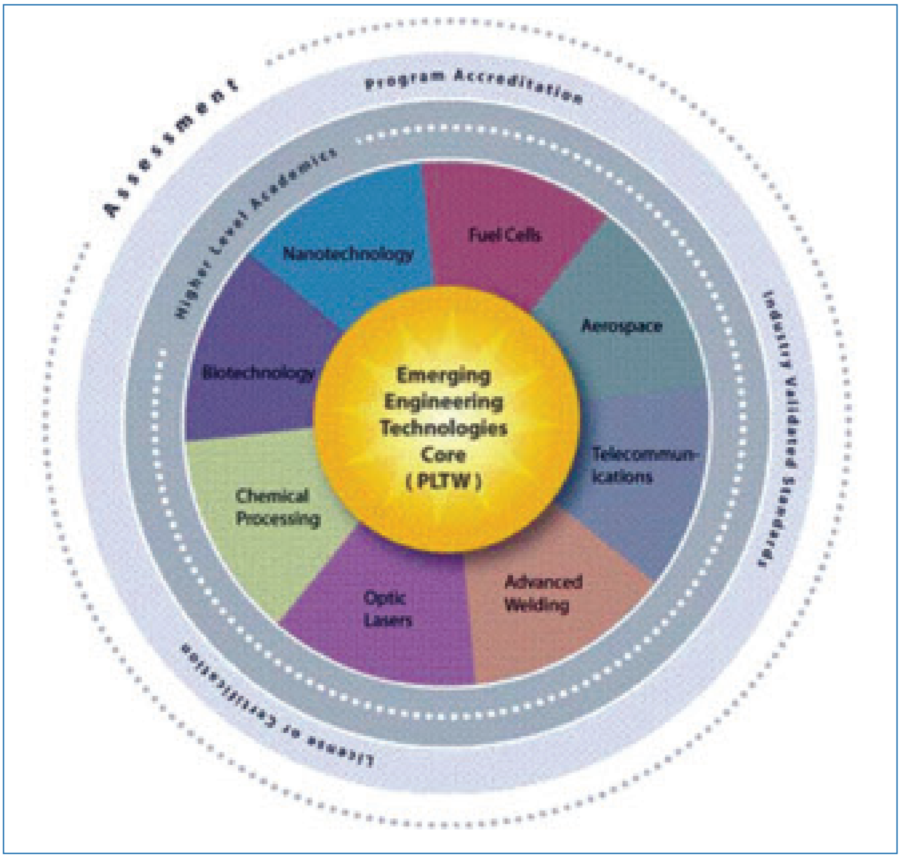


Fig. 3 — Technical elective courses being developed to augment the PLTW curriculum in Ohio.

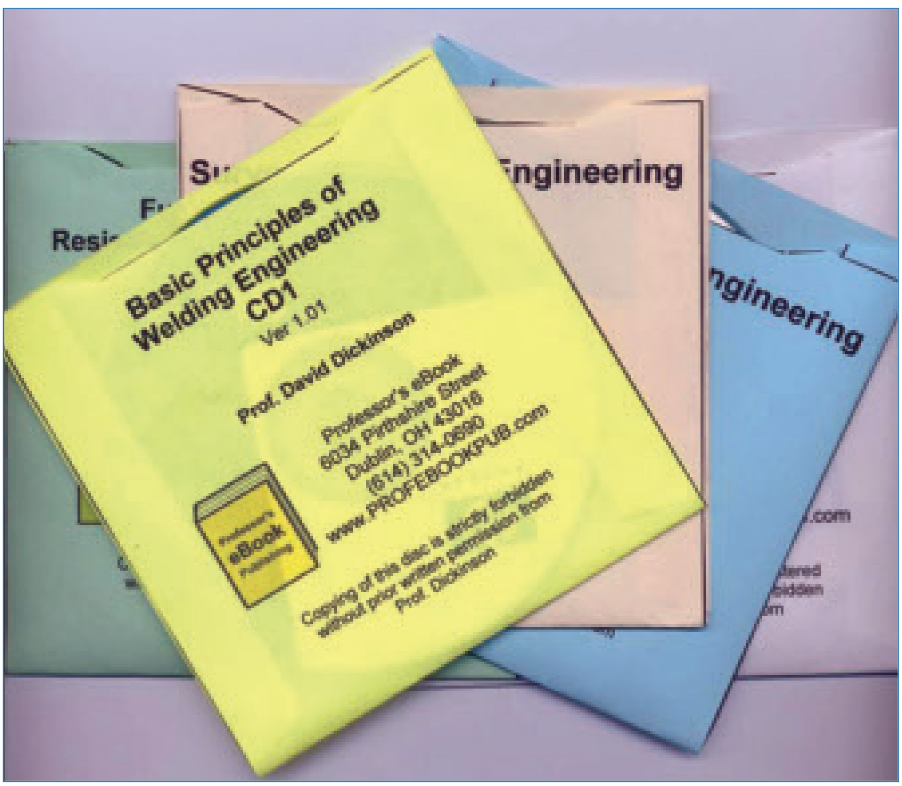


Fig. 4 — Some of the course materials provided.

year — at the time when students are making their career decisions.

The welding course is flexible in that it can be presented to large groups of students in a classroom, with a teacher and all necessary instructional materials.

All classroom teachers are required to take a two-week summer training course where they receive the supplementary materials.

Also, the course can be taught using the Internet. High schools with only a few students who wish to enroll in this program can select the Internet option. In addition, the CDs include a whole series of virtual laboratories such that the need for high schools to purchase expensive laboratory equipment is reduced.

Visuals Make This New Program Work

Dr. Richard Felder at North Carolina State University has completed a significant study regarding engineering students' learning styles. Using his model, the learning styles of freshman engineering students at The Ohio State University have been evaluated over the past four years. In three categories (Active vs. Reflective Learners, Sensing vs. Intuitive Learners, and Sequential vs. Global Learners), there were midlevel scores, reflecting engineering students' ability to accommodate most learning styles. The only exception was the Visual vs. Verbal Learning style where engineering students were decidedly "visual." Thus, to be most effective, engineering course materials should have a significant visual component. Lecture-based courses alone do not offer the visual content that a course using electronic media can. The CD-based Materials Joining Course with its visual content, virtual laboratories, and real-world problem-solving exercises fills this need.

Summary

The linking of the **Materials Joining Technical Elective** with the Project Lead the Way High School Core Engineering Program gives an exceptional means for recruiting high school students into engineering, welding, welding engineering, and welding engineering technology careers. Since the course is available on CDs, it is ideal for welding and engineering students who are best served by extensive visual-based learning materials and virtual hands-on laboratories. A complimentary demonstration disk is available for a test run of the course material. E-mail your request to *dickinson.1@osu.edu.*

Visit the Project Lead the Way Web site, *www.pltw.org,* for more information on this nationwide program, and where it is being presented in your state. ♦

The welder pictured above is shown welding on a tank. In the inset are front-end loaders on a truck.

Applying Lean to Welding Operations

BY VIWEK VAIDYA AND BRYAN GEORGE

This case study shows how the principles of Lean can be applied to welding operations in a plant producing front-end loaders (see lead photo). A systematic approach to measuring welding process parameters and welder skills was used to diagnose areas of applying Kaizen or the process of continuous improvement. Welder training and optimization of welding parameters resulted in a significant improvement in quality and reduction of waste. Design changes facilitating ease of welding and reduction of grinding were made. Weld process monitoring was used to measure deviation from optimized parameters and corrective action was implemented through welder coaching on the job. Welding duty cycles were measured to justify robotics in specific areas. Annual savings of $400,000 were achieved in a shop employing 35 welders.

Introduction

Lean manufacturing is focused on eliminating waste in the entire manufacturing process. It deals with minimizing work-in-process, eliminating processes that do not add value to the product, making the process flexible enough to make products of different design without compromising quality or cost. Historically, many manufacturing companies have been able to maintain bloated or inefficient methods because of a protected market, strong brand strength, or huge profit margins. Global competition is forcing these manufacturers to change their methods to be less wasteful, and provide value to their customers through customization and reduced cycle or delivery times.

In the early 1980s, the Lean paradigm was invented at the Massachusetts Insti-

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> *Lean principles applied to the welding activity of a front-end loader manufacturing facility resulted in a productivity improvement*

tute of Technology (MIT), and the Toyota Motor Co. was the first company to successfully apply it to automotive manufacturing. Lean philosophy is universal and can be applied to manufacturing, design, quality control, administration, order taking, accounts receivable, or any activity that needs to be improved. The process starts with a macro mapping of the activity called value stream mapping. It involves people at all levels in identifying areas of inefficiency. Once the problem is identified, groups of people work together for short periods of time in a well-documented activity called Kaizen to solve the problem. Building on small successes slowly embarks the entire enterprise on a never-ending process of continual improvement. Lean and Kaizen are work philosophies, requiring the commitment of the owner or CEO of the enterprise. Results are obtained through employee empowerment and are achieved over time.

This article describes how Lean principles were applied to the welding activity of a front-end loader manufacturing facility. The five key Lean principles were applied to the welding process as outlined below. The plant manager was the most visible promoter of the process and success was largely related to the appropriation of the continual improvement by the employees at all levels, specific to the welding activity.

Key Lean Principles

1. Perfect first-time quality through the quest for zero defects, revealing and solving problems at their ultimate source, achieving higher quality and productivity simultaneously, teamwork, and worker empowerment.
2. Waste minimization by removing all nonvalue-added activities, making the most efficient use of scarce resources (capital, people, space), just-in-time inventory, and eliminating any safety nets.
3. Continuous improvement (reducing costs, improving quality, increasing productivity) through dynamic process of change, simultaneous and integrated product/process development, rapid cycle time and time-to-market, openness, and information sharing.
4. Flexibility in production of different mixes or greater diversity of products quickly, without sacrificing efficiency at lower volumes of production, through rapid setup and manufacturing at small lot sizes.
5. Long-term relationships with suppliers and primary producers (assemblers, system integrators) through collaborative risk-sharing, cost-sharing, and information-sharing arrangements.

Perfect First-Time Quality

Welding is a multidimensional process and in-process parameters often determine the final quality of the weld. Besides the three dimensions of the welding nugget, the fourth dimension of time influences the final quality as it influences time-related parameters like welding speed, heat input, and timing in applying preheat and postheat, ultimately affecting the weld microstructures and distortion of the finished parts.

Fillet weld is the most common type of weld used in metal fabrication. Visually inspecting a fillet weld in two dimensions does not guarantee adequate weld penetration in the third dimension. Because fillet welds are usually taken for granted, they are mostly ignored by engineers and shop supervision. It is assumed that welders have sufficient skills to deposit quality welds to required sizes. However, failure analysis of many failed components often points to faulty fillet welds. For example, in a cyclic load application, fatigue failures usually originate from fillet weld toes. Large oil rigs and barges have capsized due to the failure of small, insignificant fillet welds. With this background information and some fatigue failure history with front-end loaders, it was decided that applying Lean would begin with making perfect fillet welds, every time, to print specification.

Welders were using 0.035- and 0.045-in.-diameter wires to make ¼-in. fillets in the horizontal position in production. Sixteen welders were asked to make ¼-in. fillet welds on test coupons, alongside their production jobs, and all in-process parameters were recorded. These appear in Table 1. The welds were sectioned and quality inspected. Completely penetrated ¼-in. fillet welds with a 20% maximum overwelding were used as an acceptability criterion. Ten welders out of 16 were able to make ¼-in. fillets. Thirty-seven percent of welders failed to make good quality welds the first time (Table 1). This presented a great opportunity to perform a Kaizen event for improving fillet weld quality.

Waste Minimization by Removing All Nonvalue-Added Activities

Fillet Welds

As a general comment, shop welding procedure specification data sheets were difficult to read and did not clearly state the size of welds to be applied to specific components. A good rule of thumb while welding thick to thin materials is to equal the fillet size with the size of the thinnest member being welded. In the case of lap welds, the size of the weld should be equal to the plate thickness up to a quarter of an inch. Prequalified joints further indicate that the minimum size for dynamically loaded structures is 3⁄16 in. for plate thicknesses less than ¼ in. The minimum fillet size required for thicknesses between ¼ and ½ in. base metal thickness is recommended to be 3⁄16 in. per American Welding Society Standard D1.1, *Structural Welding Code — Steel*. Considering the base metal thicknesses being fillet welded at XYZ Ltd., it was confirmed that a 3⁄16-in. fillet would be more than sufficient to cover 90% of the work.

A total of 77 welds were measured against a design requirement of 3⁄16 in. size. Weld leg sizes varied from 3⁄16 to ⅜ in. dimensions. The overwelding for the measured welds fluctuated from 33% to 206%, with the average at around 107%.

The excess weld metal and effort in depositing the extra 107% nonvalue-added wasted manpower was a significant Lean finding.

An external design engineering team looked at all the drawings used to manufacture the final product. The shop drawings did not show any welding symbols. It was soon discovered that 90% of the plates used in the construction of the front-end loaders were less than ¼ in. thick, and 90% of shop welds were ¼-in. fillets. The design team determined that the fillet welds should be resized to 3⁄16-in. fillets.

Table 1 — Kaizen Applied to Weld Monitoring Process Control: Starting Time Data

Process: GMAW | Weld metal type: ER70S-6, 0.045-in.-diameter wire | Shielding gas: Ar 90%/CO_2 10%

Type of weld: Fillet weld ¼ in. | Welding performed at the workstations, fillet welds made on 12-in.-long test assembly in horizontal position

Working Shift	Sample Number	Required Size (inches)	Over-welding %	Wire feed speed in./min	Voltage (Volts)	Gas flow (ft^3/h)	Welding speed in./min	Penetration Evaluation Acc./Rej.	Visual Evaluation Acc./Rej.	Overall Evaluation Acc./Rej.
Day	1	¼	0	458	30.2	27	22.2	Acc.	Acc.	Acc.
Day	2	¼	56	415	31.2	25	13.5	Acc.	Acc.	Acc.
Day	3	¼	25	466	30.3	40	17.6	Acc.	Acc.	Acc.
Day	4	¼	56	399	30.6	30	13.6	Acc.	Acc.	Acc.
Day	6	¼	0	402	29.5	17	17.6	Acc.	Acc.	Acc.
Day	7	¼	0	400	26.8	27	18.0	Acc.	Acc.	Acc.
Day	8	¼	0	494	30.1	30	21.2	Acc.	Acc.	Acc.
Day	10	¼	25	404	30.5	17	14.4	Acc.	Rej.	Rej.
Night	11	¼	25	454	29.5	27	18.5	Acc.	Acc.	Acc.
Night	12	¼	0	414	31.4	28	17.6	Acc.	Rej.	Rej.
Night	13	¼	0	385	29.4	40	16.9	Acc.	Rej.	Rej.
Night	14	¼	25	474	30.5	40	19.5	Acc.	Acc.	Acc.
Night	16	¼	–25	451	28.1	25	19.5	Rej.	Rej.	Rej.
Night	17	¼	–34	402	29.0	15	23.2	Acc.	Rej.	Rej.
Night	18	¼	12.5	406	30.4	22	16.0	Acc.	Acc.	Acc.
Night	20	¼	0	466	31.5	16	18.5	Acc.	Rej.	Rej.
Average	16 Welds		11%	431	29.9	27	17. 6	15 welds acceptable	6 welds undercut	10 welds acceptable
Optimized parameters after eight months of Kaizen		3/16 in.	30%	600	29.5	45	24	good	good	good

Weld Design Changes

The design of the front lift arm assembly was carefully modified to change expensive flare groove welds to simple lap fillets between the wrapper plate and the structural steel channel. Fit-up was improved on the bushing welds and line boring was implemented to save assembly time.

Welding Wire Waste Measurement

The manufacturing facility was using both 0.045- and 0.035-in.-diameter solid E 70S-6 wires for most of the work. As the weld size was optimized to 3/16-in.-size fillets, it became necessary to optimize wire usage to 0.035 in. diameter and reduce the occurrence of undercuts. All the feeders were converted to feed 0.035-in.-diameter wire. These two changes resulted in a large improvement in logistics for consumable usage and preventive maintenance. Welder training and welding process monitoring were further simplified.

Welding Gas Usage and Optimization

Initial evaluation of welding macro sections revealed uneven penetration patterns. A 10% CO_2 with balance argon mixture was delivered through a gas mixer. The uneven penetration profile of the welds indicated significant variation in the gas mixture. The mixer buffer tank had to be resized for a bigger capacity to stabilize the gas mixture.

The measured gas flow rates in some parts of the shop were as low as 17 ft^3/h, which resulted in internal fillet weld porosity. Gas flow rates were standardized to 45 ft^3/h throughout the plant.

Leaks in the gas manifold system were verified. The ratio of amount of gas used to deposit one pound of filler metal was targeted at 4.5 ft^3/lb. This is a good ratio to monitor gas waste.

Lean Resources Needed for Kaizen Applied to Welding

In order to carry out a satisfactory welding-related waste measurement, it was necessary to use various measuring devices and instruments. Without going into too much detail, a simple list of items is provided to understand what is needed to make a nonsubjective welding assessment.

Human resources:

- Motivated CEO or plant manager interested in pursuing opportunities for cost savings
- Internal or external experienced welding engineer/technician team with excellent, analytical, training, and people skills.

Material and software resources:

- Calibrated length-measuring instruments
- Stopwatch
- Wire feed speed measurement device
- Calibrated ampere and volt meters
- Shielding gas flow measurement devices
- Gas saver devices
- Gas leak detection equipment
- Duty cycle measurement device capable of data acquisition, storage, and download over 24-h measurement periods, for continuous improvement
- Fillet gauges, manual, or electronic systems
- Ability to test fillet welds quickly with destructive tests
- Ability to produce weld macrographs for quality feedback to welders
- Digital photography equipment
- Annualized gas and wire consumption data and pricing
- Cost calculation software to validate improvements of Kaizen activities.

Follow-up Actions for Applying Lean to Welding and Welding Management

The dilemma of prioritizing between passing quality audits and improvement in productivity is not new. A case in point would be to use very wide welding parameter ranges in a welding procedure specification (WPS) within code requirements, so that most welders would pass a welding audit by an ASME auditor, avoiding a serious nonconformance. On the other hand, to improve welding quality and weld penetration, higher wire feed speeds are usually required while using semiautomatic processes, as seen in this case study. The ISO 3834 quality requirements for fusion welding of metallic materials standards provides a good way around the dilemma by using specific work instructions (WIs). The WIs in a factory focus on productivity improvement, but are based on qualified WPSs. Thus, the WIs would need a tighter wire feed speed control for higher productivity; however, a nonconformance to WIs may not necessarily mean a nonconformance to the qualified WPSs.

The ISO 3834 standard has been widely used in Europe under EN729 series equivalent, and has now been adopted by Australia, Japan, and many European countries. It is a very good practical welding standard and provides many other advantages. For example, the standard requires the fabricator to disclose the size of the manufacturing facilities, including the capacities of press brakes, turning rolls, cranes, cutting equipment, etc., during the certification audit. It is used in Europe by purchasing departments in the tendering process to qualify subcontractors in their own countries and also from foreign countries.

The principal author has worked closely with the working group on ISO 3834 for the last three years and has been successful in bringing into focus the critical role of top management for Lean activities as applied to welding. The ISO 3834 Part 6 of the standard now recommends that top management review welding performance and allocate resources for welding technology selection, including implementation and performance monitoring of the welding processes. Figure 1 is an excerpt of a table from ISO 3834 part 6, and shows the use of the Deming process to welding and the role of top management in the continuous improvement process, as highlighted in this article. It is hoped that adopting the ISO 3834 standard by metal fabrication shops in North America will create the environment to foster Lean as applied to welding operations.

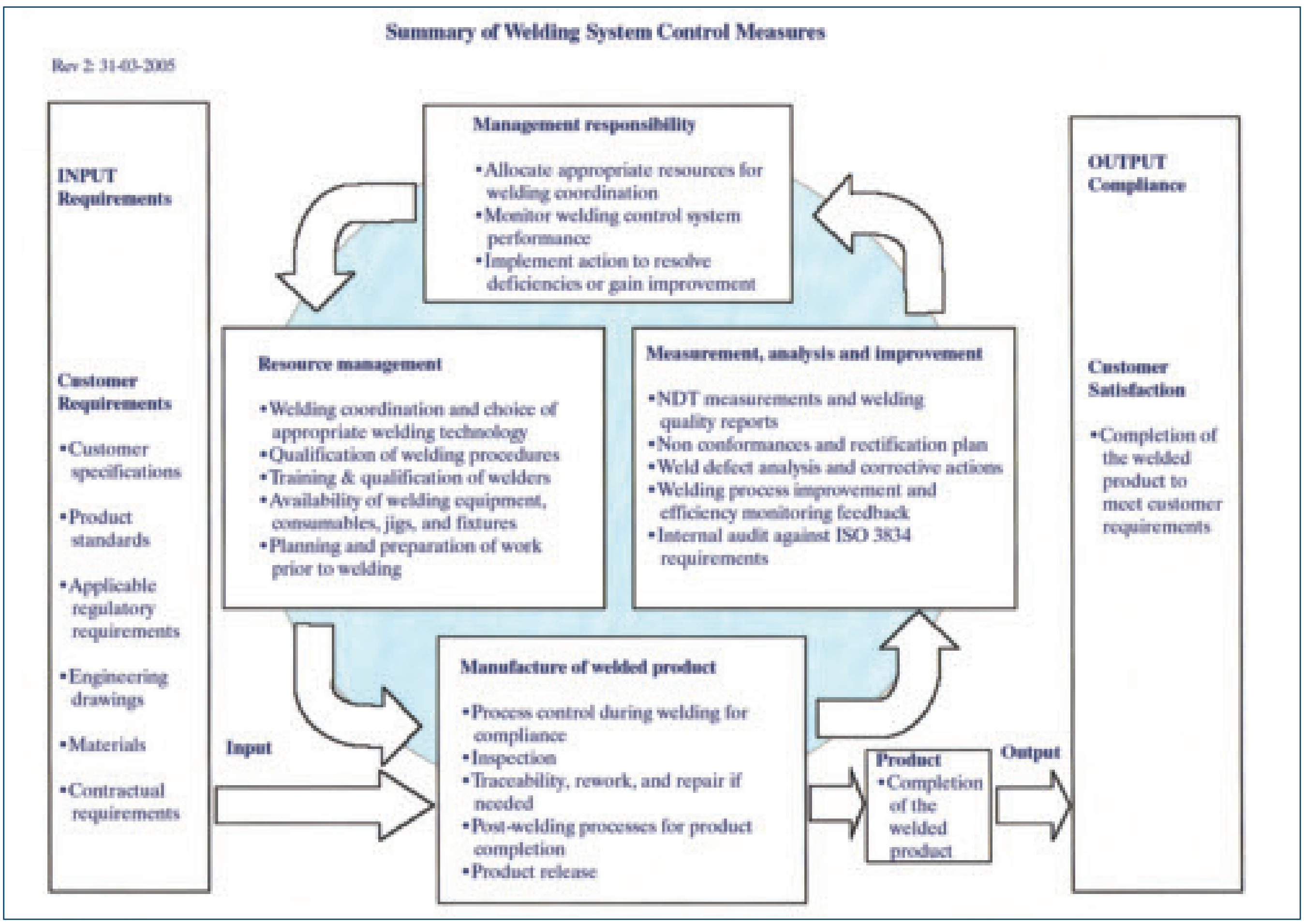


Fig. 1 — Summary of welding system control measures from ISO 3834 part 6 proposed diagram.

Table 2 — Actual Shop Conditions

Customer information: XYZ Ltd.	
GMAW: ¼-in. 2F shop actual-19.5% overwelding	
Welding position: Horizontal	
Data	
Fillet weld size in decimal inches	0.25 in.
Welding process	GMAW
Process efficiency	95%
Filler metal cost per pound	$0.75/lb
Wire diameter	0.045 in.
Wire feed speed in inches per minute	425 in./min
Calculated deposition rate at 100% shop efficiency	10.93 lb/h
Cost of shielding gas in dollars per cubic feet	$0.06/ft^3
Shielding gas flow rate in cubic feet per hour	20 ft^3/h
Shop charge out labor rate	$25.00/h
Fillet weld weight per linear foot	0.106 lb/ft
Fillet weld weight with 19.5% overwelding per linear foot	0.127 lb/ft
Calculated fillet weld cross section in square inches	0.037 in.^{2}
Calculated fillet weld size including allowable overwelding	0.273 in.
Welding arc travel speed in inches per minute	17.20 in./min
Measure shop duty cycle from CAP audit	20% observed from CAP audit
Effective welding speed reflecting duty cycle from CAP audit	17.20 ft/h
Shop effective deposition rate reflecting measured duty cycle	2.19 lb/h

Calculations and results	Cost per hour & repartition		Cost per pound & repartition		Cost per foot & repartition	
Labor	$25.00	92.71%	$11.44	92.71%	$1.454	92.71%
Wire or filler metal	$1.73	6.40%	$0.79	6.40%	$0.100	6.40%
Gas	$0.24	0.89%	$0.11	0.89%	$0.014	0.89%
Total	$26.97	100%	$12.34	100%	$1.57	100%

Welding cost calculator: Kaizen event for fillet welds. Customer: XYZ Ltd.

Table 3 — Optimized Shop Condition after Kaizen Event and Training

Customer information: XYZ Ltd.	
GMAW: ³⁄₁₆-in. fillet with 30% overwelding	
Welding position: Horizontal	
Data	
Fillet Weld size in decimal inches	0.1875 in.
Welding process	GMAW
Process efficiency	95%
Filler metal cost per pound	$0.81/lb
Wire diameter	0.035 in.
Wire feed speed in inches per minute	600 in./min
Calculated deposition rate at 100% shop efficiency	9.33 lb/h
Cost of shielding gas in dollars per cubic feet	$0.06 ft^3
Shielding gas flow rate in cubic foot per hour	45 ft^3/h
Shop charge out labor rate	$25.00/h
Fillet weld weight per linear foot	0.060 lb/ft
Fillet weld weight with 30% over welding per linear foot	0.078 lb/ft
Calculated fillet weld cross section in square in.	0.023 in.^{2}
Calculated fillet weld size including allowable over welding	0.214 in.
Welding arc travel speed in inches per minute	24 in./min.
Measure shop duty cycle from CAP Audit	20% observed from CAP audit
Effective welding speed reflecting duty cycle from CAP Audit	24 ft/h
Shop effective deposition rate reflecting measured duty cycle	1.87 lb/h

Calculations and results	Cost per hour & repartition		Cost per pound & repartition		Cost per foot & repartition	
Labor	$25.00	92.14%	$13.40	92.14%	$1.042	92.14%
Wire or filler metal	$1.59	5.87%	$0.85	5.87%	$0.066	5.87%
Gas	$0.54	1.99%	$0.29	1.99%	$0.023	1.99%
Total	$27.13	100%	$14.54	100%	$1.13	100%

Welding cost calculator: CAP CONSULTANT. Customer: XYZ Ltd.

Continuous Improvement through the Dynamic Process of Change

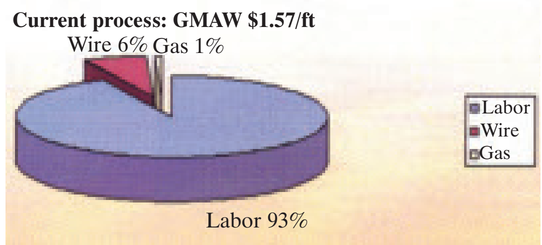
Welding Wire Size

Once the initial welding parameters were recorded, as shown in Table 1, the task of continuous improvement began with plant supervision. All welders were using water-cooled welding guns of European design. These guns never leaked any water; however, a lot of undercutting was noticed on fillet welds. Arbitrarily used in production were 0.045- and 0.035-in. diameters. The welders on the floor had implemented a "smart" solution to this problem. On a four-drive roll feeder system, two rolls were 0.035-in. and the other two were 0.045-in. diameter, so any diameter of the wire could be fed. As a corrective

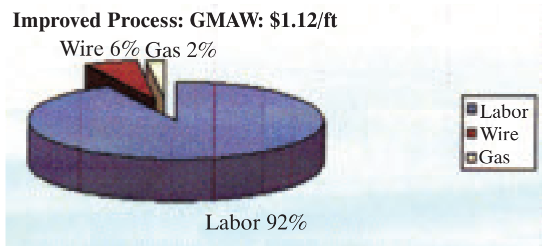
Table 4 — Cost Calculation Spread Sheet

CAP Audit: Cost calculations for XYZ Ltd.

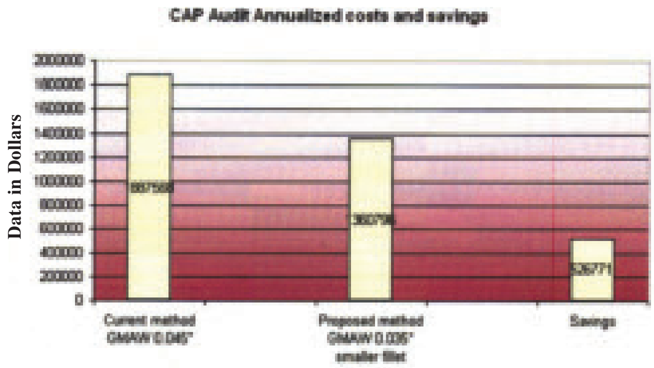
Current method	
Cost per foot of weld	GMAW 0.045 in.
Labor	$1.45
Wire	$0.10
Gas	$0.01
Total	$1.57
Effective arc speed, ft/h	17.20



Improved method	
Cost per foot of weld	GMAW 0.035 in.
Labor	$1.04
Wire	$0.07
Gas	$0.02
Total	$1.13
Effective arc speed, ft/h	24.00



Annualized calculation	
Number of welders	35
Annual footage calculation:	1,203,670 ft
Welders needed with new method	25 welders
Extra capacity	10 welders



Annual footage for steel welds (mono pass)	1,203,670 ft
Current method: GMAW, 0.045 in.	$1,887,568
Proposed method: GMAW, 0.035-in. smaller fillet	$1,360,796
Savings	$526,771
Increase in productivity	39.56%

action for undercutting, the front end of the guns was changed so that the contact tip could be properly positioned for spray transfer. All 0.045-in.-diameter wire was removed from production and standardized to 0.035-in. diameter.

Weld Monitoring

Much monitoring and skills training were required to break old habits and assimilate new ones. Every week, the Kaizen team recorded production welding parameters of wire feed speed and welding speed, including quality and extent of overwelding. The results were reviewed with the welders not performing to the new standard. To help the welder acquire the required skills, on-the-job training was provided by the Kaizen group. This process was repeated throughout the plant until desired results were obtained. The feeder speed potentiometers were physically marked with a sticker to indicate the optimized position for the wire feed speed in order to help everyone use the standardized parameters.

After eight months of training and on-the-job monitoring of welding techniques, the average welding speed increased by 6 in./min, an impressive 39% improvement. These results are summarized in Tables 2 and 3. Welders were able to produce 3⁄16-in. fillet welds in the horizontal position, with 90%Ar + 10%CO_2 gas mixture at optimized wire feed speeds of 600 in./min at an average of 24 in./min of welding speed with practically no undercut.

Cost Savings

The average welding cost per foot for a 3⁄16-in. single-pass fillet weld was reduced from $1.57 to $1.13 per foot. On an annualized basis, a potential annual savings of $526,771 was calculated (Table 4). In the first year alone, the company was able to realize more than $400,000 in savings. By reducing waste and increasing welding speed, more welding capacity was added, requiring further work balancing on the production line in the following years.

Flexibility in Production

Management was keen to go to robotics for flexibility of production. However, when the process audit was carried out, actual welding duty cycle measurements were made. Further attention was paid to the existing accuracy of fit-up.

Duty cycles were measured in the various areas of manufacturing. The following weighted-average duty cycles were observed during the audit over a three-shift time span. The high duty cycle numbers were for areas where the operator was not interrupted. An average duty cycle of 20% was calculated for the shop for cost calculations by the Kaizen team.

- Lift arm assembly average: 22.7%
- Attachments average: 16.1%
- Transmissions average: 17.1%
- Mainframe assembly average: 28.5%
- Quick attachments average: 13.5%

- Tanks average: 22.3%

The overall throughput of the plant was eight units per day. In order to improve this performance, the initial survey showed that the shop floor layout would have to be significantly improved, reducing a very large amount of work in process. Robotic welding was discouraged at this stage, as part fit-up was less than acceptable and the floor layout was inadequate to feed the robot parts and then remove the finished parts efficiently without creating further work-in-process pileups.

The overall operation needed to be more balanced. It was found that even if the welding operation could be significantly improved from a productivity point of view, the bottleneck was still frequent at the final assembly of the machines. More Kaizen needed to be done for the logistics of all electrical, mechanical, and hydraulic systems. After the initial year of welding improvements, it was decided to defer the automation projects until other operations could produce a pull effect on welding to really make flexible robotic welding worthwhile.

Long-Term Relationships with Suppliers

Further to the initial process audit, the president of XYZ Ltd. was very keen to implement corrective actions through focused Kaizen activities. The process was supported with a long-term four-year contract with the local gas and welding products supplier, who could provide not only consumables, but also welding engineering expertise.

The first Kaizen activity was focused on wire feed speeds and reducing undercuts.

The second Kaizen activity was focused on welding speeds and fillet weld sizes.

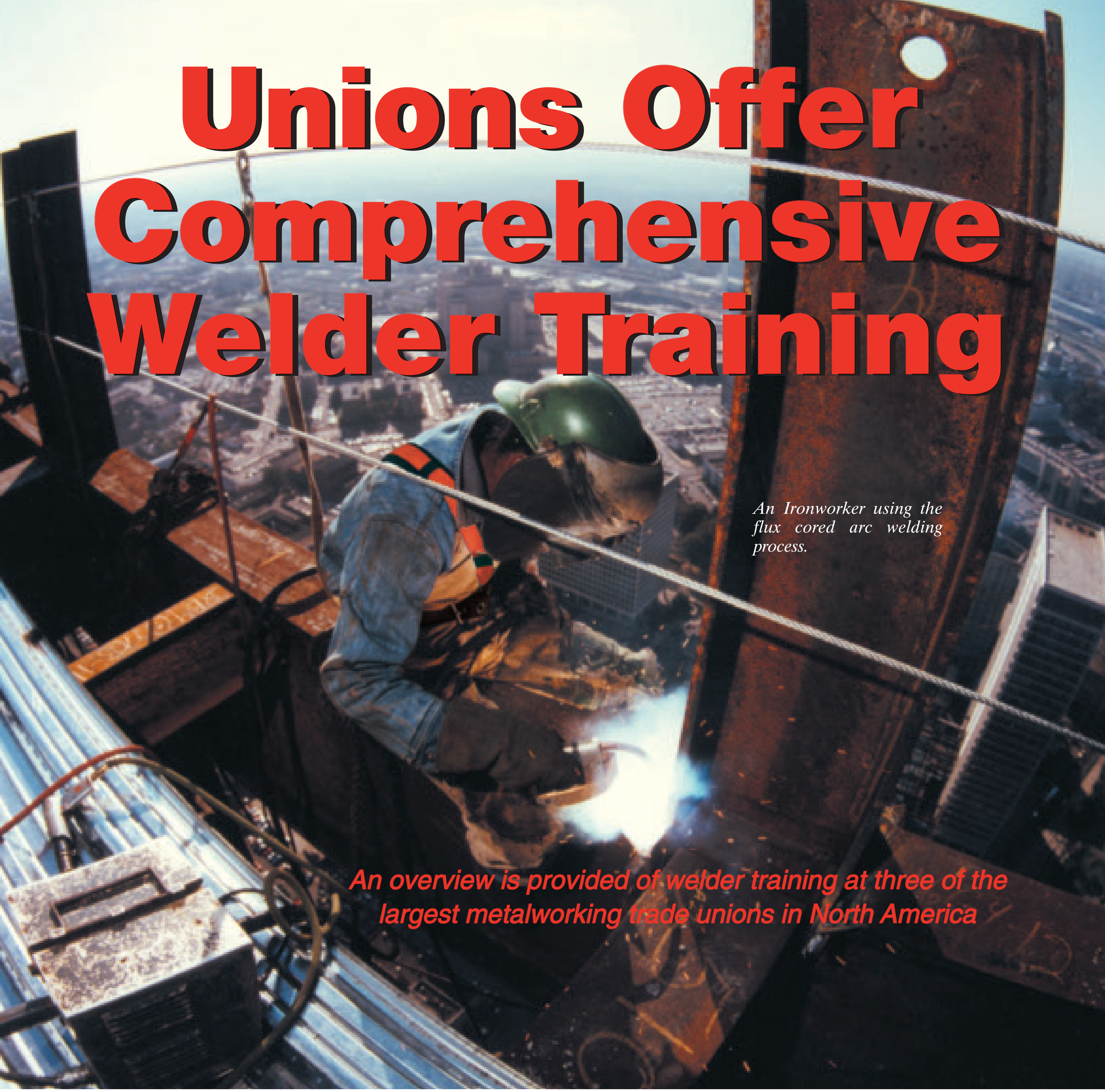
After the first eight months of assistance from the external welding engineering support, the plant inspectors were taught to measure and report key parameters targeted by the two Kaizen activities to ensure that the higher productivity standard was maintained over the four-year period.

Conclusion

While applying Lean principles to a metal fabrication facility employing arc welding in the manufacture of front-end loaders, a dramatic improvement in productivity was achieved over a 12-month period. The key to success was the keen interest of the management team to succeed in the continuous improvement process.

The auditors performed similar audits in more than 100 metal fabrication shops with good results whenever the plant manager or the CEO of the corporation was keenly involved in the results. ♦

Unions Offer Comprehensive Welder Training



An Ironworker using the flux cored arc welding process.

An overview is provided of welder training at three of the largest metalworking trade unions in North America

Based on information provided by RICK SULLIVAN, director of education and training, IMPACT, Washington, D.C.; ED ABBOTT, Ironworker Apprenticeship & Training Dept.; Washington, D.C.; MICHAEL T. HARRIS, International Training Institute for the Sheet Metal and Air Conditioning Industry, Greenwood, Ind.; and PHILIP F. MARTIN, UA training specialist, United Association of Journeymen and Apprentices of the Plumbing and Pipe Fitting Industry of the United States and Canada, Hindsdale, N.H.

The United Association, which consists of the pipefitters, plumbers, steamfitters, and sprinklerfitters, the Sheet Metal Workers, and the Ironworkers are three of the largest metalworking trade unions in the United States. Following are descriptions of welder training for members of each of these trade unions.

Ironworkers Apprenticeship Programs

The International Association of Bridge, Structural, Ornamental and Reinforcing Ironworkers was formed in 1896 and currently has local unions across the United States and Canada with a total membership of approximately 140,000. The Golden Gate Bridge, the testing and building facilities for the Stealth Fighter and Space Shuttle, and the St. Louis Arch were all built by Ironworkers. The Ironworkers also help to build schools, sports stadiums, shopping malls, hospitals, bridges, and office and industrial buildings.

Gas tungsten arc welding is another of the processes Ironworkers often use.

The foundation of the Ironworkers is a network of local union apprenticeship training centers. The apprenticeship programs found in these training centers require three or four years of study combined with comprehensive training on the job. Each local union's curriculum is based on a common core that includes a number of courses (e.g., structural, rigging, safety, blueprint reading, reinforcing) as well as a minimum of 110 hours of training in welding. Most programs require much more welding training than this minimum.

There are approximately 170 local union training centers across the United States and Canada. These training centers have classrooms for teaching the knowledge related to each technical subject. There are also shops and welding booths for hands-on training, practice, and skill assessment. There is a joint labor-management committee overseeing the operation of each local union apprenticeship program.

In 2005, the Ironworkers had the American Council on Education (ACE) evaluate all of its apprenticeship training courses for the possibility of college credit. As a result of the ACE evaluation, and in conjunction with the Ironworker Apprenticeship Certification Program, apprentices may now receive college credit for successful completion of their program. The Ironworkers have established a national associate degree online program with Ivy Tech Community College of Indiana. They also have two bachelor degree programs established with the National Labor College. In addition, many local unions have established articulation agreements with local colleges and universities.

With assistance from The Lincoln Electric Co. and the Harris Group, the Ironworkers published its new welding training package late in 2006. This package is used for apprentice training and journeyman upgrading and includes reference manuals focusing on shielded metal arc welding (SMAW), flux cored arc welding (FCAW), gas tungsten arc welding (GTAW), and oxyfuel gas cutting (OFC) and welding (OFW). In addition to the reference manuals, there is an instructor guide, student workbook, and an instructor CD-ROM that includes computer-based presentations, video segments, and Internet links.

The Ironworkers have implemented three certification programs to strengthen the quality of their training system, two of which focus directly on welding. The first of these is the Ironworker Apprenticeship Certification Program (IACP), which is designed to ensure that the entire local union apprenticeship program meets minimum quality standards. The IACP involves a self-study, external team site visit, and a final report. The Ironworkers have certified more than 20 of its apprenticeship programs and will visit all local unions within the next two years.

The Ironworkers' Welding Certification Program of North America was designed and implemented to aid local union members in training through a nationally recognized welding certification program. In cooperation with the American Welding Society, this certification program also requires a self-study, a site visit, and a final recommendation report. Each facility is initially audited and then reaudited every three years. The Ironworkers currently have 61 AWS-Accredited Test Facilities (ATF) located throughout the United States with 87 Certified Welding Inspectors employed at these facilities. Facilities are also responsible for an annual self-audit by the quality assurance manager, facility test supervisor, and a local labor or management apprenticeship committee member. Documentation is then forwarded to the national office for review and verification.

The Ironworkers' National Welder Certification Program is designed to assist local union members in obtaining and maintaining their welding qualifications.

The Ironworkers are implementing a new online system that includes the following steps:

1. The Ironworker (apprentice or journeyman) completes a specific welding qualification test at an accredited facility. This could be one of the 61 Ironworker facilities or another facility in his or her local area.

2. The Apprenticeship Coordinator at the local union then goes to the Welder Certification Program secure Web site and enters the specific test information. A dig-

ital photo of the Ironworker is also submitted online.

3. The submitted test information is verified by the staff of the National Welder Certification Program. If the applicant paid online by credit card, then the Ironworker's welding certification card is immediately mailed.

4. Apprenticeship Coordinators are able to access their local union's records online at any time to determine the status of any member.

5. Employers are able to access read-only files at any time to verify the status of Ironworkers welding at their job sites.

The Ironworkers' Welding Certification program contains many prequalified welding procedures used by their members to meet the needs of their employers in the field. Through marketing they are gaining increased recognition of their program and procedures by power companies, departments of transportation (DOT), owner groups, and employers. This certification program saves the employers time and money and allows the Ironworkers to supply the skilled welders needed on job sites.

The Ironworkers have also developed partnerships with several of the leading manufacturers of welding equipment and supplies. Through these relationships discount programs have been established that enable its training programs to purchase the latest welding technology available at an affordable cost. These programs combined with the new welder training materials ensure that instructors have the necessary tools to train their members and ensure that skilled welders are available for their employers.

By every indication, there is a looming shortage of workers in the construction industry. This may well mean that there could be a shortage of skilled Ironworker welders. Through its welding certification program, instructor training, and partnerships, the Ironworkers union is doing its best to make sure it has the welders available to meet the demands of the industry.

Additional information is available at *www.ironworkers.org*.

Structural steel work often calls for Ironworkers to use the shielded metal arc welding process.

Sheet Metal Workers Apprenticeship

The Sheet Metal Workers apprenticeship is an excellent choice for students who like to work with their hands and who like a challenge. Sheet metal apprenticeships range in length from four to five years. Students attend class at one of more than 180 Joint Apprenticeship Training Centers (82 of which are AWS-Accredited Test Facilities) located throughout the United States, Canada, and Puerto Rico. The students also receive invaluable on-the-job training throughout their apprenticeship. At the completion of the apprenticeship program, many students earn associate of applied science (AAS) or associate of science (AS) degrees from various community colleges. The sheet metal apprenticeship offers good starting pay and benefits such as health insurance, pension plans, and education.

The sheet metal industry requires many welders with a variety of skills. From the precision welding of very thin metal to the high-quality welding required for very thick structural steel, this trade offers it all. The sheet metal worker welds on a variety of metals and alloys such as carbon steel, stainless steel, aluminum, titanium, and others. Welders in this industry may work on stainless steel kitchen equipment, at pharmaceutical plants, or on large industrial projects that may involve the automotive industries as well as other large factories and power plants. Welders in this trade must be able to attain the skills necessary to pass qualification tests for various welding processes.

All students who enter the sheet metal industry apprenticeship program must start out with the CORE curriculum. The CORE curriculum will help the student develop the basic hand skills and knowledge required by every professional in the sheet metal industry. These skills include, but are not limited to, the following: math, drafting (including CAD), fabrication, installation, blueprint reading, knowledge of materials and tools, and safety requirements and procedures.

Once a student masters the skills covered in the CORE curriculum, he/she will then be allowed to specialize in one or more specific areas of the sheet metal industry.

These areas include the following:

- Heating, ventilation, air conditioning
- (HVAC) commercial work
- HVAC residential work
- HVAC service work
- Architectural sheet metal
- Welding/industrial sheet metal
- Detailing/drafting
- Testing and balancing

Industry uses welding as the preferred method of joining materials together. This type of work is usually done on thicker materials that are not easily joined by any other method. Industrial sheet metal is performed in many different types of industries such as the automotive industry, pharmaceutical industry, silicon chip manufacturing industry, and many others.

In the welding curriculum, students learn a variety of processes: shielded metal arc welding, gas metal arc welding, gas tungsten arc welding, oxyacetylene welding and cutting, plasma arc cutting, carbon arc welding, and flux cored arc welding. The students learn about different types of materials, tools, and equipment used in industry. Students also learn about different types of systems found in industrial

The Mechanical Trades Institute of UA Local 72 in Atlanta, Ga., recently held its apprentice welder contest at Lincoln Electric's Southeast Distribution Center. Here Local 72 Welding Instructor Mike Cockerham looks on as Apprentice Mike Blount works prior to the start of testing.

Mobile high-purity welder training trailer. One of a dozen mobile welding trailers the UA operates throughout the United States and Canada.

work and the special procedures used to layout, fabricate, and install these systems.

Apprenticeship requires a high school diploma or GED. Some areas of the United States and Canada require written exams and/or personal interviews to enter the apprenticeship. The industry needs willing young people with the desire and aptitude to listen, learn, and become skilled craftsmen who want to develop job-related skills and career goals.

Sheet metal workers should be in good physical condition and have above average mechanical and math skills. They require good eye-hand coordination, spatial/form perception, and manual dexterity. They should like working with both their hands and minds. They want to learn. Their personalities include patience, dependability, accuracy, ability to get along with others in a team atmosphere, and they enjoy seeing a job come to its completion.

The need for qualified welders is at an all time high throughout the United States, making this an opportune time to enter this field. Many opportunities exist as several power houses are currently being built or renovated. Some Joint Ap-

Welder training facility at UA Local 50, Toledo, Ohio.

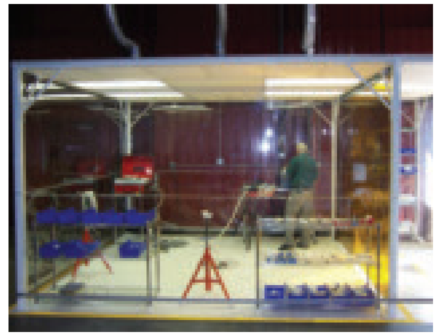
prenticeship Training Centers (JATCs) offer advanced placement into the apprentice program for students who have the skills to pass certain weld tests.

The application process and entry requirements vary throughout the JATC's. Visit *www.sheetmetal-iti.org* and click on "Locate a Training Center" to find the closest training center to you and to obtain the contact information required to find out more about apprenticeships in your area.

Plumbing and Pipe Fitting Industry Apprenticeships

The United Association of Journeymen and Apprentices of the Plumbing and Pipe Fitting Industry of the United States and Canada or "UA" as it is commonly known is a multicraft union whose members are engaged in the fabrication, installation, and servicing of piping systems. There are approximately 328,000 United Association members who belong to 316 individual local unions across North America. Founded in 1889, the United Association is one of the oldest building trades unions in the United States and Canada today. It serves as a collective voice for workers through negotiation and collective bargaining with employing contractor groups, such as the Mechanical Contractors Association of America and the National Association of Plumbing-Heating-Cooling Contractors. The UA is also a key member of the Building and Construction Trades Department, the AFL-CIO, and the Canadian Federation of Labour.

For more than a century, the UA has been training qualified craftworkers in the United States and Canada. Over the past several decades, the United Association's training programs have produced a stable, skilled workforce responsible for building and maintaining piping systems in the various industrial and residential facilities that make up the North American landscape. The UA spends more than $130 million annually on training program efforts involving approximately 100,000 journey-



Clean room for orbital tube welding training, located at the UA Regional Training Center in Charleston, S.C.

men and apprentices in more than 340 local training facilities at any given time.

The United Association had the first nationally registered joint apprenticeship program in the United States, dating back to 1936. UA apprentices learn through both classroom and on-the-job training. The five-year apprenticeship period is divided into one-year segments, each of which includes 1700 to 2000 hours of on-the-job training and a minimum of 216 hours of related classroom instruction. All UA apprentices receive a solid general education background in the trade, with core courses in basics such as mathematics, mechanical drafting, and related science. At an appropriate juncture, apprentices can choose a specific curriculum to pursue with the goal of becoming a journeyman plumber, pipefitter, sprinklerfitter, or an air-conditioning/refrigeration service technician.

Once UA members complete their five-year apprenticeships, they become full-fledged journeymen. However, their education in the trade is not over at that point. In fact, United Association members are serious about pursuing lifelong training and most of them take advantage of the many opportunities they have to update and expand their skills. In addition, all UA members are eligible to earn college degrees as part of their training. Members can choose from a wide variety of degrees, ranging from an associate's degree to a bachelor of science degree. Apprentices earn 32 college credits through Washtenaw Community College upon successful completion of their apprenticeships. These credits can be used to earn an associate's degree in construction supervision, industrial training, HVACR, and general studies. Degrees can be completed by taking from five to nine additional college-level courses. All requirements can be completed through online classes without having to attend on-campus classes. Students with prior college experience can transfer their credits into the program as well. In addition, UA associate's degree graduates can transfer into bachelor's degree programs offered through the National Labor College and Ferris State University.

To provide for comprehensive training and qualification of its member welders, the United Association established the UA Welder Training and Certification Program. There are more than 300 training schools owned and/or supported by the UA throughout North America. The program trains and qualifies welders in SMAW, GTAW, GMAW, FCAW, machine, semiautomatic, automatic, and orbital welding. Since its inception in 1993, the UA's welder training and certification program has provided more than 120,000 welding tests and has qualified more than 16,000 welders. Applicants are tested on the welding processes most commonly used on the majority of construction projects. Welders can choose to seek certification in any or all processes. The flexible program can accommodate special requirements of users and contractors. A user can request that welders be tested and certified for a specialized procedure that may be needed on a new or unique process. The program provides fully trained, pretested, certified, and immediately available journeymen welders throughout the United States and Canada at no cost to the construction user. As a demonstration of industry's recognition of the significant benefits of the program the Construction Users Roundtable (CURT) presented its prestigious 2005 Workforce Development Award to the joint UA/NCPWB Welder Certification Program.

There is a critical shortage of qualified welders today and America's power companies are leading the way in signing onto the United Association Welder Certification Program. With the energy industry's increasing need for improved quality and safety standards to protect the public, UA-trained welders are prepared to meet and exceed these requirements. Breweries and other beverage and food producers; pharmaceutical, educational, medical, and correctional facilities; malls, and other large commercial developments all depend on this quality of workmanship. United Association General President William P. Hite is fully committed to meeting the demands of industry, and has instituted a new formal policy of the United Association entitled "UA Standard for Excellence." The UA Standard for Excellence is a joint labor-management pledge to uphold the highest industry standard in the workplace, with the ultimate goal of ensuring customer satisfaction.

For additional information regarding UA apprentice training, visit *www.ua.org*.♦

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Undergraduate Welding Research at LeTourneau University

BY YONI ADONYI

College undergraduates have brought enthusiasm, motivation, and creativity to $1.65 million of projects over the past decade

LeTourneau University (LETU) is located in Longview, Tex., approximately 134 miles east of Dallas (*www.letu.edu*). Nationwide, there are few ABET-accredited institutions that teach welding engineering (WE) at the undergraduate level, and in fact, The Ohio State University holds the only WE program accredited in North America. The other ABET-accredited programs are design concentrations within a four-year BS in engineering degree such as at LeTourneau University (since 1954) and a new program that recently emerged at Montana Tech.

Several other universities, such as Weber State University in Utah and Ferris State University in Michigan, prove noteworthy because of good four-year BS programs in engineering technology. The fact is that welding engineering and topics related to WE research mostly are taught at the graduate level. Examples of institutions that offer MSc/PhDs include Ohio State, Massachusetts Institute of Technology, Renssalaer Polytechnic University, Colorado School of Mines, and others.

LeTourneau University is unique in its ABET/TAC accreditation for both a four-year engineering program and an engineering technology program. The LETU program has also been known to emphasize a "project-based" approach to teaching WE. The founder, R. G. LeTourneau, promoted welding as advanced and economical manufacturing technology, and used it in construction of his earthmoving equipment and offshore drilling platforms. In 2005, the program was renamed Materials Joining Engineering to include polymer, ceramic, and composite joining.

Undergraduate Research

How does research performed by undergraduates differ from graduate research? In two essential ways: professional preparation and actual time spent on doing work with minimal supervision. Undergraduates are generally less prepared than graduates for research because they had not taken enough classes and typically are less mature. Undergraduates also do not typically benefit from 50% release time from their studies and can only work evenings, weekends, and during summer months. On the positive side, undergraduates are enthusiastic, highly motivated, and creative, bringing fresh approaches to solving problems.

Between 1996 and 2006, more than 83 students worked at LETU on approximately 43 applied research projects. Undergraduate pay is also lower than graduate student salaries, which combined with tuition waivers not charged to the project results in lower cost than equivalent work at graduate institutions. Average project length at LETU was six months, funded at $25,000. Nevertheless, the total of $1.65 million funding in ten years came from industrial sponsors and professional organizations such as the American Iron and Steel Institute and the American Institute of Steel Construction and from state and federal sources. These projects ranged from welding process optimization to adhesive bonding and metallurgical transformations under nonequilibrium conditions in A 410 Mo stainless steel hardfacing.

Undergraduate Research Projects

Weldability Testing on High-Performance Weathering Steels

These new steels having minimum 70 and 100 ksi yield strength, respectively, (HPS 70W and 100W) represented a large amount of work in testing fusion zone and HAZ cold cracking susceptibility (Refs. 1–3). One specific contribution in this area was implementing on-site diffusible hydrogen testing, in the same environmental conditions where gapped bead-on-plate or Y-groove testing was performed.

Based on this work, preheat temperatures for avoiding hydrogen-induced cracking were established and published online under "HPS Manufacturing Guidelines" on the AISI Web site (*www.steel.org*).

Innovative Use of the Gleeble Thermomechanical Simulator

An example of applied research was simulating centrifugal casting of rolls for steel mills, where tool steel shells have to bond to the subsequently poured cast iron core — Fig. 1 (Refs. 4, 5).

The solid/liquid interface simulation work was also successfully applied to stainless steel-to-carbon steel transition layers, simulating electroslag weld hardfacing.

A recent example of an innovative use of the Gleeble was in simulation of a new hybrid welding process for on-line steel coil joining, sponsored by U.S. Steel in Kosice, Slovak Republic. The project's

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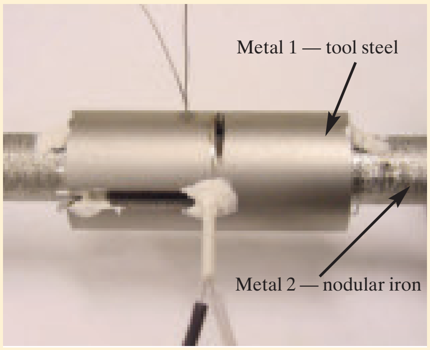


Fig. 1 — New Gleeble simulation sample geometry for dissimilar metal joining.

aim was to improve weld quality and reliability in joining advanced high-strength steels (AHSS), which were difficult to weld with the flash welding process that was used on the pickle and galvanizing lines. A novel idea of using a combination of high-frequency induction welding and resistance welding was successfully validated using the Gleeble.

Work is underway to change specimen geometry to one better simulating the lack of symmetry in sheet metal welding, while numerical modeling and small-scale prototypes are being built in Slovakia for this international cooperative project.

Adhesive Bonding vs. Welding of Steel Cabinets

Replacing unreliable and uneconomical corner gas metal arc welds in a power unit for the Defense Department was the goal of a work sponsored by the Texas Higher Education Coordinating Board, Lucent Technologies, and 3M Corp. Following welded joint redesign from corner- to lap-joint preparation, several industrial adhesives were tested and optimum combinations found. The prototype cabinets, which were adhesively bonded, performed adequately in static testing, but were clearly superior when compared to similar welded cabinets in seismic testing — Fig. 2.

Another solution provided by the research team was finding the highest strength industrial adhesive that cured at the same temperature as the paint used for the cabinet.

These projects illlustrate the applied and relevant nature of the research performed at LeTourneau University.

Future Trends

The research of the past decade resulted in nine papers, 12 technical presentations, ten reports, and seven posters.

Fig. 2 — Adhesively bonded cabinet during seismic testing at Southwest Research Institute.

Many projects performed under confidentiality agreements were never published. Most solutions provided had immediate applicability and helped in improved quality, higher productivity, and better designs. The technical value of the undergraduate research has also earned recognition through various awards from professional societies.

The LETU team has recently been challenged to approach new process simulations such as friction stir welding, as well as welding-related topics such as centrifugal casting. This illustrates this new trend of approaching materials bonding/joining in a more comprehensive fashion than before. One such example of a new trend project is working on biomedical research on leg prosthesis design, its fatigue strength (Fig. 3), and nondestructive testing. The project is led by Roger Gonzales. The LeTourneau Engineering Global Solutions (LEGS) provides a low-cost prosthesis solution to developing countries such as Kenya and Bangladesh, see *www.letu.edu/legs*.

Robert Warke joined the faculty at LETU in 2003 and his expertise in weld design and probabilistic assessment of

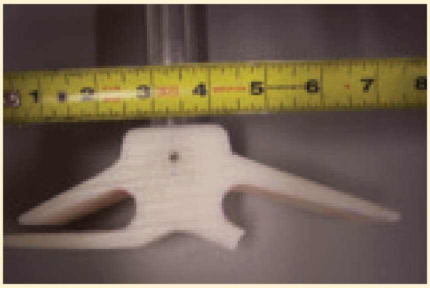


Fig. 3 — Plastic foot-to-aluminum stem joint prototype that failed during fatigue testing after two-million cycles.

welds has already been successfully used in a through-deck stud welding study funded by the American Institute for Steel Construction. We expect to work together on more materials joining design and process related research on advanced materials, ceramics, polymers and composites. This will all be taught from the improved curriculum in Materials Joining Engineering.

Conclusions

Undergraduate research presents specific challenges in the areas of student competencies, resident time and depth of understanding, limiting work to applied research and problem-solving topics. Nevertheless, several innovative solutions resulted from this work at LETU in the area of Y-groove test specimen preparation, as well as in Gleeble simulation techniques for solid-liquid interfaces and hybrid joining technologies. At the same time, the outcomes of these projects were relevant and truly needed by different industry sectors. Finally, those who hired former undergraduate researchers from LETU received the added benefit of professional competency and ability to work independently.♦

Acknowledgments

The author would like to thank all those who supported us during this first decade of undergraduate research at LETU. Thanks go out to all those students who faithfully completed their work, to Professor Emeritus William Kielhorn who through the years helped maintain the continuity of the work in an orderly and systematic way, and all of our industry partners who have validated the relevance of our endeavors and provided in-kind funding through equipment and consumable donations. Finally, all this would not have been possible without strong institutional support from LETU Administration.

Company Tackles Welder Shortage by Opening Welding School

One of the energy plants that has relied on welding skills provided by Carolina Energy.

Seeing a growing need in the energy industry for qualified welders, Carolina Energy made the decision to invest in training

"Where have all the welders gone?" In late summer 2006, this *Wall Street Journal* headline screamed a problem that industry had long been aware of — the critical shortage of skilled welders. Compare the number of career welders nearing retirement age against younger workers shying away from a welding career. Now combine that with a boom in industrial manufacturing, construction, and repair work, and it becomes clear why the shortage of skilled welders has reached critical mass.

Companies are employing a wide variety of tactics, ranging from significant signing bonuses and tuition reimbursement to starting salaries on par with a newly graduated engineer, in order to attract and retain welders. Though numerous vocational and high schools across the country have jumped on the bandwagon, expanded their welding programs, and are graduating record numbers of welders, it's still not enough to keep up with industry demand.

With all of this in mind, Carolina Energy Solutions decided to take matters into its own hands and with the help of The Lincoln Electric Co. opened its own welding school.

Story provided by The Lincoln Electric Co., Cleveland, Ohio.

Fig. 1 — This South Carolina firm specializes in providing services to the energy industry.

Fig. 2 — The startup welding school outfitted 50 welding booths for the students.

Energy Industry Demands

Based in Rock Hill, S.C., Carolina Energy Solutions (Fig. 1) works in one of the world's fastest-growing areas — the energy industry. With a focus on issues such as rising gas prices, U.S. foreign oil dependence, and alternative power sources, the energy industry is seeing unprecedented growth on all fronts. New plants are being constructed, and older plants are being upgraded and renovated. All of this activity has created exceptional demand for contractors such as Carolina Energy.

The ten-year-old firm, started by a group of welders from the nuclear power plant boom in the 1970s, offers a complete range of welding, machining, and postweld heat treating services for the nuclear, fossil, hydropower, waste-to-energy, petrochemical, gas, and general fabrication industries. The company contracts directly with utility companies across the country for outage work, new construction, and retrofits. It also subcontracts with some of the leading national and international construction/engineering firms, including Bechtel, Jacobs, Shaw, TIC, Fluor, and Zachry. Carolina Energy's technicians handle preweld and postweld heat treating, field machining and welding of piping, boilers, turbines, valve repair, fabrication and installation both at the company's South Carolina facility and in the field throughout the United States and abroad.

Whereas for some contractors welding is just one part of their overall services, welding is front and center at Carolina Energy and integral to the company's overall success. More than 80% of the firm's 400 employees are welders, making the shortage of skilled welders all that more significant.

"So we decided that since we couldn't recruit enough skilled welders fast enough to keep up with customer demand, we would just create our own," said Danny Sechler, a welding specialist and Construction Institute of America's coordinator.

In late 2006, Carolina Energy welcomed the first welding students to its new Construction Institute of America, a separate nonprofit entity managed by Carolina Energy staff and partially funded through the federal government's Workforce Investment Act. The institute is housed at the company's South Carolina campus and consists of 50 fully outfitted welding booths — Fig. 2. Carolina Energy believes its graduates will be the "welding leaders of the future." Al Lovins, who successfully operated several welding schools during the boom in the late 1970s and early 1980s, manages the school and lends 30 years of welding experience to help these students prepare for their new careers.

From the Ground Up

Opening a new welding school meant a significant investment for Carolina Energy. It meant building the school from the ground up, hiring a full-time team of experienced instructors, marketing its program to potential students, and purchasing all new equipment.

The firm planned the school to open with 50 booths outfitted and ready for hands-on work starting on day one. With this in mind, the company talked to major welding manufacturers, and in the end, chose The Lincoln Electric Co. for its new venture.

Carolina Energy's welders are skilled in the typical welding processes, shielded metal arc (SMA), gas metal arc (GMA), gas tungsten arc (GTA), and flux cored

Fig. 3 — A student practices his gas tungsten arc welding skills on pipe.

arc welding (FCAW) — Fig. 3. Because of the type of projects they handle, the welders also work with a number of specialty welding applications, such as orbital welding. (Carolina Energy was recently chosen by orbital welding equipment manufacturer, Liburdi Dimetrics, to become its authorized training and repair center.) For its arc welding equipment, the Construction Institute of America purchased and installed 50 Lincoln Invertec® V350-PRO welding machines. The school is also using Lincoln Excalibur™ electrodes and UltraCore™ welding wire.

A Good Deal

Students entering the new school start out at $18/hour or about $37,500/year and sign on to work for the company for one year following graduation. If they stay on after their first year, they move up to $28–$30/hour or about $60,000/year, which is in line with the starting salary of an engineer graduating with a four-year degree.

"In addition to extremely competitive pay, many of our students will also have the opportunity to travel, as we send our technicians out to jobs around the country," Sechler stated. "It's a great opportunity for them."

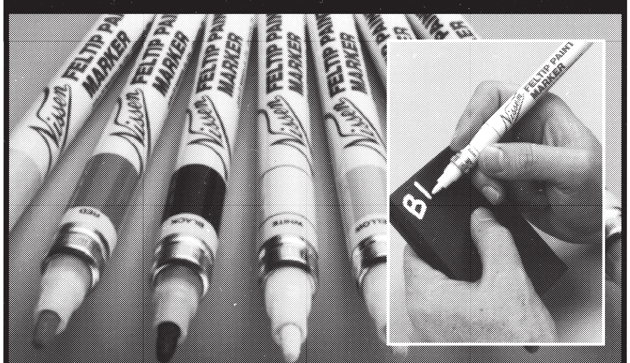
The school has a waiting list, so as soon as it sends one graduate out into the field, his or her place is taken by another. With high demand from the industry and customers, Carolina Energy is considering doubling the school's capacity to 100 booths.

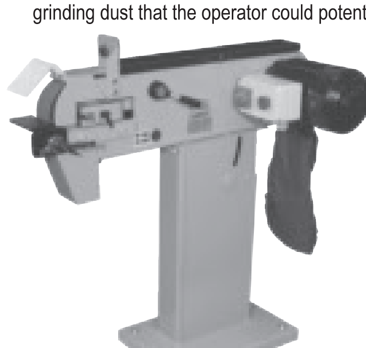
Students spend a minimum of five hours a day welding, with the balance consisting of classroom work. Students start out SMA welding, move onto flux core, then to open-butt GTA welding on pipe. They are tested after each stage and are required to meet the appropriate ASME Section IX acceptance criteria in order to move on.

"Because customer demand is so high, our students have even had the opportunity to get hands-on field experience before completing our entire program. For example, we had a project in Wisconsin that only required stick welding, so the students who had passed the ASME Section IX test were sent north to work side-by-side with our experienced welders," Sechler explained. "The customer appreciated that we were able to meet their tight schedule, and the students spent a couple of weeks on-site putting their training to work."

Once that project was completed, those students returned back to their welding booths completing the next stage of training.

"Opening our own school has given us great versatility and flexibility we didn't previously have," Sechler summarized. "Everybody benefits, Carolina Energy and our customers from having a readily available, skilled workforce, and our students receiving excellent training and guaranteed job placement."♦





Circle No. 53 on Reader Info-Card

SCHOOL PROFILES APRIL 2007

Employers
Are you in need of good welders?

Students
Are you searching for a way to hone your skills?

Below are welding schools across the country that, for a nominal fee, have taken the opportunity to promote their resources both to industry in need of welders and to those searching for a solid career path to employment. Contact them and take advantage of the services they can provide.

University of Alaska Anchorage Welding and NDT Technology

Founded 1970

The Welding/NDT program at UAA offers a choice of certificates and an Associate of Applied Science degree that centers on welding skills, welding inspection and nondestructive testing. Program courses include skill development in major welding processes, pipe fitting and basic metallurgy, as well as hands-on NDT training in the RT, UT, MT and PT processes. Our program serves about 175 students each year.

UNIVERSITY of ALASKA ANCHORAGE
Community and Technical College

3211 Providence Drive GHH 111
Anchorage, AK 99508
(907) 786-6475
Fax: (907) 786-6474
www.uaa.alaska.edu/ctc/programs/cdt/welding

Atlanta Technical College Making Great Welders

Founded 1967

Atlanta Technical College offers top-notch Welding Programs to students in the metro Atlanta area. Day and evening classes are available, and students may earn a Diploma or Technical Certificate of Credit. Atlanta Tech's state-of-the-art Welding Lab is the ideal setting for our hands-on, individualized approach to instruction. Atlanta Tech faculty are Certified Welding Instructors and Certified Welding Educators. Consultation in underwater cutting and welding is available.

ATLANTA TECHNICAL COLLEGE

1560 Metropolitan Parkway SW
Atlanta, GA 30310
(404) 225-4518
E-mail: bhicks@atlantatech.edu
www.atlantatech.edu

Atlantic Technical Center

Founded 1973

Atlantic Technical Center provides a review for persons currently employed in welding occupations who wish to take an AWS test to become a Certified Welder, or first time students who are interested in learning advanced and basic welding skills techniques. Shop activities are an integral part of this course and provide instruction to develop skills in Industrial, Structural, Aircraft, Marine, Petroleum and Nuclear Welding. At the successful completion of laboratory activities, an AWS Welding Certification test is available. Accredited by the Commission of the Council on Occupational Education.

ATLANTIC TECHNICAL CENTER

4700 Coconut Creek Parkway
Coconut Creek, Florida 33063
(754) 321-5100
Fax: (754) 321-5380
Contact: Frank Rose,
Welding Instructor, Ext. 3108
www.atlantictechcenter.com

Beaufort County Community College

was granted community college status in 1979.

Since 2001, the welding program has placed over 190 students with local industries. Our welding facilities incorporate state of the art equipment and our courses cover all of the welding trades from the beginner to the advanced welder that meet industry standards. We offer an associate degree, diploma, and six certificates in welding. We make a difference in the future of our students.

Beaufort County Community College

P.O. Box 1069
Washington, NC 27889
(252) 940-6224
Fax: (252) 946-4405
Email: tedc@beaufortccc.edu
www.beaufort.cc.nc.us

Bellingham Technical College Welding Technology Program

Founded in 1956

Bellingham Technical College's Welding Technology Program offers AAS and AAS-T degrees in Certified Welding and Fabrication for a vibrant community of Pipelines and Northwest Washington Refineries, Ship building and Repair, Transportation, and shops and fabricators. This Award-Winning program is poised for an April, 2007 expansion into an 80,000 sq. ft. State-of-the-Art facility to house our 200 plus enrollment in Pipe Welding, Aluminum Welding and Fabrication, Steel Fabrication, and Creative Welding. Our 6th Annual Welding Rodeo Sculpture Contest is a one-of-a-kind experience for Amateurs and Professional Artists throughout the Pacific Northwest.

Bellingham TECHNICAL COLLEGE

Welding Technology Dept.
3028 Lindbergh Ave.
Bellingham, WA 98225-1599
(360) 752-8346
www.btc.ctc.edu or
www.weldingrodeo.com
danderso@btc.ctc.edu

SCHOOL PROFILES APRIL 2007

Butte-Glenn Community College

Founded 1967

The Welding Technology Program is a vocational core of courses designed to produce qualified personnel for certified welding jobs. Program performance standards for certification are in accordance to those established by the American Welding Society and/or American Society of Mechanical Engineers. Courses are held in a completely modern and well-equipped welding lab. This program is designed to produce an entry-level welding technicians in the 6-G pipe position (qualifies for all positions in plate and pipe) Heavy Plate 3G and 4G are also obtainable. The student will be able to weld with SMAW, FCAW, GMAW, GTAW, OAW, OFC, PAC and AAC in all positions with a variety of metals and alloys. Students will be able to certify under at least one of the following codes: API, AWS, and ASME, according to individual skills.

3536 Butte Campus Drive
Oroville, CA 95965
Mike Rabo, rabomi@butte.edu
(530) 895-2360 Fax: (530) 895-2302
Don Robinson, robinsondo@butte.edu
(530) 895-2469 Fax: (530) 895-2302

Central Piedmont Community College

Founded 1963

The James Turner Institute of Welding Technology at CPCC provides students with a sound understanding of the science, technology, and applications essential for successful employment in the welding and metal industry. Instruction includes consumable and non-consumable electrode welding and cutting processes. Additional courses in math, writing, computer technology, blueprint reading, metallurgy, welding inspection, and non-destructive examination provide the student with industry-standard skills developed through classroom and practical applications. CPCC is an AWS QC7 accredited test facility.

Get There.
CENTRAL PIEDMONT COMMUNITY COLLEGE

P. O. Box 35009
Charlotte, NC 28235 USA
(704) 330-CPCC (2722)
Email: steve.gore@cpcc.edu
www1.cpcc.edu

Chippewa Valley Technical College

Chippewa Valley Technical College's Welding program provides training in SMAW (stick), GMAW (wirefeed), GTAW (TIG), oxy-acetylene welding and cutting, pipe welding, and robotic welding. There are two section formats available, a one-year day section and a two-year (four semester) evening section. Students graduate with a technical diploma and the opportunity for a Wisconsin state welding certification. Instructors are Jon Will (jwill@cvtc.edu), AWS CWI/CWE; Brent Rosenberg (brosenberg @cvtc.edu); and Walter Quaschnick (wquaschnick@cvtc.edu).

620 West Clairemont
Eau Claire, WI 54701
(715) 858-1814
www.cvtc.edu

College of the Canyons

College of the Canyons, an AWS Accredited Testing Facility, has trained welders for 31-plus years. Courses cover industrial welding, pipe, metallurgy, weld inspection, certification preparation and metal sculpturing, as well as technologies such as oxyacetylene, laser, shielded metal arc, gas tungsten arc, gas metal arc, orbital gas tungsten arc and controlled atmosphere chamber welding. Instructors are AWS-certified. Certificates and degrees are offered. Courses are offered day and night, and programs can often be completed in one year.

26455 Rockwell Canyon Road
Santa Clarita, CA 91355
(661) 259-7800
Email: tim.baber@canyons.edu
www.canyons.edu

Cosumnes River College

Cosumnes River College offers a certificate in welding. Our classes begin with the Basic Introduction to welding WELD 100, and then the student can choose to take Advanced SMAW, FCAW and GMAW in WELD 110. We offer an in house welding certification WELD 114 in all welding process, and we have a welding class that specializes in GMAW and GTAW. Our program is dedicated to meeting the needs of industry. Currently, our students are working on certifications for Flux core arc welding with NR 232, SMAW with E-7018 and GMAW on sheet steels. The welding instructor, Mr. Jason M Roberts is a certified welding educator, certified welding inspector and currently earning a certificate in OSHA safety training to be able to offer a certified safety training program for Fall 2007.

8401 Center Parkway
Sacramento, CA 95823-7146
www.crc.losrios.edu/

CTC Lackawanna Co,

(Formerly Lackawanna Co AVTS)

Founded in 1973

CTC serves the secondary students and adult community of the greater Scranton (PA) region. Emphasis is placed on safety as well as blueprint reading, properties of metal, metal identification, types and use of electrodes, welding rods, electrical principles, and welding symbols. Secondary and Adult students are prepared to take AWS certification exams.

3201 Rockwell Ave
Scranton PA 18508
(570) 346-8471
Email: admctc@ctclc.edu
www.ctclc.edu.

SCHOOL PROFILES APRIL 2007

Dabney S. Lancaster Community College

Founded 1967

Dabney S. Lancaster Community College offers welding training on its western Virginia campus. Earn a certificate or associate in applied science degree. Employer-driven curriculum teaches the skills needed in today's workforce: oxy fuel, SMAW, GTAW, GMAW and pipe welding. Key support courses such as metallurgy, blueprint reading and quality control. Benefit from free qualification testing. Enjoy small classes, free tutoring and personal attention. Customized courses available for employers. Offering quality, affordable education and training since 1967.

1000 Dabney Drive,
Interstate 64, exit 24
Clifton Forge, VA 24422-1000
(540)863-2895
Email: mbryant@dslcc.edu
www.dslcc.edu

Del Mar College

Founded 1935

Del Mar College is a comprehensive community college in Corpus Christi, Texas. Our welding program offers skill development in SMAW, GMAW, GTAW, FCAW, and various other processes on plate and pipe welding to industry standards. Certificate and Associate Degree programs offered. Visit us on the website or call 1-800-652-3357 for information.

101 Baldwin Blvd.
Corpus Christi, TX 78404-3897
(800) 652-3357
www.delmar.edu

The Divers Academy International

The Divers Academy offers the highest quality training in the shortest amount of time to jumpstart your career. It is known for its full-immersion training methodology and its modern training facilities. Underwater Cutting and Welding is just one part of a comprehensive 5-month curriculum. Founded in 1977, the Divers Academy International trains divers for Commercial Deep Sea Diving and Wet Welding, providing students with an employer's most sought-after qualification: on-the-job experience. Financial aid is available for those who qualify.

Lakeside Business Park
1500 Liberty Place
Erial, NJ 08081-1139
(800) 238-DIVE
admissions@diversacademy.com
www.diversacademy.com

Doña Ana Community College

Founded 1973

The Doña Ana Community College Welding Technology program has a national reputation for excellence, and is taught by top-notch AWS CWE's and CWI's. Our 75-90 full and part-time students take courses in: SMAW, GMAW, GTAW, FCAW, SAW, steel, stainless, aluminum, pipe, metallurgy, NDT and DT, welding Codes, welding symbols and blueprint reading, pipe welding, fabrication, and welder qualification. Graduates leave as AWS/ASME certified welders. Courses are offered days or evenings. Certificate and Associate Degrees offered.

MSC 3DA,
3400 S. Espina St.
Las Cruces, N.M. 88003-8001
(505) 527-7500
David Twitty: dtwitty@nmsu.edu
Terry Mount: tmount@nmsu.edu
www.dabcc.nmsu.edu

El Camino College

Founded 1947

The El Camino College welding department strives to meet diverse student needs by providing quality instruction in morning, afternoon, and evening classes. Introductory, intermediate, and advanced welding courses in oxy acetylene welding and cutting, gas tungsten arc, shielded metal arc, gas metal arc, and flux cored arc welding are offered. Students can earn a welding certificate or AS Degree.

Welding Department
16007 Crenshaw Boulevard
Torrance, CA 90506
(310) 660-3600
www.elcamino.edu

Frank Phillips College

The Frank Phillips College Welding Technology Department is dedicated to providing students with superior performance-paced training in our new state-of-the-art facility. FPC provides the latest training in metallurgy, fab and layout, SMAW, GTAW (TIG) , GMAW (MIG), Oxyfuels and the PipePro System. Located in a hub of oil and gas industries, our team has an excellent reputation for high job placement of quality craft personnel.
"Start Here…Go Anywhere!"

Welding Technology Department,
Borger, TX
(806) 457-4200, ext. 782
Email: msimmons@fpctx.edu

The Grand River Technical School

The welding technology course is designed to prepare students for entry-level employment in the welding field. Students will acquire knowledge and hands-on experience in welding/cutting processes that are in high demand. Students will receive instruction on safety practices, printreading, work ethics, and pre-employment preparation. Upon successful completion students receive a certificate for 1080 hours, may become certified, and have the opportunity to receive an associates degree through a college articulation agreement.

1200 Fair Street
Chillicothe, MO. 64601
(660) 646-3414
Fax: (660) 646-3568
www.grts.org

Great Basin College Welding

Founded 1967

Great Basin College offers an Associates of Applied Science Degree and a One Year Certificate in Welding Technology, established in 1990. Currently, 20 students are enrolled in a program that prepare them with skills to create new products; repair existing products; and work in the mining, manufacturing, construction, transportation and agricultural industries. Program highlights include instruction in welding theory, blueprint reading, fabrication, quality control, metallurgy, qualification testing, destructive and nondestructive testing principles, and safety.

Elko, Nevada
(775) 753-2207 or (775) 753-2170
Rich Barton e-mail:
richardb@gwmail.gbcnv.edu
Jon Licht e-mail:
jonl@gwmail.gbcnv.edu
www.gbcnv.edu

Harper College

Harper College's 16 credit-hour certificate program provides students with entry-level skills in welding repair. The program emphasizes advanced welding theory, extensive practice in major arc welding process, and out-of-position and multi-pass arc welding including GMAW, SMAW, and GTAW. Upon completion, students are prepared to pass guided bend tests to become certified welders in accordance with AWS (American Welding Society) D1.1 Structural Welding Code.

1200 W. Algonquin Road
Palatine, IL 60067-7398
(847) 925-6507
E-mail: lacosta@harpercollege.edu
Web: harpercollege.edu

Hobart Institute of Welding Technology

Founded 1930

Hobart Institute of Welding Technology's course offerings is available in a 42-page catalog that explains in detail the wide range of welding classes offered. More than 25 separate welding courses are described by course objective, content and testing requirements. Inside the 2007 catalog is course schedules, training rates, and enrollment forms. Training may be done at our facility or yours.

400 Trade Square East
Troy, OH 45373
(800) 332-9448
FAX: (937) 332-5200
Website: www.welding.org

Ivy Tech Community College

Founded 1963

The Welding Training Program at Ivy Tech Community College offers a technical certificate, and associate of applied science degrees in Manufacturing and Industrial Technology with a concentration in Welding. Skills taught at our facility could lead to AWS and ASME certification. Ivy Tech Community College, Lafayette is an AWS educational institution member and have AWS certified welding inspectors and certified welding educators on staff. Our welding program has sustained a steady enrollment of over one-hundred students each semester for the past several years.

3101 South Creasy Lane
Lafayette, IN 47905
(765) 269-5146
Dennis A. Nance,
Email: dnance@ivytech.edu

Kenai Peninsula College

Kenai Peninsula College is a branch of the University of Alaska located 150 miles South of Anchorage on the Kenai Peninsula. KPC offers certification on AWS D1.1 .375 steel plate 3G & 4G SMAW, ASME Section IX pipe certification on steel 6-inch schedule 80 6G SMAW. Our certificate program includes Math, Blueprint, and English (students must certify on pipe to complete certificate). KPC students are provided with 3M® powered air purifying respirator welding hoods.

34820 College Drive
Soldotna, Alaska 99669
(907) 262-0300
Fax: (907) 262-0395
Fritz Miller, Welding Instructor
(907) 262-0356
iffwm@uaa.alaska.edu
www.kpc.alaska.edu

Lansing Community College

Founded 1957

Lansing Community College offers an Associates Degree in Welding Technology as well as a Certificate of Achievement one year Degree in Welding. Our nine Welding Classes consist of Basic Oxyacetylene, Brazing, Torch Cutting / Plasma Cutting and SMAW in our 1st course and the other courses advance into the Advanced SMAW, Pipe Welding, GMAW, GTAW, Structural Fabrication, blueprint Reading, Rigging, and Metallurgy. We do customized training with Industries. We have over 500 students per year. Instructors are CWI's and instructors with many years of experience.

P.O. BOX 40010
Lansing, MI 48901-7210
(517) 483-9682
Fax: (517) 483-1320
William Eggleston,
Email: beggleston@lcc.edu
www.lcc.edu

Lincoln Electric Welding School

Founded 1917

Learn to weld at the Lincoln Electric Welding School. We have trained over 100,000 welders in many different trades (ironworkers, boilermakers, pipefitters, sheet metal, etc). You will learn to weld with the latest technology in equipment,on different base metals (carbon steel, stainless, aluminum, cr/mo tubing, etc) and many different processs (SMAW, GMAW, GTAW, FCAW, SAW). Our instructors have real world experiance doing trackside welding at motorsports events like Daytona (NASCAR,ROLEX), INDY (500, BRICKYARD 400), we also do job site training at your location.

22801 St. Clair Ave.
Cleveland, Ohio 44117
Bill West: (216) 383-2259
Jennifer Howell (216) 383-8325
www.lincolnelectric.com

Locklin Tech

Locklin Tech offers secondary and post-secondary training for a broad range of careers in the welding industry. NCCER Contren® Learning Series curriculum helps students gain valuable global skills. Industry recognized credentials are maintained through NCCER's National Registry. Instructor James Sullivan is active in SkillsUSA and has been the recipient of the AWS Howard E. Adkins Instructor Award at the section, district and national levels.

5330 Berryhill Road
Milton, FL 32570
(850) 983-5700
www.locklintech.com

Maysville Community and Technical College Rowan Campus

This program offers plate and pipe weld training using the SMAW, GMAW, and GTAW processes. Training can lead to a certificate, diploma, or Associate Degree as well as certification on structural steel with the SMAW and GMAW processes. Program is certified by the AWS as an Educational Institution Member and certified by the United Association of Plumbers and Pipefitters as an orbital tube welding training/certification center.

Welding Technology
609 Viking Dr.
Morehead, KY 40351
Dean Howard / Stanley Click
(606) 783-1538 ext. 66347 or 66334
Deanb.howard@kctcs.edu
Stanley.click@kctcs.edu

Mesabi Range Community & Technical College

Mesabi Range offers a rigorous welding curriculum following national skills standards developed by the American Welding Society. The Entry Level Welder Diploma and the Advanced Welder Diploma, established in 1997, give the successful graduate very marketable skills in the welding industry. Experienced, knowledgeable instructors, a great staff, up-to date equipment, and a modern shop provide a great learning environment. We have 100% job placement in the last nine years. Welding certifications are available.

P.O. Box 648
1100 Industrial Park Drive
Eveleth, MN 55734
(218) 741-3095
Fax: (218) 744-7644
Website: www.mr.mnscu.edu

Moraine Park Technical College

Moraine Park Technical College offers a 1-year welding diploma program that focuses on GMAW, SMAW, and GTAW on steel, stainless, and aluminium. The program includes Print Reading and Fabrication courses that focus on the manufacturing process of a product from conception to final production via basic layout tools and CNC equipment. Instruction includes AWS and ASME welding codes, including qualification tests and writing WPS's, with the opportunity to weld-certify upon completion of the program.

700 Gould Street
Beaver Dam, WI 53916
920-887-4494
Larry Clark,
lclark@morainepark.edu
or
920-887-4490
Sue Silverstein,
ssilverstein@morainepark.edu
www.morainepark.edu

SCHOOL PROFILES APRIL 2007

North Dakota State College of Science

The North Dakota State College of Science is a two-year, comprehensive, residential college that offers degrees, certificates and diplomas in over 80 academic options in traditional career and technical studies and in the liberal arts. NDSCS offers a one-year certificate and two-year diplomas and degrees in Welding Technology. The college is an American Welding Society S.E.N.S.E. certified facility. Last year, 99 percent of NDSCS graduates entered the workforce or continued their college education. Unlike most two-year colleges, NDSCS offers a university atmosphere for students — residence halls, clubs and organizations, fine arts, athletics and numerous social activities.

North Dakota State College of Science

800 Sixth St. North
Wahpeton ND 58076-0002
(701) 671-2483
www.ndscs.edu

North Georgia Technical College

Founded 1907

North Georgia Technical College's Welding and Joining Technology Diploma Program is designed to prepare students for careers in the welding industry. The program offers learning opportunities to develop academic, technical and professional knowledge and skills required for job acquisition, retention and advancement. Welding theory and practical application necessary for successful employment is emphasized. Graduates have the qualifications of a welding and joining technician and are prepared to take qualification tests.

NORTH GEORGIA TECHNICAL COLLEGE

P.O. Box 65
Clarkesville, GA 30523
(706) 754-7700
www.northgatech.edu

Northland Community & Technical College

Northland Community & Technical College is located in East Grand Forks and Thief River Falls, MN. NCTC's Welding Technology diploma program in East Grand Forks is accredited by the AWS and designated as a S.E.N.S.E (Schools Excelling through National Skills Education) Level 1 and 2 program. This program is taught by a C.W.I and C.W.E. Welding students cover processes of SMAW, GMAW, FCAW, GTAW and SMAW Pipe. In addition, students complete course work in Cutting Processes, Blueprint Reading, Metallurgy, Fabrication, Human Relations and First Aid/CPR. Program enrollment is currently set at 41 students.

NORTHLAND COMMUNITY & TECHNICAL

brian.suckow@northlandcollege.edu
East Grand Forks, MN Campus
1-800-451-3441
joel.ziegler@northlandcollege.edu
Thief River Falls, MN Campus
1-800-959-6282
www.northlandcollege.edu

Odessa College Welding Technology

The Odessa College Welding Technology Department in Odessa, Texas offers a full range of certificate and associate degree options. Labs are equipped with 15 OFW stations and 45 modern welding stations for training in SMAW, GMAW, FCAW and GTAW processes. Classes are offered in the mornings and evenings accommodating an average of 100 students each semester. Odessa College recently received a $1.75 million Department of Labor Grant for the West Texas Welding Training Center. Opening in October 2007, the new 30-station facility will offer specialized short courses through the Continuing Education Division.

ODESSA COLLEGE

201 W. University
Odessa, TX 79764
(432) 335-6474
James Mosman – Department Chair
Email: jmosman@odessa.edu

Orange Coast College

Founded 1947

The Orange Coast College welding curriculum has been a part of this college curriculum since the college was first conceived. Our program offerings include both a Welding Certificate of Achievement and an Associate in Science Degree. We are proud to offer a comprehensive welding program which includes Oxy-acetylene welding and cutting, SMAW, GMAW, FCAW, GTAW, Orbital welding and Plasma cutting. On our academic side we teach Metallurgy for welders, Codes and Specifications for welders, Math and Science for welders and Testing and Inspection for welders. Our instructors have AWS QC-1 CWI and CWE credentials as well as California Community College teaching credentials. We qualify welders to ANSI standards and we are a licensed Los Angeles City testing laboratory. Our testing laboratory does both destructive and non-destructive examinations.

ORANGE COAST COLLEGE

2701 Fairview Road
Costa Mesa, CA 92626
(714) 432-5820

Owens Community College

Owens Community College Welding Technologies provides students with knowledge and skills for job placement in the welding industry. Students are educated in all aspects of welding including SMAW, MIG and TIG welding, torch and plasma cutting as well as brazing. Students who excel in their welding skills are encouraged to complete their plate and pipe welding certification. Students may also chose from coursework in welding fabrication, welding codes and procedures and Certified Welding Inspector.

OWENS COMMUNITY COLLEGE

Welding Technologies
P.O. Box 10,000
Oregon Road
Toledo, Ohio 43699-1947
(567) 661-7729
Email: James_Gilmore@owens.edu

SCHOOL PROFILES APRIL 2007

Pennsylvania College of Technology

Founded 1989

Pennsylvania College of Technology, a Penn State affiliate since 1989, has a reputation for excellent graduate placement, "degrees that work" in more than 100 careers, and a modern campus and has a student body of 6,500. Penn College offers a complete welding education. In addition to an associate degree and certificate, Penn College offers a unique Bachelor of Science degree in Welding and Fabrication Engineering Technology that prepares graduates for technical careers and positions in mid-management, supervision, sales, service, and research. Contact us for more information, or visit our Web site.

Pennsylvania College of Technology
PENNSTATE

One College Avenue
Williamsport, PA 17701
(800) 367-9222
Email: admissions@pct.edu
www.pct.edu/schools/iet/weld/

Pulaski Technical College

The Welding Program at Pulaski Technical College in North Little Rock, Arkansas focuses on structural welding and offers AWS Level I and II certification. The two-semester Technical Certificate program includes instruction in welding processes, joint design and metallurgy. The Certificate of Proficiency will allow an individual to complete certification requirements in 3G (vertical) positioning.

PTC
PULASKI
Technical College

Technical and Industrial Programs
3000 West Scenic Drive
North Little Rock, AR 72118
501-812-2200
www.pulaskitech.edu
swilliams@pulaskitech.edu

Rock Valley College

RVC's welding program currently includes 60 students trained in the facility which includes a lab with 28 welding booths. Welding processes being taught include: MIG, TIG, Stick, Flux Core, and Oxyacetylene. RVC is an AWS Certified Accredited Testing Facility. The welding lab has been at current location for six years staffed by one full time and five part-time faculty. RVC is a certified ICAR welding testing center. For information, contact Mike Merriman.

Rock Valley College

Rockford, Illinois
(815) 921-3015
Mike Merriman
Email: m.merriman@rockvalleycollege.edu.
www.rockvalleycollege.edu

Santa Fe Community College

Founded 1966

The Applied Welding Technologies Program is a one and one-half year certificate program that consists of SMAW, GMAW, GTAW, FCAW, Oxy-Fuel Welding/Cutting, blueprint reading and power tool and equipment operation performed on carbon steel, stainless steel and aluminum. The training helps prepare students to pass nationally recognized plate and pipe welding certification tests. The welding lab at SFCC is an AWS Accredited Testing Facility

SANTA FE
COMMUNITY COLLEGE

3000 NW 83rd Street
Gainesville, FL 32606
(352) 395-5253
Fax: (352) 395-5364
joseph.mahoney@sfcc.edu

South Plains College

Founded: 1957

The SPC Welding Technology Program offers basic and advanced certificates along with an Associate of Applied Science degree. Entry level and advanced training certificates through AWS are also awarded to those who qualify. Specific areas of training include: OFC, PAC, SMAW plate and pipe, GMAW plate and pipe, FCAW plate and pipe, GTAW sheet and pipe, welding symbols, blueprint reading, welding metallurgy and structural and pipe layout and fabrication.

SPC

South Plains College
1401 S. College, Box 88
Levelland, Texas 79336
806-894-9611, ext: 2284
pstracen@southplainscollege.edu
www.southplainscollege.edu/welding/index.htm

SouthWest Collegiate Institute for the Deaf of Howard College

Founded in 1980

The Welding Technology Program is unique in that we specialize in educating only deaf and hard of hearing students. The program offers a Level I Certificate which requires 31 semester credit hours of course work. Some of the courses offered are: Blueprint Reading, Oxy-fuel Welding and Cutting, Welding safety, Metal Arc Welding, MIG Welding.

Randy Key

HC

3200 Ave. C
Big Spring, Texas 79720
(432) 264-3700 V/TTY
(432) 264-3707
rkey@howardcollege.edu
www.howardcollege.edu

SCHOOL PROFILES APRIL 2007

Tri-County Technical College

Founded 1965

The welding department at Tri-County Technical College has trainied welders for industry since 1965. We offer an associates degree, diploma, and two shorter certificate programs. With two CWI / CWE's on staff we can provide welder certification testing, as well as customized company training.

7900 Highway 76
P.O. Box 587
Pendleton, SC 29670
(864) 646-1405
pphelps@tctc.edu

Trident Technical College

Founded in 1964

Trident Technical College's welding technology program offers an associate degree in occupational technology with a welding career path and certificates in shielded metal arc, gas tungsten arc, gas metal arc and flux cored arc welding, as well as advanced certificates. The program is an AWS S.E.N.S.E. Level I and Level II program. With a student body of more than 11,000 students, TTC is committed to providing diverse and innovative educational programs and services in a highly technical and competitive global environment.

P.O. Box 118067
Charleston, SC 29423
(843) 574-6139
Fax: (843) 574-6173
ronald.vann@tridenttech.edu
www.tridenttech.edu

Tulsa Welding School

Founded 1949

Tulsa Welding School is the largest accredited* welding institution in America with training centers in Tulsa, OK and Jacksonville, FL. Founded 58 years ago, diploma and Associate degrees are awarded. Welding competencies include structural, pipe, pipeline, and thin alloy welding. Associate level also includes numerous NDT techniques plus QA/QC methods. Graduates are available every three weeks along with thousands of alumni who contact TWS. *ACCSCT

Tulsa, OK
Annie Arnett
918.587.6789, X260
Email: aarnett@TWSweld.com
or
Jacksonville, FL
Drew Duffy
904.646.9353, X260
Email: dduffy@TWSweld.com

The Ketchikan Campus of the University of Alaska Southeast

The Ketchikan Campus of the University of Alaska Southeast is the primary post secondary welding department in the region. AWS Entry and Advanced Level classes are offered each semester. The eight stations are state of the art. Students are prepared for immediate employment in entry level welding jobs. Classes are geared for employment in production and construction industries. Welders will be needed on new projects in Alaska. Information available from Steve Brandow.

(907) 228-4534
Steve Brando
steven.brandow@uas.alaska.edu.

Welder Training and Testing Institute

Founded in 1968

WTTI maintains a freestanding campus in Pennsylvania housing a weld lab equipped with sixty-five work stations. Training is provided in all major welding processes. Classrooms are fully equipped to support lessons in theory, blueprint-reading, and fitting. Specialized on-site training is available to industry with the option of a 10 station multi-process mobile welding lab. WTTI also offers CWI and NDT training and certification, as well as, welder certification through our AWS Accredited Test Facility.

729 E. Highland Street
Allentown, PA 18109
(800)223-WTTI
Email: info@wtti.edu

Attention: Welding School Administrators

This is the first Welding School Profile of this type that AWS *Welding Journal* has published. If you would like for us to send you information on how your school can be included in the 2008 edition, just e-mail a note to Rob Saltzstein at salty@aws.org or to Lea Garrigan Badwy at garrigan@aws.org. You can send us a fax at 1-305-443-7559. Please include the name of your welding school, the mailing address, the contact person, phone, fax and e-mail information.

We will be sure your school is on the mailing list and e-mail list to receive advance information on the 2008 Welding School Profile edition of *Welding Journal*.

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

IEEE Int'l Conf. on Robotics and Automation. April 10–14, Angelicum University, Rome, Italy. Visit *www.icra07.org.*

♦**Int'l Conf. on Welding and Joining of Materials.** April 16–18, Cusco, Peru. Sponsors: AWS Peru Section, University of Illinois — Chicago, and Pontificia Universidad Católica del Perú. Visit *www.pucp.edu.pe/acad/ingesold/icwjm_2007/ingles/index.php.*

World Trade Fair for Industrial Technology. April 16–20, Hannover Fairgrounds, Hannover, Germany. Organized by Deutsche Messe AG. Visit *www.messe.de.*

Automotive Laser Applications Workshop: Lasers — Ultimate Flexibility. April 17–19, St. John's Inn, Plymouth, Mich. Visit *www.alawlaser.org.*

MoldMaking Expo. April 18, 19, Donald E. Stephens Convention Center, Rosemont, Ill. Sponsored by *MoldMaking Technology, Plastics Technology,* and *Modern Machine Shop* magazines. Visit *www.moldmakingexpo.com.*

ALUMEX 2007, 4th Int'l Aluminum Exhibition. April 22–24, Dubai Int'l Convention Center, Dubai, UAE. Visit: *www.alumex-dubai.com.*

14th Int'l Conf. on the Joining of Materials (JOM-14), and 5th Int'l Conf. on Education in Welding. April 29–May 2, at LO-Skolen, Helsingör, Denmark. Visit *jom_aws@post10.tele.dk.*

62nd STLE Annual Meeting. May 6–10, Marriott Hotel (downtown), Philadelphia, Pa. Contact: Society of Tribologists and Lubrication Engineers, (847) 825-5536, ext. 201; *www.stle.org.*

Materials Joining: Building for the Manufacturing Future. May 8, 9, Greater Columbus Convention Center, Columbus, Ohio. Contact: Edison Welding Institute, *www.ewi.org/conference07.*

Int'l Welding and Joining Conf. — Korea 2007. May 10–12, COEX Convention Center, Seoul, Korea. Visit *www.iwjc2007.org.*

PowderMet 2007, Int'l Conf. on Powder Metallurgy & Particulate Materials. May 13–16, Denver, Colo. Visit *www.mpif.org.*

Marine Log's Tugs & Barges 2007 Conference & Expo. May 15, 16, Stamford Marriott, Stamford, Conn. Details vessel design, construction, and regulation. Visit *www.marinelog.com.*

Automotive Industry Advancements with NDT Conf. May 16, 17, Doubletree Hotel, Dearborn, Mich. Contact: American Society for Nondestructive Testing, (800) 222-2768; *www.asnt.org.*

XXXVIII Int'l Steelmaking Seminar. May 20–23, Belo Horizonte, Minas Gerais, Brazil. Sponsored by Associação Brasileira de Metalurgia e Materials. Simultaneous translations in English and Portuguese. Visit *www.abmbrasil.com.br/seminarios.*

♦**Joining Dissimilar Metals Conf.** May 22, 23, Orlando, Fla. Talks will detail latest innovations and appropriate welding processes and metallurgy. Keynote speaker will be Dr. Thomas Eagar. Contact: AWS Conferences and Seminars Business Unit, (800) 443-9353, ext. 223; *www.aws.org/conferences.*

♦**National Robotics Arc Welding Conf.** May 22, 23, Milwaukee, Wis. Sponsored by the AWS Milwaukee Section and the AWS D16 Committee for Robotic and Automatic Welding. Includes a tour of the John Deere plant in Horicon, Wis. For complete information, to register, or exhibit, visit *www.aws.org/sections/milwaukee*.

Tube Russia 2007. May 28–31, ZAO Expocenter, Moscow, Russia. Tube manufacture, raw materials, and measuring and control technology. Contact Messe Düsseldorf North America, (312) 781-5180; *www.mdna.com.*

Int'l Robots & Vision Show, 38th Int'l Symposium on Robots, and Sensors Expo. June 12–14, Donald E. Stephens Convention Center, Rosemont, Ill. Visit *www.robots-vision-show.info.*

Duplex 2007, Int'l Conf. and Expo. June 18–20, Grado and Aquileia, Italy. English is the official language. Sponsored by the Italian Metallurgical Assn. Visit *www.aimnet.it/duplex2007.htm.*

♦**8th Int'l Conf. on Brazing, High-Temperature Brazing, and Diffusion Bonding (LÖT 2007).** June 19–21, Aachen, Germany. Sponsors include American Welding Society and ASM Int'l. Contact: DVS (German Welding Society), *tagungen@dvs-hg.de; www.dvs-ev/loet2007.*

♦**12th Beijing Essen Welding & Cutting Fair.** June 19–22, Shanghai New Int'l Expo Center, Shanghai, China. Sponsored by AWS. Visit *http://essen.cmes.org.*

♦**Explosion of New Processes Conf.** Aug. 14, 15, San Diego, Calif. To include higher-powered ultrasonic welding, laser and various types of friction stir welding, fiber laser, additive manufacture, hybrid welding, and GMA "buried" arc welding. Contact: AWS Conferences and Seminars Business Unit, (800) 443-9353, ext. 223; *www.aws.org/conferences.*

Metariciclo 2007: Second Run; Int'l Exhibition on Technologies for the Recovery and Recycling of Ferrous and Nonferrous Metals. Sept. 13–15, Garda Exhibition Centre, Montichiari, Brescia, Italy. Contact: *www.metalririclo.com.*

EMO Hannover — World of Machine Tools and Metalworking. Sept. 17–22, Hannover Fairgrounds, Hannover, Germany. Visit *www.hf-usa.com/emo.*

24th Annual ASM Heat Treating Society Conf. and Exposition. Sept. 17–19, Cobo Hall, Detroit, Mich. Visit *www.asminternational.org/heattreat.*

3rd Annual Careers in Construction Week. Oct. 15–19, Gainesville, Fla. Contact: National Center for Construction, Education, and Research, *www.nccer.org.*

Southeast Asia Wire and Tube Trade Fairs. Oct. 16–18, Bangkok, Thailand. Contact: Messe Düsseldorf North America, *info@mdna.com; www.mdna.com.*

♦**Weld Cracking VI Conf.** Oct. 16, 17, Imperial Palace Hotel, Las Vegas, Nev. To include conditions that trigger cracking in weldments and steps to prevent cracking in steel, stainless steels, aluminum, and titanium. Contact: AWS Conferences and Seminars Business Unit, (800) 443-9353, ext. 223; *www.aws.org/conferences.*

ICALEO® 2007 Conf. Oct. 29–Nov. 1, Hilton Hotel, Walt Disney World Resort, Orlando, Fla. Contact: Laser Institute of America, Conference Dept., *conferences@laserinstitute.org*.

Kiev Industrial Week 2007. Oct. 31–Nov. 2, National Complex Expocenter of Ukraine, Kiev, Ukraine. Contact *www.weldexpo.com.ua.*

16th Steelmaking Conf. and 6th Ironmaking Conf. Nov. 6–8, Metropolitano Convention Center, Rosario, Argentina. *www.siderurgia.org.ar.*

♦**FABTECH International & AWS Welding Show.** Nov. 11–14, McCormick Place, Chicago, Ill. This show is the largest event in North America dedicated to showcasing a full spectrum of metal forming, fabricating, tube and pipe, and welding equipment and technology. Contact: American Welding Society, (800/305) 443-9353, ext. 462; *www.aws.org.*

♦**Friction Welding.** Nov. 12, 13, Chicago, Ill., during the FABTECH Int'l and AWS Welding Show. Will include numerous short presentations on linear friction, friction stir, and conventional friction welding. Contact: AWS Conferences and Seminars Business Unit, (800) 443-9353, ext. 223; *www.aws.org/conferences.*

Educational Opportunities

ASME Section IX Seminars. May 22–24, Pittsburgh, Pa.; Oct. 23–25, Houston, Tex.; Dec. 3–5, Atlanta, Ga.; April 8–10, 2008, Las Vegas, Nev. Contact: ASME Continuing Education Institute, (800) 843-2763; *www.asme.org/education.*

Aluminum Brazing Course. June 12, 13, Hartford, Conn. Details furnace, torch, induction, and dip brazing. Contact: Kay & Associates, *www.kaybrazing.com;* (860) 651-5595.

The Implementation of Robot MIG Weld Best Practices and Weld Process Controls Workshop. June 14, 15, Ft. Collins, Colo. A Rimrock-Wolf Robotics Work Shop presented by Ed Craig. Call (828) 658-3574, or visit *www.weldreality.com.*

AISC Building Standard and Bridge Criteria Course. June 19–21, Chicago, Ill. Atema, Inc. Contact: *atemasolutions.com.*

Automotive Body in White Training for Skilled Trades and Engineers. Orion, Mich. A 5-day course covers operations, troubleshooting, error recovery programs, and safety procedures for automotive lines and integrated cells. Contact: Applied Mfg. Technologies, Inc., (248) 409-2000; *www.appliedmfg.com*

Boiler and Pressure Vessel Inspectors Training Courses and Seminars. Columbus, Ohio. Contact: Richard McGuire, (614) 888-8320; *rmcguire@nationalboard.org*; *www.nationalboard.org*.

Certified Laser Safety Officer® Exams. June 8, Baltimore, Md.; Sept. 21, San Francisco, Calif.; Nov. 2, Orlando, Fla. Contact: Board of Laser Safety®, *www.lasersafety.org.*

Continuing Education for Welding Inspectors and CWIs. Nov. 27–30, Chicago, Ill. Atema, Inc. Contact: *atemasolutions.com..*

CWI/CWE Course and Exam. This 10-day program prepares students for the AWS CWI/CWE exam. Contact: Hobart Institute of Welding Technology, (800) 332-9448; *www.welding.org*.

CWI Preparation. Courses on ultrasonic, eddy current, radiography, dye penetrant, magnetic particle, and visual at Levels 1–3. Meet SNT-TC-1A and NAS-410 requirements. Contact: T.E.S.T. NDT, Inc., (714) 255-1500; *ndtguru@aol.com*; *www.testndt.com.*

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

Environmental Health and Safety-Related Web Seminars. These 30-min-long Web seminars on various topics are online, real-time events conducted by industry experts. Most seminars are free. Visit *www.augustmack.com/Web%20Seminars.htm.*

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

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

Fabricators and Manufacturers Assn. and Tube and Pipe Assn. Courses. Contacts: (815) 399-8775; *info@fmametalfab.org*; *www.fmametalfab.org*.

Fundamentals of Brazing Course. This 3-day course begins on these dates: April 17, Phoenix, Ariz.; May 15, Hartford, Conn.; Sept. 11, Cincinnati, Ohio; Oct. 16, Greenville, S.C.; Nov. 13, Hartford, Conn. Includes furnace, torch, dip, resistance, and induction brazing of metals based on Ni, Al, Ag, Cu, Ag, etc. Contact: Kay & Associates, *www.kaybrazing.com;* (860) 651-5595.

Gas Detection Made Easy Courses. Web-based and classroom courses for managing a gas monitor program from technology of gas detection to confined-space safety. Contact: Industrial Scientific Corp., (800) 338-3287; *www.indsci.com/serv_train.asp.*

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

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

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

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

Motorsports Welding School, Advanced Materials Course. Cleveland, Ohio. This 5-day course begins on these dates: April 30, Sept. 17, Oct. 15, Dec. 10. Contact: The Lincoln Electric.Co., *www.lincolnelectric.com/focus/motorsports/school/school.asp;* (216) 383-8325.

Motorsports Welding School, Basic Materials Course. Cleveland, Ohio. All are 5-day courses beginning on these dates: April 23, May 21, June 11, July 30, Sept. 10, Sept. 24, Oct. 8, Nov. 12, Dec. 3. Contact: The Lincoln Electric.Co., (216) 383-8325; *www.lincolnelectric.com/focus/motorsports/school/school.asp.*

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

NDT and CWI/CWE Courses and Exams. Welder Training and Testing Institute, Allentown, Pa., and at customer's facility, nationwide. Contact: (800) 223-9884; *www.wtti.edu.*

AWS Certification Schedule

Certification Seminars, Code Clinics and Examinations

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

Certified Welding Inspector (CWI)

Location	Seminar Date	Exam Date
Jacksonville, FL	Apr. 29-May 4	May 5
Baltimore, MD	Apr. 29-May 4	May 5
Waco, TX	EXAM ONLY	May 5
Detroit, MI	May 6-11	May 12
Miami, FL	May 6-11	May 12
Corpus Christi, TX	EXAM ONLY	May 19
Albuquerque, NM	May 20-25	May 26
San Francisco, CA	May 20-25	May 26
Oklahoma City, OK	May 20-25	May 26
Long Beach, CA	EXAM ONLY	May 26
Birmingham, AL	Jun. 3-8	Jun. 9
Hartford, CT	Jun. 3-8	Jun. 9
Miami, FL	EXAM ONLY	Jun. 14
Fargo, ND	Jun. 10-15	Jun. 16
Kansas City, MO	Jun. 10-15	Jun. 16
Phoenix, AZ	Jun. 24-29	Jun. 30
Miami, FL	EXAM ONLY	Jul. 12
Orlando, FL	Jul. 8-13	Jul. 14
Spokane, WA	Jul. 8-13	Jul. 14
Bakersfield, CA	Jul. 15-20	Jul. 21
Louisville, KY	Jul. 15-20	Jul. 21
Beaumont, TX	Jul. 22-27	Jul. 28
Milwaukee, WI	Jul. 22-27	Jul. 28
Denver, CO	Jul. 29-Aug. 3	Aug. 4
San Antonio, TX	Aug. 5-10	Aug. 11
Pittsburgh, PA	Aug. 5-10	Aug. 11
Columbus, OH*	Aug. 6-10	Aug. 11
San Diego, CA	Aug. 12-17	Aug. 18
Miami, FL	Aug. 12-17	Aug. 18
Rochester, NY	EXAM ONLY	Aug. 18
Charlotte, NC	Aug. 19-24	Aug. 25
Portland, ME	Aug. 19-24	Aug. 25
Corpus Christi, TX	EXAM ONLY	Sep. 1
Miami, FL	EXAM ONLY	Sep. 20
Anchorage, AK	EXAM ONLY	Sep. 22
Salt Lake City, UT	Sep. 23-28	Sep. 29
Philadelphia, PA	Sep. 23-28	Sep. 29
Tulsa, OK	EXAM ONLY	Sep. 29
Seattle, WA	Sep. 30-Oct. 5	Oct. 6
Minneapolis, MN	Sep. 30-Oct. 5	Oct. 6
St. Louis, MO	Oct. 14-19	Oct. 20
Miami, FL	Oct. 14-19	Oct. 20
Baton Rouge, LA	Oct. 21-26	Oct. 27
Long Beach, CA	Oct. 21-26	Oct. 27
Newark, NJ	Oct. 28-Nov. 2	Nov. 3
Roanoke, VA	Oct. 28-Nov. 2	Nov. 3
Corpus Christi, TX	EXAM ONLY	Nov. 3
Nashville, TN	Nov. 25-30	Dec. 1
Dallas, TX	Nov. 25-30	Dec. 1
Portland, OR	Dec. 2-7	Dec. 8
Columbus, OH*	Dec. 3-7	Dec. 8
Sacramento, CA	Dec. 9-14	Dec. 15
Miami, FL	Dec. 9-14	Dec. 15
Syracuse, NY	Dec. 9-14	Dec. 15
Reno, NV	Dec. 16-21	Dec. 22
Houston, TX	Dec. 16-21	Dec. 22

* Mail seminar registration and fees for Columbus seminars only to National Board of Boiler & Pressure Vessel Inspectors, 1055 Crupper Ave., Columbus, OH 43229-1183. Phone (614) 888-8320. Exam application and fees should be mailed to AWS.

For information on any of our seminars and certification programs, visit our website at **www.aws.org/certification** or contact AWS at (800/305) 443-9353, Ext. 273 for Certification and Ext. 224 for Seminars.

Please **apply early** to save Fast Track fees. **This schedule is subject to change without notice.** Please verify the dates with the Certification Dept. and confirm your course status before making final travel plans.

9-Year Recertification for CWI and SCWI

Location	Seminar Dates	Exam Date
Sacramento, CA	Apr. 23-28	NO EXAM**
Pittsburgh, PA	Jun. 11-16	NO EXAM**
San Diego, CA	Aug. 13-18	NO EXAM**
Dallas, TX	Oct. 29-Nov. 3	NO EXAM**
Orlando, FL	Dec. 3-8	NO EXAM**

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

Certified Welding Supervisor (CWS)

Location	Seminar Dates	Exam Date
Nashville, TN	Apr. 16-20	Apr. 21
Atlanta, GA	Apr. 23-27	Apr. 28
Columbus, OH	May 7-11	May 12
Minneapolis, MN	Jun. 11-15	Jun. 16
Philadelphia, PA	Jul. 16-20	Jul. 21
Atlanta, GA	Jul. 23-27	Jul. 28
Seattle, WA	Aug. 13-17	Aug. 18
Atlanta, GA	Sept. 24-28	Sept. 29
Tulsa, OK	Oct. 15-19	Oct. 20
Atlanta, GA	Nov. 12-16	Nov. 17
Long Beach, CA	Nov. 26-30	Dec. 1

CWS exams are also given at all CWI exam sites.

Certified Radiographic Interpreter (RI)

Location	Seminar Dates	Exam Date
Philadelphia, PA	Apr. 30-May 4	May 5
Nashville, TN	Jun. 4-8	Jun. 9
Manchester, NH	Jul. 23-27	Jul. 28
St. Louis, MO	Sept. 24-28	Sept. 29
Philadelphia, PA	Oct. 22-26	Oct. 27
Jacksonville, FL	Nov. 26-30	Dec. 1

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

Certified Welding Educator (CWE)

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

Senior Certified Welding Inspector (SCWI)

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

Certified Welding Fabricator

This program is designed to certify companies to specific requirements in the ANSI standard AWS B5.17, *Specification for the Qualification of Welding Fabricators*. There is no seminar or exam for this program. Call ext. 448 for more information.

Code Clinics & Individual Prep Courses

The following workshops are offered at all sites where the CWI seminar is offered (code books not included with individual prep courses): Welding Inspection Technology (general knowledge and prep course for CWI Exam-Part A); Visual Inspection Workshop (prep course for CWI Exam-Part B); and D1.1 and API-1104 Code Clinics (prep courses for CWI Exam-Part C).

On-site Training and Examination

On-site training is available for larger groups or for programs that are customized to meet specific needs of a company. Call ext. 219 for more information.

American Welding Society

Founded in 1919 to advance the science, technology and application of welding and allied joining and cutting processes, including brazing, soldering and thermal spraying.

Circle No. 6 on Reader Info-Card

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 July 1, 2007. The committee looks forward to receiving these nominations for 2008 consideration.

Sincerely,

Alfred F. Fleury
Chairman, Counselor Selection Committee

SOCIETY NEWS

BY HOWARD M. WOODWARD

Officers' Transition Ceremony Held in Miami

BY KRISTIN CAMPBELL
assistant editor, *Welding Journal*

Gerald D. Uttrachi was honored as the incoming AWS president at the 2007 transition ceremony that took place February 9 at AWS headquarters in Miami, Fla.

In Uttrachi's talk, he reflected on his 40 years of working with the Society. As part of his new responsibilities, he will represent the Society at functions to be held in Peru, Denmark, Korea, China, and Russia.

Uttrachi said one of his objectives is to discuss the shortage of welders and how to attract more women into the industry. He stated that these dialogues could be a good way to entice more people to consider welding and convince them that it is a nice industry to be in. Uttrachi concluded, "I will do my best in the next year, and hopefully when I return, there will be some fun things to talk about and some successes."

Damian J. Kotecki reflected on his 19-month term in office. He recalled his speaking engagements at 26 AWS Sections, and his international lecture tours. Kotecki said, "We have made a lot of contacts in many parts of the world, and there is great potential in countries like India and China in addition to others." He stressed that it is important for AWS to continue a strong presence in the U.S. while at the same time realizing that we are in a "global economy," and we need to optimize the opportunities we have internationally.

Uttrachi agreed with Kotecki on this matter, and said it is very important that AWS keeps its name in front of the international societies.

John C. Bruskotter, accompanied by his wife, **Donna,** was formally installed for his first term as a vice president. Also present at the event were past president **James E. Greer** (2004–2005); treasurer **Earl C. Lipphardt**; and vice presidents **Victor Y. Matthews** and **Gene E. Lawson.**

Ronald C. Pierce, AWS Foundation chair, and **Sam Gentry,** AWS Foundation executive director, named **Alexis Victoria Tabares** (daughter of AWS employee **Neida Herrera**), and **Pricilla Yaniz** (daughter of AWS employee **Sissibeth Lopez**), as recipients of the Carol J. DeLaurier Memorial Scholarship. This scholarship guarantees a college education under the Florida Prepaid College Plan to children of AWS employees.

Gerald Uttrachi expressed his plans for his year as president of the Society.

The presentation of the Michael A. Rowland Exemplary Employee of the Year Award is a highlight of the annual transition program. The award recognizes an AWS employee who has demonstrated exceptional service or has made outstanding contributions to the Society, as nominated by his/her peers.

Doris Moore accepted the award from **Damian Kotecki** and **Ray Shook,** AWS executive director. Moore, manager of administrative services, joined AWS in 1981. Her peers wrote about her, "Doris has the best attitude of any employee. She is always willing to lend a hand and never complains. She does her job with a positive, professional attitude and works with great attention to detail. She makes people feel welcome and at ease and never brings a negative attitude to her job, and has been a true inspiration to us all. No one deserves this award more than Doris Moore."

Moore was overwhelmed by winning the award. "Thank you very much," she said. "I love my job, and I love working for the American Welding Society." ♦

Doris Moore accepts the Michael A. Rowland Exemplary Employee of the Year Award from Damian Kotecki, outgoing president.

Ronald Pierce presented AWS Foundation scholarships to Pricilla Yaniz (left) and Alexis Victoria Tabares.

What's Your Idea?

You are urged to participate in an online survey to evaluate ideas for future AWS products and services. Please take a few minutes to answer the questions posted at *www.aws.org/education/pdc07-survey.html.*

Conducted by the AWS Product Development Committee, your responses to the survey questions will help the Society generate products that will better meet your needs as AWS members, and better serve the welding community.

Thank you in advance for your participation — **Harvey Castner,** chairman, Product Development Committee, and an AWS director-at-large. ♦

Tech Topics

Summary of Changes in ASME Section IX, 2006 Addenda

BY WALTER J. SPERKO

Welding Procedure (QW-200) Changes

Since 1978 it has been required that the organization that qualified a WPS or a welder certify the qualification records by signature. These addenda recognize that there are ways to certify a document by means other than by signature. QW-103.2 has been modified to allow certification by signature or by other means as described in the manufacturer's or contractor's Quality Assurance System. This would largely allow electronic or any other form of certification that one chooses to use as an alternative to signature. A certification statement similar to that found on forms QW-483 and QW-484 found in the nonmandatory Appendix B, however, still needs to be on qualification record regardless of the certification method.

QW-407.4, which governs the thickness of base metal qualified when the weld will be heat treated above the upper transformation temperature, has been revised to make life easier for nonmetallurgist users of Section IX to specifically identify the materials to which this variable applies. Previously, the variable used the term "upper transformation temperature" with the intent that it only applied to steels that went through a solid-state phase change. It would not, therefore, apply to austenitic stainless steel, such at Type 304L, since those materials do not go through any phase change during heating or cooling. However, some aluminum alloys can be heat treated above the upper transformation temperature during solutionizing, and QW-407.4 was never intended to apply to aluminum alloys. It has been revised to apply only to ferrous materials except for those that are classified as P-numbers 7, 8, or 45.

Impact-Tested Qualifications

The first change is in QW-403.5 and deals with Group numbers. Code materials are assigned P or S numbers, and iron-based alloys are also assigned Group numbers. When an impact-tested qualification of a WPS is required, QW-403.5 requires that testing be performed using materials from the same P number and Group number as the material that will be used in production. This revision clarifies that, if one has a WPS already qualified with impact testing using, for example, P-1, Group 1 material, one can add an additional PQR showing the same P-number material but a different group number such as P-1, Group 2. If the essential and supplementary essential variables are the same in both PQRs (except for the Group numbers), the WPS is qualified to weld not only P-1 Group 1 materials to themselves and P-1 Group 2 materials to themselves, but it is also qualified to weld P-1 Group 1 materials to P-1 Group 2 materials.

When welding P-11 materials (quenched and tempered high-strength low-alloy steels), there has always been a requirement buried in QW-213 that, if thermal cutting or thermal backgouging is going to be used in production welding, those practices had to be included in the procedure qualification test coupon. QW-213 has been deleted in these addenda, but the requirement has been moved into the tables of variables in QW-250 as essential variable QW-410.64 for all processes. This should make it more obvious to users and less likely to be missed.

Heat input measurement has been traditionally measured using the heat input formula, V × A × 60/travel speed. Section IX, QW-409.1 provides control of the length of the weld bead per unit length of deposit (a real simple way to control heat input with SMAW) or bead size. While QW-409.1 has always permitted using bead size, it has never said that the bead size is measured by multiplying the width of the bead by the thickness of the bead; that has been clarified in these addenda.

Tube-to-Tubesheet Welding

For those who build heat exchangers, Section IX has added rules to QW-193 for making tube-to-tubesheet welds. These rules are very similar to those found in Section VIII, Division 2, Article F-3, and identical to the rules in Section III, NB/C/D-4350.

Tube-to-tubesheet welding is qualified by welding ten mock-ups of the tube-to-tubesheet joints using the same geometry holes in the tubesheet and the same tube size and thickness as that to be used in production. Testing consists of performing liquid penetrant examination followed by cross sectioning of each joint and examining it at ten-× magnification for cracks or flaws. The minimum leak path (distance from the root of the weld to the surface nearest the root) must equal that required by the design or by the construction code, typically two-thirds of the tube thickness.

The new Section IX tube-to-tubesheet welding rules only become mandatory when the applicable construction code (Section VIII, Section III, etc.) invokes them. If they are not invoked, tube to tubesheet welds have to be qualified by groove or fillet weld testing. Both Sections VIII and III are proceeding to drop their rules for tube-to-tubesheet welding and will be referring to the Section IX rules in the future. Those accustomed to following the Section VIII rules should be aware that the Section IX rules have added current, current type and polarity, type of welding (manual, machine, etc.), diameter, progression, cleaning method, and the addition of expansion prior to welding to the list of essential variables. Whether WPSs qualified under old Section VIII would be acceptable for new work once the Section IX rules are adopted would have to be addressed by Subcommittee VIII by inquiry. For welder and welding operator qualification, QW-305.5 specifies that the standard rules for groove and fillet weld qualification apply when the WPS is qualified by groove or fillet weld test, but if the WPS is qualified by mock-up, the welder or welding operator has to be qualified by mock-up.

High-Performance Cr-Mo Welding

Those who work with Grade 91 and the other high-performance chromium-molybdenum (Cr-Mo) steels (Grades 92, 911, etc.) need to pay attention to two changes that have been made in the construction codes (Section I, PW-39, and B31.1, Table 132) regarding postweld heat treatment (PWHT) of these materials.

When joining the high-chromium alloys to lower-chromium alloys or carbon steel, carbon in the lower-chromium steels will migrate to the higher-

WALTER J. SPERKO (sperko@asme.org), *P.E., is president of Sperko Engineering, and vice chair of Subcommittee IX. Readers are advised that these are Mr. Sperko's opinions and not the official opinions of Subcommittee IX. These changes became mandatory January 1, 2007.*

chromium steel during PWHT. This will result in a soft zone in the lower chromium steel. The higher the PWHT temperature and the longer the joint is held at PWHT temperature, the more diffusion occurs and the bigger the soft zone becomes. While the minimum PWHT temperature for welds involving Grade 91 welded to itself have been raised, the PHWT temperature for dissimilar joints remains at 1300°F (705°C) to minimize this undesirable effect. To minimize the size of the soft zone, do not heat treat dissimilar metal joints at temperatures much over minimum, and don't hold them at temperature longer than required.

The second change deals with PWHT when the 1425°F (775°C) upper temperature limit is exceeded. For most materials, such excursions have little consequence since the material properties return to practically their original condition when the material cools down. The worst-case scenario for the old Cr-Mo steels is the WPS might have to be requalified since the lower transformation temperature was exceeded. However, high-performance Cr-Mo steels develop their properties via normalizing and tempering; this results in the precipitation of the carbides that give these materials their superior elevated-temperature performance. If the lower transformation temperature is exceeded (it can be as low as 1450°F), the carbide matrix is destroyed and the material loses its elevated temperature strength. Since it is not possible to reform the normalized and tempered microstructure using local heating, it is necessary to cut out and replace the weld joint, including a minimum of three inches of base metal on each side of the joint that was overheated. Alternative solutions include normalizing and tempering of the entire assembly that includes the overheated joint or justifying use of the weld based on using properties of materials that do not achieve their performance by normalizing and tempering (e.g., using the allowable stress values for Grade 9 instead of those for Grade 91).

It is anticipated that B31.3 and Section III will also adopt what is described above, but they will undoubtedly have small differences, so be sure to follow the rules in the specific Code Section in which you are working.

Temper Bead Welding

There have been additional tweaks to the rules for temper bead welding. While no construction code has invoked the Section IX temper bead rules, Section XI, In-service Inspection for Nuclear Power Plant Components, has proposed a Code Case allowing their use, and other Code Sections are in the process of adopting them with the National Board Inspection Code leading the way.

Grinding weld beads between layers addressed in QW-410.65 was expanded from simply allowing grinding to be used as a cleaning method to requiring that the same extent of grinding be used in production as was used in qualification. That is, if one ground a weld layer on a test coupon sufficiently to remove half the previous layer, or one ground enough to remove any ripples or if one ground just enough to clean the surface, that same technique must be specified in the temper bead WPS. The intent of this variable is to control the effective thickness of the layers, although the words do not say that.

Placement of surface temper bead near the toe of the final weld layer has to be within ±1⁄16 in. (± 1.5 mm) of the distance from the toe of the weld used on the test coupon according to the new QW-410.61. Alternatively, one can establish a wider range for this distance by welding and testing multiple test specimens that were welded using different bead placement distances. In all cases, the ratio of heat input of the surface temper bead to that of the layer against the base metal at the weld toe that was used in qualification has to be used on the production part.

Finally, the bead overlap has to be controlled. A new figure QW-462.13 (Fig. 1) was added showing how overlap is measured, and as long as the overlap is between 25 and 75%, no special testing is required. However, if the qualifier wishes to use overlap <25% or >75%, the extent of overlap must be qualified and restricted to what was used on the test coupon.

Base Metals and Filler Metals

Several new materials were added to QW/QB-422, and several editorial errors were corrected.

AWS has revised several filler metal specifications that have been adopted by ASME. SFA5.1, which covers carbon steel electrodes for SMAW, has added limits on the chemical analysis of E60XX series filler metals such as E6010. Since there were no limits on the chemical analysis of, for example, E6010 electrode, one could not simply assume that the weld metal chemical analysis of E6010 was A-1; one had to establish it by obtaining a chemical analysis from the PQR test coupon or from the supplier's data and record it on the PQR. This revision limits the chemical composition of all E60XX electrodes to an A-1 chemical analysis.

Revisions to SFA 5.28, which covers low-alloy bare and composite wires, has some errors in the chemical analysis limits for B9 filler metals.

The maximum limit for nickel should be 0.80%, manganese is limited to 1.20%, silicon should be 0.15–0.50%, chromium should be 8.00–10.50%, molybdenum, 0.80–1.20% and vanadium should be 0.15–0.30%.

It should also be noted that a cross-reference table to metric and ISO designations for welding electrodes are now included in some of the filler metal specifications. For example, Table A1 of SFA5.1 shows E7018 as E4918 (metric) and as H38xB32 (ISO 2560).

SFA5.11 has been revised to assign AWS classifications to Hastelloy 231™ (ENiCrMo-9). Hastelloy G-30™ (ENiCrMo-11), AVESTA P-12R™ (ENiCrMo-12), Hastelloy C2000™ (ENiCrMo-17), Nicrofer 5020hMo™ (ENiCrMo-18), Inconel™ filler metal 52M (ERNiCrFe-7A),VDM Nicrofer 6025HT™ (ERNI-CrMo-12), VDM Nicrofer 45™ (ERNiCrFeSi-1), and Haynes HR160™ (NiCoCrSi-1) among other commercial nickel-alloy filler metals.

All ASME Code Committee meetings are open to the public. The meeting schedule is available on the writer's Web site and at *www.asme.org*. ♦

Nominations Sought for Prof. Koichi Masubuchi Award

December 1 is the deadline for submitting nominations for the 2007 Prof. Koichi Masubuchi Award, sponsored by the Dept. of Ocean Engineering at Massachusetts Institute of Technology. It is presented each year to one person who has made significant contributions to the advancement of materials joining through research and development.

The candidate must be 40 years old or younger, may live anywhere in the world, and need not be an AWS member. The nomination should be prepared by someone familiar with the research background of the candidate, and include a résumé listing background, experience, publications, honors, awards, plus at least three letters of recommendation from researchers.

This award was established to recognize Prof. Koichi Masubuchi for his numerous contributions to the advancement of the science and technology of welding, especially in the fields of fabricating marine and outer space structures.

Submit nominations to Prof. **John DuPont** at *jnd1@lehigh.edu.* ♦

Amendment A1 to QC1:2006, *Standard for the Certification of Welding Inspectors*

(To download this Amendment, visit *www.aws.org/certification/docs/qc1-06-a.pdf.*)

(All changes are shown in underlined text.)

Statement on Use (paragraph added as shown between the extracted text)

Certification is achieved by satisfying a combination of defined education, experience, and/or examination requirements. Certification is not an assurance of future competence or ability.

An endorsement to a certification adds to a certification by indicating demonstration of ability in a particular skill area that is not sufficiently broad or unique to support a separate and distinct certification designation, nor is it a core area of expertise or knowledge such that it be included as part of the underlying certification itself. An endorsement is not an indication of approval by AWS or an assurance of future performance.

AWS disclaims liability for any injury to persons or to property, or other damages of any nature whatsoever, including special, indirect, consequential, or compensatory damages, directly or indirectly resulting from the negligent conduct or other acts or omissions of any individual certified by AWS.

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3. Definitions

endorsement. Indication of an additional skill documented in writing and added to ones certification credential(s).

6.2.2 Applicants shall pass the examination(s) as follows:

Examination	Minimum Number of Questions	Minimum Percentage of Correct Answers
Part A — Fundamentals	150	72%
Part B — Practical	46	72%
Part C — Code Book	46	72%
Code Book Endorsements	NA	72%
Other Endorsements	NA	As defined in the endorsement specifications

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6.2.5 Re-examinations shall be considered as retaking the same exam. Candidates may take one (1) re-examination within one year of the original test date without further training. Any additional re-tests taken will require documentation of 40 hours of further training received in welding inspection meeting the requirements of 16.5.1. The maximum number of re-tests taken in any three-year period is three (3).

16.3.1 CWI recertification by taking the Part B Practical examination or by taking a Committee-approved endorsement, and meeting the requirements of 6.2.2 of this standard.

16.7 CWIs failing to meet the alternative requirements for recertification using experience and continuing education shall be required to recertify by taking the Part B Practical examination or by taking an endorsement approved by the Committee for re-certification, and meet the minimum scores in 6.2.2 to maintain certification at the CWI level. CWIs failing to meet the requirements of 6.2.2 may take re-examinations (Part B or endorsement) in accordance with 6.2.5 to re-certify. CWIs failing to meet the requirements of 6.2.2 but who meet the requirements of 7.1 shall receive new certification at the CAWI level and will be subject to the requirements of 15.1 of this standard. Individuals failing to meet the requirements of 6.2.2 or 7.1 shall no longer be certified at any level after their certification expires. Such individuals will be notified of their status in writing.

AWS Standards for Public Review

A5.7/A5.7M:200X, *Specification for Copper and Copper Alloy Bare Welding Rods and Electrodes.* Revised — $25. 4/9/07.

B2.1-1-027:200X, *Standard Welding Procedure Specification (SWPS) for Self-Shielded Flux Cored Arc Welding of Carbon Steel (M-1/P-1/S-1), Groups 1 and 2, 1/8 through 1/2 Inch Thick, E71T-11, As-Welded Condition, Primarily Plate and Structural Applications.* Revised — $25. 4/2/07.

D1.3:200X, *Structural Welding Code — Sheet Steel.* Revised — $32. 4/16/07.

D1.5M/D1.5:200X, *Bridge Welding Code.* Revised — $192. 4/16/07.

D15.1:200X, *Railroad Welding Specification for Cars and Locomotives.* Revised — $123. 3/26/07.

ISO 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., 4th Fl., New York, NY, 10036; (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, (305) 443-9353, ext. 466, *adavis@aws.org.*

ISO/DIS 3821 — *Gas welding equipment — Rubber hoses for welding, cutting and allied processes.*

Standards Approved by ANSI

D8.1M:2007, *Specification for Automotive Weld Quality — Resistance Spot Welding of Steel.* New. 1/12/07.

A5.2/A5.2M:2007, *Specification for Carbon and Low Alloy Steel Rods for Oxyfuel Gas Welding.* Revised. 2/12/07.

A5.32/A5.32M-97 (R2007), *Specification for Welding Shielding Gases.* Reaffirmed. 1/22/07.

Technical Committee Meetings

April 2–4, A2 Committee on Definitions and Symbols. Raleigh, N.C. Contact: S. Morales, ext. 313.

April 3, D8 Committee on Automotive Welding. Detroit, Mich. Contact: A. Alonso, ext. 299.

April 17, SH1 Subcommittee on Fumes and Gases. Columbus, Ohio. Contact: S. Hedrick, ext. 305.

April 17–19, D14 Committee on Machinery and Equipment. Longview, Tex. Contact: J. Gayler, ext. 472.

April 19, D15C Subcommittee on Track Welding. Jacksonville, Fla. Contact: S. Morales, ext. 313.

April 25, SH4 Subcommittee on Labeling and Safe Practices. Pittsburgh, Pa. Contact: S. Hedrick, ext. 305.

May 21–23, D16 Committee on Robotic and Automatic Welding. Milwaukee, Wis. Contact: J. Gayler, ext. 472.

New Standard Projects

Development work has begun on the following revised standard. Affected persons are invited to contribute to its development. Contact S. Morales at ext. 313. Participation on AWS Technical Committees and Subcommittees is open to all persons.

B2.1-1-027:200X, *Standard Welding Procedure Specification (SWPS) for Self-Shielded Flux Cored Arc Welding of Carbon Steel (M-1/P-1/S-1, Groups 1 and 2), 1/8 through 1/2 Inch Thick, E71T-11, As-Welded Condition.*

This SWPS is to be used only as permitted by AWS B2.1, *Specification for Procedure and Performance Qualification,* and the applicable fabrication document(s) [such as code, specification, or contract document(s)].

The fabrication document(s) should specify the engineering requirements such as design, need for heat treatment, fabricating tolerances, quality control, and examination and tests applicable to the end product. Stakeholders include manufacturers, welders, CWIs, and engineers. ♦

ERRATA

AWS A5.28/A5.28M:2005, *Specification for Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding*

The following errata have been identified and the corrections have been incorporated into the current reprint of A5.28/A5.28M. Page 26, Fig. A2, Optional GTAW Groove Weld Test Assembly for Mechanical Properties and Soundness.

Change the data in the Dimensions table as shown below:

DIMENSIONS		in.		mm	
C	Specimen Center	~~3/8~~	1/4	~~9.5~~	6.5
L	Length, min.	10		250	
P	Point of Temperature Measurement	1		25	
R	Root Opening	~~1/2~~	1/4	~~13~~	6.5
S	Backup Strip Overlap, min.	~~1/4~~	3/8	~~6~~	9
T	Thickness	~~3/4~~	1/2	~~19~~	13
V	Backup Strip Thickness, min.	~~3/8~~	1/4	~~9~~	6.5
W	Width, min.	5		125	
X	Backup Strip Width, min.	1		25	
Z	Discard, min.	1		25	

ERRATA

ANSI/AWS A5.32/A5.32M-97 (R2007), *Specification for Welding Shielding Gases*

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

Page 4 — Table 3, Dew Point Conversion Chart, third column with column heading "ppm", corrected the typographical error by changing 32.8 to 3.28 at the time of publishing reaffirmed edition ANSI/AWS A5.32/A5.32M-97 (R2007).

New AWS Supporters

Sustaining Companies

CPS Energy
145 Navarro
San Antonio, TX 78205
www.cpsenergy.com
Representative: **John L. Mendoza**

CPS Energy is the nation's largest municipally owned energy company. It provides electricity to more than 600,000 customers and natural gas to more than 300,000 customers. The company's proceeds remain in San Antonio where it accounts for more than a fifth of the city's operating budgets for police and fire protection, street improvements, parks, and other services. The company's mission is to produce and deliver competitive energy products and services to meet the changing expectations of our customers.

Diversified Storage Systems
1135 E. Wooley Rd.
Oxward, CA 93030
Representative: **Sheryl Feldhans**
www.cementsilos.com

Diversified Storage Systems is a manufacturer of silos for the storage of powder bulk materials, equipment for the transfer of powder materials, portable and fixed silos, guppys, PD tanks, transfer pods, load out systems, gas and diesel blowers, bulk bag transfer systems, and dust collectors.

Educational Institutions

Abilene High School
1300 N. Cedar
Abilene, KS 67410

CUASMEX
Gral. Felipe Angeles 463
Fracc. Amp. Fco. I. Madero
Saltillo, Coahuila 25120, Mexico

Dodge City High School
2201 Russ Blvd.
Dodge City, KS 67801

Hays High School
2300 E. 13th St.
Hays, KS 67601

Hutchinson Vo-Tech USD 308
1500 Plaza Way
Hutchinson, KS 67501

Jefferson West High School
619 Condray
Meriden, KS 66512

Manhattan High School
2100 Poyntz Ave.
Manhattan, KS 66502

Millcreek Center Welding Technology
311 E. Park
Olathe, KS 66061

Newton High School
900 W. 12th St.
Newton, KS 67114

Parson High School District #503
3030 Morton
Parsons, KS 67357

Wichita Heights High School
5301 N. Hillside
Wichita, KS 67219

Wichita High School — Southeast
901 S. Edgemoor
Wichita, KS 67218

Zephyr Products, Inc.
3030 Wilson Ave.
Leavenworth, KS 66048

Affiliate Companies

A. M. Gambao & Son
620 N. Elm St.
W. Bridgewater, MA 02379

Adam Steel LLC
1235 Sandwood Ave.
Florence, SC 29506

B & K Installations, Inc.
246 SW 4th Ave.
Homestead, FL 33030

C & B Welders, Inc.
2643-5 W. Monroe St.
Chicago, IL 60612

Complete Automation, Inc.
1776 D. W. Clarkson Rd.
Lake Orion, MI 48362

Dimension Fabricators, Inc.
1910 Maxon Rd.
Schenectady, NY 12308

Integrated Welding Systems, Inc.
34314 Oak Knoll Rd.
Burlington, WI 53105

Jetson, Inc.
13414 Hwy. 65 NE
Ham Lake, MN 55304

Johnson Mfg. Co.
114 Lost Grove Rd.
Princeton, IA 52768

Krause Manufacturing
6059 Guide Meridian
Bellingham, WA 98226

North Industrial Machine
PO Box 1734
Hartsville, SC 29551

OEM Remanufacturing
13315 156 St. NW
Edmonton, AB, T5V 1V2, Canada

Service Engineering Repair Co., Inc.
PO Box 1110, 1430 N. Main St.
Borger, TX 79007

Tashjian Towers Corp.
2183 S. Highland Ave.
Sanger, CA 93657

Young's Welding, Inc.
4115 S. Johnson Rd.
Chanute, KS 66720

Supporting Companies

Autotool, Inc.
8150 Business Way
Plain City, OH 43064

Cassimus Co.
14492 Wicks Blvd.
San Leandro, CA 94577

Conewago Enterprises, Inc.
576 Edgegrove Rd.
Hanover, PA 17331

Mechelonic Welders Pvt. Ltd.
#237, A-7, KIADB Industrial Area
Bommasandra, Hosur Rd.
Bangalore, Karnataka 560099, India

Metalpol, SA de CV
Santiago Papasquiaro #158
Parque Ind. Lagunero
Gomez Palacio 35070, Mexico

Rocky's Welding, Inc.
7726 W. Dahlia Dr.
Peoria, AZ 85381

Membership Counts

Member Grades	As of 3/1/07
Sustaining	449
Supporting	282
Educational	420
Affiliate	386
Welding distributor	48
Total corporate members	**1,585**
Individual members	45,528
Student + transitional members	5,231
Total members	**50,759**

SECTION NEWS

DISTRICT 1

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

BOSTON

February 5
Speaker: **Tim Messer,** QA manager
Affiliation: Dresser-Masoneilan
Topic: The design and manufacture of control valves
Activity: Following the talk, the Section members toured the Dresser-Masoneilan facility in Avon, Mass., to study its manufacturing procedures. **James Harrington Jr.** received the District CWI of the Year Award from Section Chair **Tom Ferri** and District 1 Director **Russ Norris.** The plant tour was conducted by **Tim Messer, Peter Hillsron, Ken Young, Rafael Rodriguez, Jack Theriault,** and **Ed Silvestri.**

CWI award winner James Harrington Jr. (center) is shown with Boston Section Chair Tom Ferri (left) and Russ Norris (right), District 1 Director.

Shown at the Boston Section tour are (from left) Tim Messer, Peter Hillsron, Ken Young, Rafael Rodriguez, Jack Theriault, Ed Silvestri, and Chair Tom Ferri.

CONNECTICUT

January 31
Activity: The Section held an executive board meeting at Jacoby's Restaurant in Meriden, Conn., presided by Chairman **Al Moore** of Marion Inspection and Testing Services. District 1 Director **Russ Norris** discussed AWS events on the District and national levels. See photo on next page.

Foundation Salutes Sections Supporting Scholarships

The AWS Foundation thanks the following Sections for supporting the Every Member Campaign and the Welding for the Strength of America Capital Campaign:

Alaska, *Dist. 19*
Boston, *Dist. 1*
Central Mass./Rhode Island, *Dist. 1*
Chattanooga, *Dist. 8*
Central Nebraska, *Dist. 16*
Cincinnati, *Dist. 7*
Colorado, *Dist. 20*
East Texas, *Dist. 17*
El Paso, *Dist. 18*
Greater Huntsville, *Dist. 8*
Hawaii, *Dist. 21*
Illinois Valley, *Dist. 13*
Johnstown-Altoona, *Dist. 7*
Kansas City, *Dist. 16*
Lexington, *Dist. 14*
Mobile, *Dist. 9*
Nebraska, *Dist. 16*
North Central Florida, *Dist. 5*
Northern New York, *Dist. 6*
Olean-Bradford, *Dist. 6*
Palm Beach, *Dist. 5*
Pittsburgh, *Dist. 7*
Reading, *Dist. 3*
Saginaw Valley, *Dist. 11*
Southeast Nebraska, *Dist. 16*
Southern Colorado, *Dist. 20*
Tulsa, *Dist. 17*
Twin Tiers, *Dist. 6*
Western Carolina, *Dist. 8*

These Sections supported the following programs from Nov. 15, 2006 through Feb. 15, 2007:

The Every Member Campaign, which solicits $1 per member from Sections. Sections may donate from their treasury or solicit their members through direct-mail solicitation.

Section Investment Agreements, a pooled income program where the investment is combined with other Section investments to command a higher interest rate than normally received.

Welding for the Strength of America Capital Campaign, and the **AWS Welder Workforce Development Program**

All donations to this endowment will be used to train welders to join the work force now and in the future.

The emphasis will be to train entry-level welders to expand the welding business capacity within the United States.

Training will be dispersed throughout the United States.

We will focus and work with companies on an individual basis to assist with training needed welding personnel for the specific human resource needs they have.

All earnings from this endowment will be used for this mission.

For information about the AWS Foundation and its programs, contact **Sam Gentry** at (800) 443-9353, ext. 331. ♦

Shown at the Connecticut Section's board meeting are (from left) John Matthews, Bob Cullen, Kathie McGirr, and Chairman Al Moore.

Shown at the New Jersey Section program are (from left) Troy Saylor, speaker Ed Starkey, and Vince Murray, Section chair.

Frank Simone (left) receives the Section Meritorious Award from Jim Korchowsky, Philadelphia Section chair.

Speaker Gary Gresko (right) is shown with Jim Korchowsky, Philadelphia Section chairman .

MAINE

JANUARY 4
Speaker: **Tom Cormier,** CWI
Affiliation: Metso Paper
Topic: SkillsUSA test preparation
Activity: The attendees discussed the requirements and processes that will be used in the March 16th welding trials to be held in Bangor, Maine.

JANUARY 25
Activity: The Maine Section hosted its second annual vendors' night program in the welding lab at Southern Maine Community College, South Portland, Maine. CWI **Mark Legel,** a welding instructor at the college, demonstrated welding tools and equipment suitable for home and shop use, along with a discussion of safety topics. The attendees had hands-on opportunities to work with various products from Advantage Gases, Hobart Brothers, Lincoln Electric, Makita Tools, Miller Electric, Smith Cutting Equipment, Walter Abrasives, and Arc One Helmets.

DISTRICT 2

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

NEW JERSEY

JANUARY 16
Speaker: **Ed Starkey,** product manager
Affiliation: Inweld, Coplay, Pa.
Topic: The future of Inweld
Activity: The Section will sponsor a seminar on welding codes April 12 at Somerset County Vocational School. Contact Chairman **Vince Murray** at (973) 478-5000; or *vmurray@aglweldingsupply.com.* The meeting was held at L'Affaire Restaurant in Mountainside, N.J.

PHILADELPHIA

JANUARY 10
Speaker: **Gary Gresko,** director of training
Affiliation: Boilermakers Local 13
Topic: Employment opportunities in the welding field
Activity: Following the talk, the attendees toured the apprentice training weld shop and union hall at Boilermakers Local 13. **Frank Simone,** Section treasurer and board member, was presented the Section Meritorious Award from Chairman **Jim Korchowsky. Rick Davis** received the Dalton E. Hamilton Memorial District CWI of the Year Award.

FEBRUARY 7
Speaker: **Jim Henry**
Affiliation: Stoody Co.
Topic: Hardfacing and buildup
Activity: At this Philadelphia Section pro-

Rick Davis displays his District CWI of the Year Award presented to him at the Philadelphia Section program.

Shown at the February Philadelphia Section program are (from left) Chair Jim Korchowsky, CWI award winners Hobert Hoops and David Vinson, and Ken Stockton, District 2 director.

Philadelphia Section Chair Jim Korchowsky (left) is shown with speaker Jim Henry at the February meeting.

Shown at the February Philadelphia Section meeting are (from left) James Rynex, Chair Jim Korchowsky, Dan Roskiewich, District 2 Director Ken Stockton, and Bob Sandelier.

gram, District 2 Director **Ken Stockton** and Section Chair **Jim Korchowsky** presented **Hobert Hoops** and **David Vinson** the District Dalton E. Hamilton Memorial CWI of the Year Award. The District Educator Award was given to **Dan Roskiewich,** and Section Educator Awards were presented to **Bob Sandelier** and **James Rynex.**

DISTRICT 3

Director: Alan J. Badeaux Sr.
Phone: (301) 753-1759

LANCASTER

JANUARY 24

Activity: The Section members toured Turkey Hill Dairy in Conestoga, Pa. Chairman **John Ament** arranged the tour that was conducted by **Ernie Pinckney** and **Derek Frey.** The tour concluded with a tasting of freshly made ice cream. **John Boyer** received the Section and the District Educator of the Year Awards. Boyer is a welding instructor at Lancaster County Career and Tech Center, Mt. Joy Campus. Reading Section Chairman **Chris Ochs** was presented the Section and the District Private Educator Awards.

Lancaster Section members are shown enjoying some freshly made Turkey Hill Dairy ice cream following their tour of the facility in January.

READING

JANUARY 18

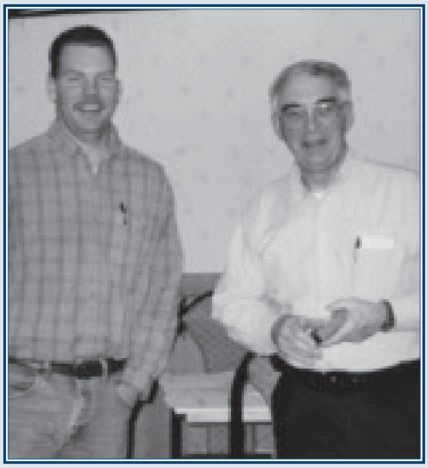
Speaker: **Robert S. Brown,** consultant
Affiliation: RBS Alloy Applications, LLC
Topic: Techniques for welding stainless steel
Activity: The Section hosted its annual Past Chairmen's Night program at Super King Buffet Restaurant in Reading, Pa. Past chairs in attendance included **Merilyn McLaughlin, Steve Gammon, Dave Hibshman, Francis Butkus, Peter Shaub, Larry Hefner, Paul Levengood, Dan DeAntonio, John Miller,** and **Robert Brown.** See photos on next page.

YORK CENTRAL PA.

FEBRUARY 1

Speaker: **Larry Lowe,** district sales manager
Affiliation: Walter Surface Technology

Past Reading Section chairs are (seated) Merilyn McLaughlin and Steve Gammon, and (standing, from left) Dave Hibshman, Francis Butkus, Peter Shaub, Larry Hefner, Paul Levengood, Dan DeAntonio, John Miller, and Robert Brown.



Shown at the Reading Section program are Chair Chris Ochs (left) and speaker Robert S. Brown.

Larry Lowe accepts a speaker gift from Margaret Malehorn, York Central Pennsylvania Section chair.

Shown at the York Central Pennsylvania Section's students' night program are (far left) Chair Margaret Malehorn and (back row) Advisor Brian Yarrison. Far right is Advisor Josh Seitzer.

Topic: Safety when working with abrasives
Activity: The York Central Pennsylvania Section hosted its annual students' night program at York County School of Technology. Every student received a complimentary dinner and a pair of ArcOne glasses. Organizing the event were Section Chair **Margaret Malehorn,** and Student Chapter Advisors **Brian Yarrison** and **Josh Seitzer.**

DISTRICT 4

Director: Roy C. Lanier
Phone: (252) 321-4285

DISTRICT 5

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

SOUTH CAROLINA

JANUARY 18
Speaker: **Tom Thebe,** CFO
Affiliation: Protected Vehicles, Inc.
Topic: Overview and history of PVI and its products
Activity: Following the talk, **Jimmy Lamb** and **Jim Tuten** conducted a tour of the facility for the 42 attendees.

PALM BEACH

JANUARY 17
Speaker: **Dave Sorenson**
Affiliation: Harris Products
Topic: Brazing and soldering filler meals and equipment
Activity: The program was held at Palm Beach Community College.

DISTRICT 6

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

NIAGARA FRONTIER

FEBRUARY 3
Activity: The Section participated in the Batavia Area BOCES student welding competition held in Batavia, N.Y. The prize winners included **Jeff Kohorst, Spencer Reyna,** and **Tim Baker,** who took first, second, and third places in the Senior division, respectively. In the Junior division, **Rick Smith, Dewayne Wilcox,** and **R. J. Steams,** took first, second, and third place, respectively.

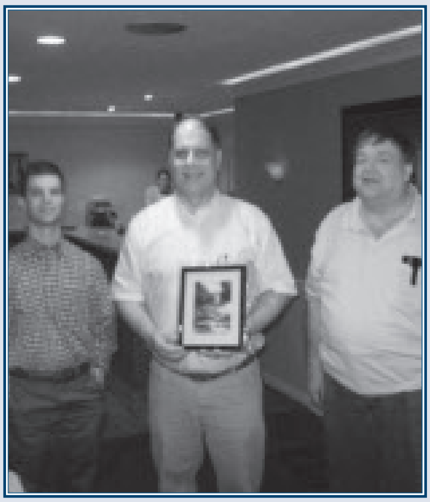
NORTHERN NEW YORK

FEBRUARY 13
Speaker: **Timothy A. Gray,** senior engineer and group coordinator for ultrasonic applications
Affiliation: Center for Nondestructive Evaluation at Iowa State University
Topic: The nondestructive examination of friction stir welds with model-assisted approaches for computing probability of defect detection
Activity: This was the annual joint meeting with members of the Eastern New York Chapter of ASM International. The program was held at Mill Road Restaurant and Tavern in Latham, N.Y.

Participants in the Niagara Frontier Section's welding competition are shown at the February event.

Speaker Dave Sorenson (right) is shown with Frank Rose, Palm Beach Section chair.

The South Carolina Section members are shown during their tour of Protected Vehicles, Inc. Chair Gale Mole is front row, far right.



Pictured at the joint Northern New York Section-ASM Chapter program are (from left) ASM Chair Rich DiDomizio, speaker Timothy Gray, and Section Chair Bruce Lavallee.

The top welders are shown at the Batavia Area BOCES welding competition sponsored by the Niagara Frontier Section.

Tom Nugen discussed industrial gases at the Cincinnati Section program.

Shown at the Columbus Section program are speaker Brian Victor (left) and Kevin Clear, Section chair.

Shown at the Johnstown/Altoona Section program are (from left) Vice Chair Bart Sickles, District 7 Director Don Howard, speaker Peter Howe, and Bill Krupa, secretary-treasurer.

Shown at the Triangle Tech Student Chapter election of officers program are (from left) Jerry DiBernardo, William Conrad, Dianna Schmidt, Jeff Fetters, and Thomas Rocks.

DISTRICT 7

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

CINCINNATI

JANUARY 23
Speaker: **Tom Nugen**
Affiliation: Indiana Oxygen
Topic: An introduction to industrial gases
Activity: The program was held at Corinthian Restaurant in Cincinnati, Ohio.

COLUMBUS

JANUARY 18
Speaker: **Brian Victor**
Affiliation: Edison Welding Institute
Topic: Laser drilling of concrete
Activity: The program was held at Arlington Cafe in Columbus, Ohio.

DAYTON

JANUARY 11
Speaker: **Michael D. Uchrich**
Affiliation: Air Force Research Laboratory, Dayton, Ohio
Topic: The 3D characterization of the structure and crystallography of aerospace materials using a scanning electron microscope
Activity: This was a joint meeting with members of the Dayton and Cincinnati Chapters of ASM International. The program was held at Chantrells Restaurant in Springboro, Ohio.

JOHNSTOWN/ALTOONA

JANUARY 10
Speaker: **Peter Howe,** managing director
Affiliation: AWS Certification Dept.
Topic: AWS certification programs
Activity: The meeting was held in Johnstown, Pa.

Triangle Tech Student Chapter

JANUARY 4
Activity: This Pittsburgh Section Student Chapter held its election of officers. **Jerry DiBernardo,** asst. director, and **Thomas Rocks,** director, of Triangle Technical School congratulated **William Conrad,** president; **Dianna Schmidt,** vice president; and **Jeff Fetters,** secretary, on their elections to office for 2007.

Western Area CTC Student Chapter

JANUARY 23
Speaker: **Dale Glavin,** training coordinator
Affiliation: Steamfitters Local 449
Topic: What it takes to be a steamfitter
Activity: This program was held at the Western Area Career and Technology Center in Canonsburg, Pa. **Anthony Reis** is advisor, and **Carl Cosentino,** chairman.

Notice . . .

See page 118: WACTC is the featured American Welder Learning Track school.

DISTRICT 8

Director: Wallace E. Honey
Phone: (256) 332-3366

DISTRICT 9

Director: George D. Fairbanks
Phone: (225) 673-6600

Shown at the Western Area CTC Student Chapter program are (front row from left) Charles Sheppard, J'Rell Barker, Matt McKinney, Jason Walker, Jon Houston, Chris Kelly, Nathan Clark, and speaker Dale Glavin. Back row, from left are Carl Gottardi, Kevin Brownlee, Ryan Yoders, Dave Clemens, Travis Ware, Brandon Kleinhans, Ryan Badders, Mason Adams, and Nathan Dutton.

BATON ROUGE

JANUARY 17

Speaker: **Jerry S. Majors,** staff materials engineer

Affiliation: Lockheed Martin Space Systems Co., New Orleans, La.

Topic: New welding technologies and overview of the space system

Activity: The meting was held at Turner Industries in Baton Rouge, La.

MOBILE

FEBRUARY 8

Activity: **Bill Faircloth** demonstrated how to do materials characterization, and Charpy impact hardness testing at –40°F. He also showed high-magnification images of a weld cross section and determined the tensile strength of a specimen, and displayed the result of a 39,000 lb/in.^{2} tubing burst test. The event was held at Faircloth Metallurgical Services in Mobile, Ala.

NEW ORLEANS

JANUARY 16

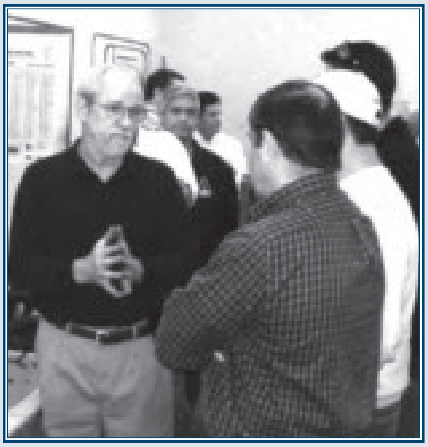
Speaker: **Dwight Witter**

Affiliation: Can-USA

Topic: Nondestructive testing

Activity: Gifts were presented to the local welding students in attendance. The January 50/50 raffle winner was **Aldo Duron** with Ironworkers Local 58. The special host plaque was presented to Can-USA representatives **Dwight Witter** and **Clayton Hinyup** for the company's ongoing support. The meeting was and hosted by Can-USA at its facility in Marrero, La.

Shown at the Baton Rouge program are (from left) Chair Calvin Pepper, speaker Jerry Majors, and Tom Shelton, secretary.



Bill Faircloth discussed destructive weld testing methods with 42 members of the Mobile Section.

David Beneteau (center) receives the District Meritorious Award from District 11 Director Eftihios Siradakis (left) and Detroit Section Chair Ray Roberts.

Shown at the New Orleans Section program are (from left) speaker Dwight Witter, Chairman Travis Moore, and Clayton Hinyup.

DISTRICT 10

Director: Richard A. Harris
Phone: (440) 338-5921

DISTRICT 11

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

DETROIT

FEBRUARY 9

Activity: The Section hosted its 67th annual ladies' night program at Atheneum

Lakeshore Chair Jeff McLead (left) is shown with (from left) Silver Membership Award recipients Milton Kemp and Michael Knauer, and Past Chair Robert Snodgrass.

John Hinrichs (left) and Bruce Halverson discussed welding of the Freedom *LCS #1 (shown during launch) at the Milwaukee Section program.*

Shown at the Upper Peninsula Section program are award winners (from left) Debby Kellner, Dale Lange, Richard Klaar, and Dan Roland.

International Banquet Center in Detroit, Mich. **David Beneteau,** vice president of CenterLine (Windsor) Ltd., and Section vice chair, chaired the event. The funds raised each year support the Section's scholarship program, which has distributed more than $750,000 in scholarships for students pursuing welding-related educations. District 11 Director **Eftihios Siradakis** and Section Chair **Ray Roberts** presented **David Beneteau** with the District Meritorious Award.

NORTHWEST OHIO

JANUARY 23

Activity: **Bob Gillmor,** company owner, led the Section members on a tour of Gillmor Ordnance, Ltd., based in Old Fort, Ohio. The facility specializes in building realistic cast gun-metal replicas of howitzers, cannons, mortars, gun carriages, bells, and caissons for use in movies, including *The Last Samurai,* the Civil War series, *George Washington, Wounded Knee,* etc.

Speaker Dennis Klingman (left) is shown with Northwest Pennsylvania Section Chair Steve DeHart.

Motorsports Upcoming Event

April 5, 11th Annual Motorsports Welding Program and display of drag and NASCAR vehicles, Owens Community College. Speaker will be **Dennis Klingman,** The Lincoln Electric Co. For information, call **Dick West,** (419) 862-2933; or **Larry Blake,** (419) 349-1521.

Northwest Pennsylvania Student Chapter

JANUARY 16

Speaker: **Dennis C. Klingman**

Affiliation: The Lincoln Electric Co.

Topic: Career opportunities in welding

Activity: More than 100 people participated in this open house and Welding and the Workplace Speaker Series program hosted by Tristate Business Institute Advanced Welding Lab, in Erie, Pa. Northwest Pennsylvania Section Chair **Steve DeHart** presented the speaker award to Klingman and assisted with the tour of the company.

DISTRICT 12

Director: Sean P. Moran

Phone: (920) 954-3828

LAKESHORE

FEBRUARY 8

Activity: The Section's Ladies' Night program was held at Barlow Planetarium at the University of Wisconsin-Fox Valley to see the *Spirit of America* laser light exhibit. Following the show, the dinner and meeting were held at Stone Toad in Menasha. **Milt Kemp** and **Michael Knauer** received their Silver Membership Awards for 25 years of service to the Society. Past Chair **Robert Snodgrass** received an award for his distinguished service to the Section.

MILWAUKEE

FEBRUARY 15
Speakers: **John Hinrichs** and **Bruce Halverson**
Affiliation: Friction Stir Link, Inc., and Marinette Marine Corp., respectively
Topic: Friction stir welding of the aluminum upper deck structures of the Littoral Combat Ship (LCS) #1 *Freedom*
Activity: The program was held at Tanner Paull Post in West Allis, Wis.

UPPER PENINSULA

JANUARY 11
Speaker: **Ron Myers,** sales engineer
Affiliation: The Lincoln Electric Co.
Topic: Welder safety
Activity: Four members received awards. **Debby Kellner** received the District Meritorious Award, **Dan Roland** was presented the Private Sector Instructor Award, **Dale Lange** earned the District Educator Award, and **Richard Klaar** accepted the District Dalton E. Hamilton Memorial CWI of the Year Award.

DISTRICT 13

Director: W. Richard Polanin
Phone: (309) 694-5404

DISTRICT 14

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

INDIANA

JANUARY 17
Activity: The Section held a roundtable discussion to plan for its 29th Annual Mid-West Team Welding Tournament, and to select officers for the upcoming year.

FEBRUARY 3
Activity: The Section hosted its annual CWI/CWE testing at the Holiday Inn Select in Indianapolis, Ind., for 33 applicants. Chairman **Gary Dugger** was the test supervisor, with Indiana Section members serving as proctors.

ST. LOUIS

JANUARY 25
Activity: The Section members toured LaBarge Products, Inc., in St. Louis, Mo. The facility manufactures military supply fuel and water transport pump systems. The tour was conducted by **Tom Tweedy,** foreman, and LaBarge Vice Presidents **Bill Wertheimer** and **Michael Nowak.**

DISTRICT 15

Director: Mace V. Harris
Phone: (952) 925-1222

The Indiana Section hosted its annual CWI/CWE testing program in February.

Shown during the Northwest Section tour of OEM Fabricators are (from left) Thomas Aaby, Scott Exner, and Section Secretary Logan Kucerak.

Ronald Briddell (left), St. Louis Section treasurer, gives an appreciation gift to tour guides Tom Tweedy, Bill Wertheimer, and Michael Nowak, at LaBarge Products, Inc.

NORTHWEST

JANUARY 17
Activity: The Section members toured the Woodville, Wis., headquarters of OEM Fabricators, to study its machining, welding, sawing, oxygen, laser, plasma arc cutting, painting, and assembly operations. The guides included **Christian Gausman, Tom Aaby, Chris Kronberger, Kim Shields, Mike Wendt, Mike Finch,** and **Jaime Burr.** Special thanks to **Scott Exner** for organizing the event.

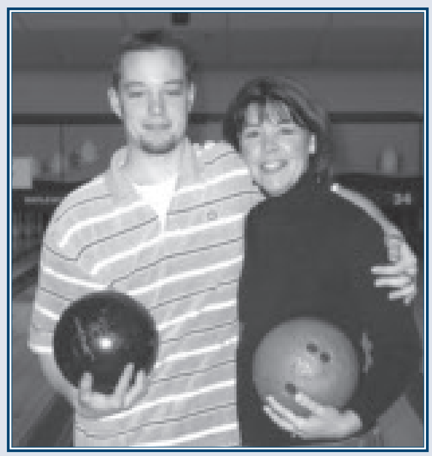
DISTRICT 16

Director: David Landon
Phone: (641) 621-7476

KANSAS CITY

JANUARY 11
Activity: The Section members toured Acuren's Testing Facility in Shawnee, Kans., to study its radiographic testing procedures, and the trucks used to perform weld testing in the field.

FEBRUARY 8
Activity: **Brian McKee** led the Kansas City Section on a tour of the Harley-Davidson facility in Kansas City, Mo.



Winning bowlers at the Nebraska fund raising event were Aaron and Lori Rodgers.

NEBRASKA

JANUARY 20
Activity: The Section hosted its First Annual Bowling Fund Raiser at Maplewood Lanes in Omaha, Neb., to support its scholarship program. The event featured 12 teams and a silent auction. Items were donated by Praxair, Olsson and Assoc., Metropolitan Community College, and Linweld. The tournament winners were **Aaron** and **Lori Rodgers** who donated their cash winnings to support the schol-

Shown at the Nebraska fund-raising event are (from left) Treasurer Dan Fogleman, Chair Rick Hanny, Karl Fogleman, Monty Rodgers, and Secretary Jason Hill.

Shown at the joint East Texas Section-LeTourneau University Student Chapter program are (from left) Dan Moers, Louis Wilpitz, Josh Swenson, Richard Baumer, Josh Trosen, Nathaniel Horton, Robert Warke, and speaker Stephen Liu.

Shown at the January Sabine Section program are (from left) speaker Linda Kovatch, Ken Kovatch, and Vice Chair Morris Weeks.

Shown at the November Sabine Section program are speaker Russell Miller (left) with Chairman Glynn Savage.

arship fund. **Scott Blankman** and **Gary Barnes** took second place honors, and third place went to **Mandi Flesher** and **Monty Rodgers.**

DISTRICT 17

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

EAST TEXAS

JANUARY 18
Speaker: **Daniel R. Lopez,** senior inspector
Affiliation: BP America, North American Business Unit
Topic: The changing role of the welding inspector in the petrochemical industry
Activity: Special guests at this program were local welding students. The meeting was held at Vaughans Restaurant in Tyler, Tex.

Tulsa Section Chairman Jerry Knap (left) is shown with speaker George Johnson.

EAST TEXAS/LeTourneau University Student Chapter

FEBRUARY 16
Speaker: **Stephen Liu,** director
Affiliation: Center for Joining and Coating Research, Colorado School of Mines
Topic: Consumable development for underwater wet welding
Activity: The program was held at LeTourneau University in Longview, Tex.

SABINE

NOVEMBER 28
Speaker: **Russell Miller,** general manager
Affiliation: Ohmstede Ltd., Beaumont, Tex.
Topic: Design and construction trends for pressure vessels
Activity: The program was held at Rocky's Roadhouse in Beaumont, Tex.

JANUARY 23
Speaker: **Linda Kovatch,** director
Affiliation: Lone Star Diving Co., Beaumont, Tex.
Topic: The latest in underwater diving and salvage techniques and equipment
Activity: This Sabine Section program was held at Acapulco Mexican Grill in Beaumont, Tex.

TULSA

JANUARY 23
Speaker: **George Johnson**, owner
Affiliation: Capital X-Ray
Topic: The ASME quality control code
Activity: The meeting was held at 5 and Diner in Tulsa, Okla.

DISTRICT 18

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

DISTRICT 19

Director: Neil Shannon
Phone: (503) 201-5142

SPOKANE

JANUARY 5
Speaker: **Bill Tatt,** regional sales manager
Affiliation: Bohler Thyssen
Topic: Welding austenitic stainless steels and associated corrosion issues
Activity: The talk was followed by a classroom discussion and a hands-on opportunity to allow Section members to run a variety of processes using Bohler Thyssen consumables. The program was hosted by Spokane Community College faculty **Jeff Schwab** and **Phil Smith.**

DISTRICT 20

Director: William A. Komlos
Phone: (801) 560-2353

ALBUQUERQUE

DECEMBER 6
Speaker: **Thomas J. Lienert**
Affiliation: Los Alamos National Laboratory, and Section vice chairman
Topic: Welding of aluminum alloys
Activity: The meeting was held at Clovis Community College in Albuquerque, N.Mex. **Bill Adams,** a welding instructor at the college, received the District 20 Educator Award.

DECEMBER 7
Speaker: **Thomas J. Lienert**
Affiliation: Los Alamos National Laboratory, and Section vice chairman
Topic: Welding of aluminum alloys
Activity: This meeting was held at Eastern New Mexico University in Portales, N.Mex. **Brandon Whatley,** a welding instructor at the university, received the Section Educator Award. **Dusty Heritage,** associate dean for career and technical education, received a Section appreciation award. Presentations were also made by the owners of local machine and fabrication shops, including **Duane Green** of The Machine Ship, Inc., and **Robert Flowers** of RDF Enterprises.

IDAHO/MONTANA

FEBRUARY 8
Speaker: **Bill Komlos,** District 20 director
Affiliation: Arc Tech LLC, consultant
Topic: Joint restraint and mitigation of residual welding stress
Activity: Section Chair **Paul Tremblay** presented the District 20 Director Award to **Denis Clark.**

DISTRICT 21

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

Speaker Bill Tatt (left) accepts a appreciation gift from Treasurer Rich Irving at the Spokane Section program.

Shown at the Albuquerque Section program, speaker and Vice Chair Tom Lienert (left) presents the District Educator Award to Bill Adams at the December 6 meeting.

Albuquerque Section Vice Chair Tom Lienert (left) is shown with Associate Dean Dusty Heritage and welding instructor Brandon Whatley at the December 7 program.

Idaho/Montana Section members learned about residual welding stresses at the February program.

Shown at the San Francisco program are (from left) Vice Chair Tom Smeltzer, speaker Matt Weber, and Chairman Rich Hashimoto.

Participants in the Taiwan International Section's CWI testing program are shown January 20 in Shanghai. Section Chair Chon L. Tsai is the fourth person from the left.

Bill Komlos, District 20 director, explained welding-related stresses for the Idaho/Montana Section members.

DISTRICT 22

Director: Dale Flood
Phone: (916) 933-5844

SAN FRANCISCO

FEBRUARY 7
Speaker: **Matt Weber**
Affiliation: Nova Group, Napa, Calif.
Topic: Finding skilled labor in the Bay Area
Activity: The program was held at Spenger's Restaurant in Berkeley, Calif.

International

TAIWAN

JANUARY 25
Activity: The International Section and American Bureau of Shipping Consulting (Shanghai) jointly sponsored a CWI program in Shanghai, Jan. 15–20. Participants included 15 ABSC-SHA inspectors taking the CWI examination and one taking the Senior CWI test. Section Chairman **Chon L. Tsai** oversaw the event.

Share Your Wisdom with the World

The Welding Handbook Committee seeks volunteers to help update *Welding Handbook,* Volume 4, Materials and Applications. Volume 4 will include chapters on carbon- and low-alloy steels, high-alloy steels, coated steels, tool and die steels, stainless and heat-resistant steels, clad and dissimilar metals, surfacing materials, cast irons, maintenance and repair welding, and underwater welding and cutting.

Volunteers are especially needed for the chapters on high-alloy steels, coated steels, clad and dissimilar metals, and maintenance and repair welding. If your expertise is in any of these areas, discuss this opportunity to serve with **Annette O'Brien,** *aobrien@aws.org;* (800) 443-9353, ext. 303.

The D3 Committee for Marine Construction seeks volunteers to help revise D3.5, *Guide for Steel Hull Welding,* and D3.7, *Guide for Aluminum Hull Welding.*

These two National Standard Guides are extensively used for instruction and training in the naval and commercial shipbuilding industries.

This is a great opportunity for those having experience in welding commercial or naval vessels to participate in the development of these guides. If you have experience in steel hull welding or aluminum hull welding and want to learn how you can contribute to the updating of these important documents, contact **Brian McGrath,** *bmcgrath@aws.org;* (800) 443-9353, ext. 311.

Member-Get-A-Member Campaign

Listed are the members participating in the 2006–2007 Campaign for the period June 1, 2006, through May 31, 2007. See page 83 for rules and the prize list. Call the Membership Dept. (800/305) 443-9353, ext. 480, for information about your status as a member proposer. Listings are for February 16, 2007.

Winner's Circle

AWS Members who have sponsored 20 or more new members, per year, since 6/1/1999. The superscript denotes the number of times Winners Circle status has been earned if more than once.

J. Compton, San Fernando Valley[6]
E. Ezell, Mobile[4]
J. Merzthal, Peru[2]
G. Taylor, Pascagoula[2]
B. Mikeska, Houston
R. Peaslee, Detroit
W. Shreve, Fox Valley
M. Karagoulis, Detroit
S. McGill, NE Tennessee
T. Weaver, Johnstown/Altoona
G. Woomer, Johnstown/Altoona
R. Wray, Nebraska
M. Haggard, Inland Empire

Note: The superscript indicates the number of times an Individual Member has achieved Winner's Circle status. Status awards will be determined at the close of each membership campaign year.

President's Guild

AWS Members sponsoring 20 or more new Individual Members between June 1, 2006, and May 31, 2007.

L. Taylor, Pascagoula — 45
J. Compton, San Fernando Valley — 20

President's Roundtable

AWS Members sponsoring 9–19 new Individual Members between June 1, 2006, and May 31, 2007.

M. Palko, Detroit — 16
R. Myers, L.A./Inland Empire — 11
R. Ellenbecker, Fox Valley — 9
A. Hoover, Northwestern Pa. — 9
L. Mathieu, International — 9

President's Club

AWS Members sponsoring 3–8 new Individual Members between June 1, 2006, and May 31, 2007.

G. Fudala, Philadelphia — 8
W. Shreve, Fox Valley — 8
E. Ezell, Mobile — 7
R. Wilsdorf, Tulsa — 7
J. Bruskotter, New Orleans — 5
G. Taylor, Pascagoula — 5
B. Converse, Detroit — 4
T. Ferri, Boston — 4
H. Jackson, L.A./Inland Empire — 4
J. Leen, Chicago — 4
P. Zammit, Spokane — 4
S. Chuk, International — 3
J. Goldsberry Jr., SE Nebraska — 3
G. Lau, Cumberland Valley — 3
T. White, Pittsburgh — 3

President's Honor Roll

AWS Members sponsoring 1 or 2 new Individual Members between June 1, 2006, and May 31, 2007. Only those sponsoring 2 AWS Individual Members are listed.

C. Amick, Columbia — 2
A. Badeaux, Washington, D.C. — 2
W. Cash, Fresno — 2
G. Cottrell, South Florida — 2
G. Cunningham, North Texas — 2
J. Dolan, New Jersey — 2
D. Gillies, Green & White Mts. — 2
R. Gollihue, Tri-State — 2
D. Irvin, Mid-Ohio Valley — 2
G. Koza, Houston — 2
M. Lamarre, Palm Beach — 2
E. Lamont, Detroit — 2
D. Lawrence, Peoria — 2
J. Little, British Columbia — 2
D. Malkiewicz, Niagara Frontier — 2
P. Newhouse, British Columbia — 2
R. Pierce, Mobile — 2
M. Rieb, Inland Empire — 2
D. Shackelford, L.A/Inland Empire — 2
L. Weathers, Tulsa — 2
D. Wright, Kansas City — 2
R. Wright, San Antonio — 2

Student Member Sponsors

AWS Members sponsoring 3 or more new AWS Student Members between June 1, 2006, and May 31, 2007.

C. Daily, Puget Sound — 196
D. Williams, North Texas — 63
A. Demarco, New Orleans — 45
G. Euliano, Northwestern Pa. — 43
H. Jackson, L.A./Inland Empire — 43
H. Hughes, Mahoning Valley — 40
S. Burdge, Stark Central — 34
S. Siviski, Maine — 30
B. Yarrison, York-Central Pa. — 30
J. Ciaramitaro, N. Central Florida — 27
B. Suckow, Northern Plains — 26
A. Zinn, Eastern Iowa — 24
T. Kienbaum, Colorado — 22
A. Reis, Pittsburgh — 22
M. Anderson, Indiana — 21
T. Geisler, Pittsburgh — 21
D. Ketler, Willamette Valley — 20
B. Lavallee, Northern New York — 19
G. Smith, Lehigh Valley — 18
R. Boyer, Nevada — 17
M. Pointer, Sierra Nevada — 17
W. Harris, Pascagoula — 16
R. Robles, Corpus Christi — 16
M. Arand, Louisville — 15
C. Donnell, Northwest Ohio — 15
B. Butela, Pittsburgh — 14
S. Robeson, Cumberland Valley — 14
D. Zabel, Southeast Nebraska — 14
A. Badeaux, Washington D.C. — 13
J. Daugherty, Louisville — 13
L. Collins, Puget Sound — 11
D. Kowalski, Pittsburgh — 11
M. Koehler, Milwaukee — 10
G. Koza Jr., Houston — 10
S. Luis Jr., Calif. Central Coast — 10
J. Cox, Northern Plains — 9
L. Davis, New Orleans — 8
A. Mattox, Lexington — 8
G. Putnam, Green & White Mts. — 8
D. Newman, Ozark — 7
J. Robillard, Columbus — 7
C. Schiner, Wyoming — 7
W. Younkins, Mid-Ohio Valley — 7
D. Combs, Santa Clara Valley — 6
G. Gammill, Northeast Mississippi — 6
R. Grays, Kern — 6
R. Hutchison, Long Beach/Or Cty. — 6
C. Kipp, Lehigh Valley — 6
G. Saari, Inland Empire — 6
J. Angelo, El Paso — 5
T. Buchanan, Mid-Ohio Valley — 5
J. Carney, Western Michigan — 5
C. Chancy, Long Beach/Or Cty. — 5
J. Boyer, Lancaster — 4
A. Dropik, Northern Plains — 4
C. Neichol, Houston — 4
M. Rahn, Iowa — 4
R. Richwine, Indiana — 4
C. Schiner, Wyoming — 4
J. Swoyer, Lehigh Valley — 4
D. Wright, Kansas City — 4
C. Yaeger, NE Carolina — 4
T. Zablocki, Pittsburgh — 4
C. Bridwell, Ozark — 3
S. Click, Lexington — 3
T. Garcia, New Orleans — 3
F. Gorglione, Connecticut — 3
L. Gross, Milwaukee — 3
L. Ibarra, San Francisco — 3
W. Menegus, Lehigh Valley — 3
S. Miner, San Francisco — 3
T. Moore, New Orleans — 3
R. Rowe, Kansas City — 3
M. Vann, South Carolina — 3
R. Vann, South Carolina — 3 ♦

Guide to AWS Services

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

AWS PRESIDENT

Gerald D. Uttrachi
guttrachi@aol.com
WA Technology, LLC
4313 Byrnes Blvd., Florence, SC 29506

ADMINISTRATION

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

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

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

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

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

Administrative Services

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

IT Network Director
Armando Campana..*acampana@aws.org* .(296)

Director
Hidail Nunez..*hidail@aws.org* ....(287)

Human Resources

Director, Compensation and Benefits
Luisa Hernandez.. *luisa@aws.org* ......(266)

Manager, Human Resources
Dora Shade.. *dshade@aws.org* ....(235)

INT'L INSTITUTE of WELDING

Senior Coordinator
Sissibeth Lopez . . *sissi@aws.org* ......(319)
Provides liaison services with other national and international professional societies and standards organizations.

GOVERNMENT LIAISON SERVICES

Hugh K. Webster. .... *hwebster@wc-b.com*
Webster, Chamberlain & Bean, Washington, DC
(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)

RWMA — Resistance Welding Manufacturing Alliance

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

WEMCO — Welding Equipment Manufacturers Committee

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

CONVENTION and EXPOSITIONS

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

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

Society and Section News Editor
Howard Woodward..*woodward@aws.org* (244)

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 COMMUNICATIONS

Director
Ross Hancock.. *rhancock@aws.org* ....(226)

Assistant Director
Adrienne Zalkind.. *azalkind@aws.org* ...(416)

MEMBER SERVICES

Department Information ....(480)

Deputy 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.

EDUCATION SERVICES

Director, Education Services Administration and Convention Operations
John Ospina.. *jospina@aws.org* ....(462)

Director, Education Product Development
Christopher Pollock.. *cpollock@aws.org* (219)

Tracks effectiveness of programs and develops new products and services. 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.
Also 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.

AWS AWARDS, FELLOWS, COUNSELORS

Senior Manager
Wendy S. Reeve... *wreeve@aws.org* .....(293)
Coordinates AWS awards and AWS Fellow and Counselor nominees.

CERTIFICATION OPERATIONS

Department Information ....(273)

Managing Director
Peter Howe.. *phowe@aws.org* ....(309)

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

Director, Int'l Business Accreditation and Welder Certification
Walter Herrera.. *walter@aws.org* ....(475)
Provides information on personnel certification and accreditation services.

TECHNICAL SERVICES

Department Information ....(340)

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

Director, National Standards Activities
John L. Gayler.. *gayler@aws.org* ....(472)
Structural Welding, Machinery and Equipment Welding, Robotic and Automatic Welding, Computerization of Welding Information

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

Technical Publications
AWS publishes about 200 documents widely used throughout the welding industry.
Senior Manager
Rosalinda O'Neill.. *roneill@aws.org* ....(451)

Staff Engineers/Standards Program Managers
Annette Alonso.. *aalonso@aws.org* .....(299)
Welding in Sanitary Applications, Automotive Welding, Resistance Welding, High-Energy Beam Welding, Aircraft and Aerospace, Oxyfuel Gas Welding and Cutting

Stephen Borrero.. *sborrero@aws.org* ....(334)
Welding Iron Castings, Joining of Metals and Alloys, Brazing and Soldering, Brazing Filler Metals and Fluxes, Brazing Handbook, Soldering Handbook

Rakesh Gupta.. *gupta@aws.org* ....(301)
Filler Metals and Allied Materials, Int'l Filler Metals, Instrumentation for Welding, UNS Numbers Assignment

Brian McGrath . *bmcgrath@aws.org* ....(311)
Methods of Inspection, Mechanical Testing of Welds, Thermal Spray, Arc Welding and Cutting, Welding in Marine Construction, Piping and Tubing, Titanium and Zirconium Filler Metals, Filler Metals for Naval Vessels

Selvis Morales.....*smorales@aws.org* ...(313)
Welding Qualification, Friction Welding, Railroad Welding, Definitions and Symbols

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.*

Nominees for National Office

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

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

To be considered a candidate for the positions of president, vice president, treasurer, or director-at-large, the following qualifications and conditions apply:

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

Vice President: To be eligible to hold the office of vice president, an individual must have served at least one year as a director, other than executive director and secretary.

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

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

Interested persons should submit a letter stating which office they seek, including a statement of qualifications, their willingness and ability to serve if nominated and elected, and a biographical sketch.

E-mail the letter to Gricelda Manalich, *gricelda@aws.org,* c/o Damian J. Kotecki, chair, National Nominating Committee.

The next meeting of the National Nominating Committee is scheduled for November 2007. The terms of office for candidates nominated at this meeting will commence January 1, 2009.

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 FABTECH International & AWS Welding Show held each fall. The deadline for submissions is December 31 prior to the year of awards presentations. Send candidate materials to Wendy Sue Reeve (*wreeve@aws.org),* secretary, Honorary-Meritorious Awards Committee, 550 NW LeJeune Rd., Miami, FL 33126. Descriptions 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 over the past five-years to enhance the American Welding Society's goal of advancing the science and technology of welding.

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

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

AWS Publications Sales

Purchase AWS Standards, books, and other publications from
World Engineering Xchange (WEX), Ltd.
Toll-free (888) 935-3464 (U.S., Canada)
(305) 824-1177; FAX (305) 826-6195
www.awspubs.com

Welding Journal Reprints

Copies of *Welding Journal* articles may be purchased from Ruben Lara.
Call toll-free
(800/305) 443-9353, ext. 288; *rlara@aws.org*

Custom reprints of *Welding Journal* articles, in quantities of 100 or more, may be purchased from
FosteReprints
Toll-free (866) 879-9144, ext. 121
sales@fostereprints.com

AWS Foundation, Inc.

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.

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

AWS Mission Statement

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

It is the intent of the American Welding Society to build AWS to the highest quality standards possible. The Society welcomes your suggestions. Please contact any staff member or AWS President Gerald D. Uttrachi, as listed on the previous page.

EWI Implements Software for Managing Welding Data

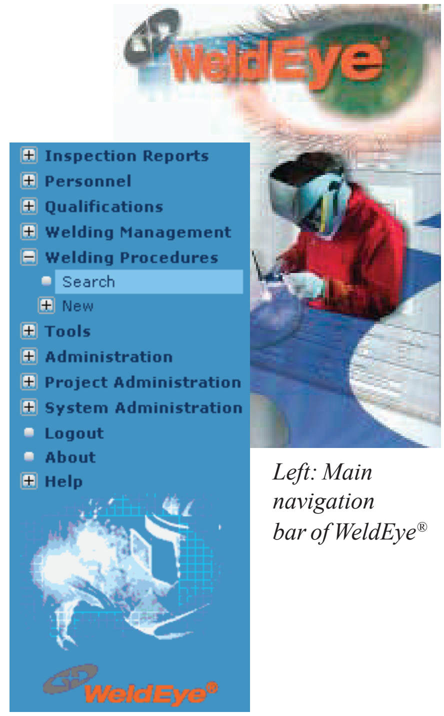
As a leading developer of materials joining solutions for a diverse client base, EWI has built an extensive knowledgebase of welding and joining applications, processes, and procedures. Understandably, managing the wealth of welding information resulting from years of R&D had gradually become a more cumbersome and complex task.

To solve this challenge, EWI recently implemented WeldEye,® a commercial welding data management software package. Utilization of the software will provide a robust, secure, searchable, and expandable electronic archive of welding information to improve efficiency and reduce documentation management costs. Chris Conrardy, EWI's Director of Technology and Innovation, believes "This software will enhance EWI's ability to protect, maintain, search, and retrieve material joining information for our clients." WeldEye will allow EWI to securely manage clients' confidential data as well as EWI's data developed over the past twenty years under its Cooperative Research Program.

EWI selected WeldEye based on its flexibility. The software package is deployed on a secure web server, allowing multiple authorized users to simultaneously access welding data from any computer via a secure internet connection. The software package allows a variety of records to be captured, including: procedure qualification records; welding procedure specifications; welder performance qualifications; inspector qualifications; inspection records; weld production status records.

Importantly, the software also allows the user to attach other types of information to the records, such as photographs, mechanical test results, NDE reports, and spreadsheets. This feature provides flexibility to capture the types of data that are important to particular clients. The software also provides flexible search tools, allowing a record to be quickly located. Once located, records can be printed or emailed in Adobe pdf format. At present, the software is designed to record primarily arc welding information, however EWI is working with the manufacturer to incorporate other modules for friction stir welding, laser welding, and brazing.

Most recently, EWI facilitated the deployment of WeldEye at Rock Island Arsenal and Picatinny Arsenal. The software is also used to manage weld procedures and documentation for a Navy Joining Center (NJC) project that focused on developing practical techniques for Gas Metal Arc Welding (GMAW) large titanium structures.



Left: Main navigation bar of WeldEye®

Optimized GMAW parameters were required for a number of combinations of titanium grade, thickness, joint type, welding position, and weld size. EWI managed these large parameter sets and accompanying data using the WeldEye software. For more information, contact Candice Mehmetli by email at: cmehmetli@ewi.org.

AN INVITATION TO AUTHORS

to present Brazing and Soldering Abstracts at the AWS 36th International Brazing and Soldering Symposium (IBSS)

November 13-14, 2007 - Chicago, Illinois

The American Welding Society's C3 Committee on Brazing and Soldering invites you to submit your work for consideration in the Symposium. The program organizers are accepting on a separate piece of paper **500-600-word abstracts** describing original, previously unpublished work. The work may pertain to current research, actual or potential applications, new developments, or outlook into some actual technical areas.

A Symposium Proceedings will be published as a part of the book "AWS Abstracts of Papers" together with other Symposiums and Technical Sessions being held at FABTECH International & AWS Welding Show.

All abstract submissions must be completed by **April 20, 2007**. A final abstract with requested revisions and will be due on **June 1, 2007.**

Before submitting your abstract, we ask that you carefully consider your ability to present your work at the Symposium. Speakers are not required to pay a registration fee for the AWS Professional Program, but are responsible for their travel, housing and any other related expenses.

Return your application and abstract via email to gladys@aws.org or fax it to 305-648-1655 by **April 20th**.

AUTHOR APPLICATION FORM

FOR

36th INTERNATIONAL BRAZING AND SOLDERING SYMPOSIUM

Chicago, Illinois - November 13-14, 2007

Please complete this form legibly. This completed form is to accompany the 500–600 word summary as described on the back. Please fax it to 305-648-1655 or via email to gladys@aws.org by ***no later than*** *April 20, 2007.*

Primary Author (full name): ❑ Dr. ❑ Professor ______________________________

Affiliation: ______________________________

Mailing Address: ______________________________

City ______________ State/Province ______________ Zip/Mail Code ______________ Country ______________

E-mail: ______________________________

Coauthor(s) Name: ____________ **Affiliation:** ____________ **Address:** ____________ **City:** ____________ **State/Province:** ____________ **Zip/Mail Code:** ____________ **Country:** ________ **Email:** ________	**Coauthor(s) Name:** ____________ **Affiliation:** ____________ **Address:** ____________ **City:** ____________ **State/Province:** ____________ **Zip/Mail Code:** ____________ **Country:** ________ **Email:** ________
Coauthor(s) Name: ____________ **Affiliation:** ____________ **Address:** ____________ **City:** ____________ **State/Province:** ____________ **Zip/Mail Code:** ____________ **Country:** ________ **Email:** ________	**Coauthor(s) Name:** ____________ **Affiliation:** ____________ **Address:** ____________ **City:** ____________ **State/Province:** ____________ **Zip/Mail Code:** ____________ **Country:** ________ **Email:** ________

PROPOSED TITLE (10 words or less): ______________________________

____

Keywords: Please indicate the top four keywords associated with your research below:

______________________ ______________________

______________________ ______________________

Guidelines for abstract submittal and selection criteria:
Only those abstracts submitted on this form will be considered. Follow the guidelines and word limits indicated. Complete this form and submit it electronically via email to gladys@aws.org or via fax 305-648-1655.

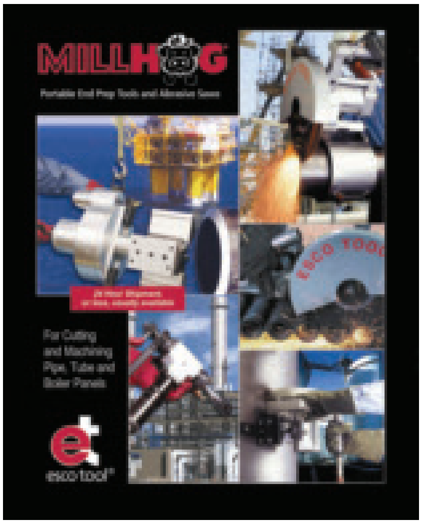
SUBJECT CLASSIFICATIONS:

1. Classify your paper by choosing **one** of the appropriate boxes in each of the following two groups (a) and (b):
   a. ❑ Applied Technology ❑ Education ❑ Research Oriented
   b. ❑ Original Contribution ❑ Progress Report ❑ Review ❑ Tutorial
2. Brazing process (es) used: ______________________________
3. Materials used: ______________________________
4. The main emphasis is more: ❑ process oriented ❑ materials oriented
5. Industries this paper most applies to are: ______________________________
6. Has material in this paper ever been published or presented previously? Yes ❑ No ❑

Below are some of the topical areas covered at IBSS:

__**Aircraft and Aerospace**
__**Automotive and Transportation**
__**Ceramic / Glass to Metal Joining**
__**Electronic Packaging / Sensors**
__**Fuel Cells**
__**Filler Metal Properties**
__**Fluxes and Atmospheres**
__**Furnace / Vacuum Brazing**
__**Joint Reliability**
__**Lead Free Solders**
__**Light Metals**
__**Materials and Process Design / Control**
__**Modeling and Process Control**
__**Power and Electrical Equipment**
__**Sensors / Micro-Electronics**
__**Solder Joining Methods**
__**Special / Advanced Brazing Processes**
__**Test Methods and Evaluation**

Welding End Prep Tools Displayed in Catalog



The 28-page, *2007 Millhog® Portable End Prep Tools and Abrasive Saws Catalog* features a variety of new tools and accessories. Included are a full line of tools for cutting and machining pipe, tube, sheet, vessels, and boiler panels. New special-purpose tools include the Commander®, which bevels heavy-wall tube and is available in pneumatic- and hydraulic-drive models, and the Dictator® model designed to prep heavy-wall pipe, including superduplex alloys. New to this edition is the Fin Millhog®, which removes fin from the tube OD and bevels in one step. Provided are in-depth product descriptions, photographs, specifications, and ordering information. Visit *www.escotool.com.*

ESCO Tool **112**

PO Box 530, Medfield, MA 02052

CD on OSHA Cr(VI) Compliance Released

The company has released a new Arc Welding Safety CD (MC06-209) featuring industry and product news, including the latest information on the new OSHA hexavalent chromium [Cr(VI)] standards and OSHA's Small Entity Compliance for Hexavalent Chromium Standard. The current standard lowers the permissible exposure limit (PEL) for Cr(VI) compounds to 5 μg/m^3 of air as an 8-h time-weighted average, which is one-tenth of the previous PEL. The CD also provides safety information on arc welding and fume-extraction equipment, plus provides useful links to MSDS on hardfacing consumables, stainless and high-alloy consumables, and low-alloy consumables, as well as various safety and health topics. The CD may be requested at the company's Web site *www.lincolnelectric.com* (click Quick Links, then select Welding Safety).

The Lincoln Electric Co. **113**

22801 St. Clair Ave., Cleveland, OH 44117

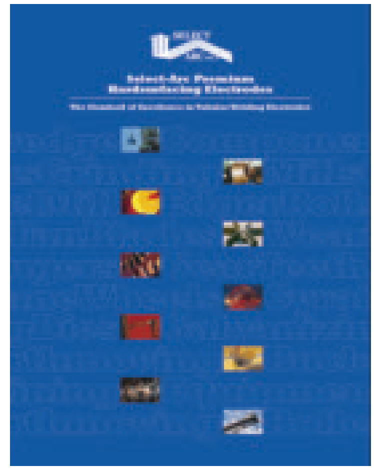
Tools and Abrasives Featured in New Catalog

The *Enco 2007 Master Catalog* contains more than 40,000 items including 5000 new products in the company's lines of cutting tools, abrasives, raw materials, measuring, and machine tools. New items include Seco carbide indexable cutting tools and Osborn abrasive brushes plus new products in the Dewalt power tools and raw material product lines. Also displayed are new lines of Emerson Motors and Rong-Fu CNC mill-drills. Other products detailed are drills, end mills, calipers, and lathe chucks.

Enco **114**

PO Box 357, Farmingdale, NY 11735

Hardfacing Products Detailed in Brochure



A new 12-page brochure details the company's complete line of hardfacing electrode products. Information is provided on the processes and specific product data on buildup, hardfacing, nickel-based, and roll rebuilding alloy wires. New products include the SelectWear 420-S and 423-S for steel mill caster rolls, idler rolls, and table rolls, and the SelectWear Zucar-O, designed specifically for hardfacing sugar cane crusher rolls. Visit *www.select-arc.com.*

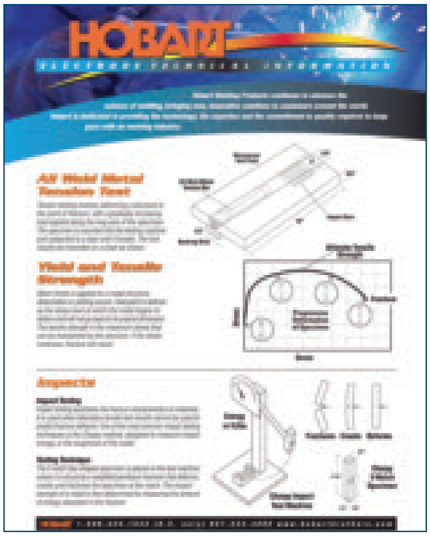
Select-Arc, Inc. **115**

PO Box 259, Fort Loramie, OH 45845-0259

View Ultrasonic Welding Video Online

A 4-minute-long video shows the unique performance advantages of the company's ultrasonic wire splicer and digital metal spot welding machine. The video shows the microprocessor-controlled machines forming metallurgical bonds in seconds without melting, arcs, sparks, or fumes. Shown is the Wedge-Reed coupling system that combines high vibratory force with low-amplitude ultrasonics to create reliably accurate welds, and the flexibility of the power supplies programmed to store and recall up to 250 job settings. Displayed is the SonoWeld® digital spot welding machine capable of precision welding up to ten stranded wires in a single pulse. The SpliceRite™ ultrasonic wire welding machine is shown to handle wire-to-wire applications without crimping, including tin-coated or oxidized wires. Visit the Sonobond Ultrasonics Web site *www.sonobondultrasonics.com.*

Technical Posters Feature Covered Electrodes

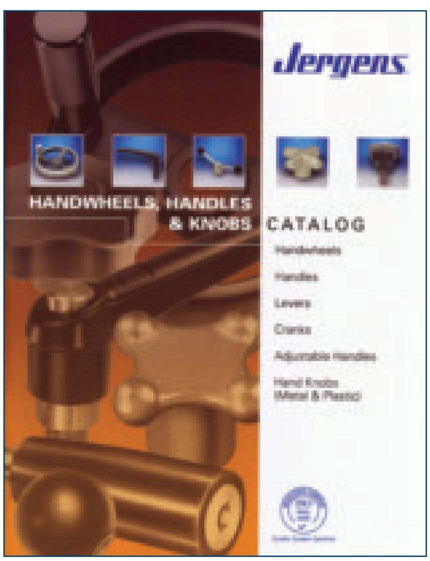


Designed to help educate end-users on important information about covered electrodes, the company offers a series of technical posters. The first poster clarifies terms and procedures, including yield and tensile strength, and testing techniques in concise and easy-to-understand language. Diagrams are used to illustrate how welding industry engineers use destructive weld tests, all-weld-metal tension tests, and the Charpy V-notch impact method to ensure the integrity of its covered electrodes. Visit *www.hobartbrothers.com.*

Hobart Brothers Co. **116**

101 Trade Square East, Troy, OH 45373

Catalog Pictures Knobs, Cranks, and Handwheels



A 64-page catalog depicts the company's lines of handwheels, handles, levers, cranks, plus a wide variety of knobs. Included are full specifications in both U.S. Customary and metric measurements, along with application tips. Technical information details the materials, and provides schematic drawings, photos, and other value-added features. The company's Web site, *www.jergensinc.com,* provides 3-D models for all of its handwheel, handle, and knob models.

Jergens, Inc. **117**

Jergens Way, 15700 S. Waterloo Rd., Cleveland, OH 44110-3898

Do You Have Some News to Tell Us?

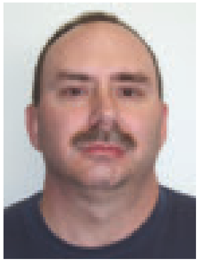
If you have a news item that might interest the readers of the *Welding Journal*, send it to the following address:

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

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

Rimrock-Wolf Robotics Staffs Customer Support

Nathan Nicholas



Dale Lockwood

Tom Hanner

Rimrock-Wolf Robotics, Fort Collins, Colo., recently hired **Nathan Nicholas** and **Dale Lockwood** as customer support engineers, and **Tom Hanner** as a customer support technician. Nicholas, based in Fort Collins, previously worked for General Motors and General Electric. Lockwood and Hanner, based in the New York area, will service the northeastern area of the country.

Bosch Rexroth Names Division Controller

Mike Hall

Bosch Rexroth Corp., Charlotte, N.C., has announced the appointment of **Mike Hall** to division controller — linear motion and assembly technologies. With the company for 15 years, Hall has served in various accounting and finance roles of increasing responsibility.

Tregaskiss Hires Product Engineer

Ryan Lizotte

Tregaskiss Welding Products, Windsor, Ont., Canada, has hired **Ryan Lizotte** as a product engineer. Lizotte brings six years of experience in manufacturing as well as CAD experience to the position.

VP Buildings Names Manager for Georgia District

Josh Mundy

VP Buildings, Memphis, Tenn., a manufacturer of steel building systems for low-rise commercial applications, has named **Josh Mundy** its district manager for metro Atlanta and southern Georgia. Before joining the company, Mundy worked in sales and project management in commercial construction in the Atlanta area.

Progressive Systems Taps National Sales Manager

David DiBiase

Progressive Systems, Inc., Berea, Ky., a robotic systems integrator, has hired **David DiBiase** as national sales manager. DiBiase brings 28 years of experience in sales and marketing to the position.

Oxford Alloys Hires Sales Director

Oxford Alloys, Inc., Baton Rouge, La., a supplier of welding filler metals, has appointed **Beth Haupt** director of sales and marketing. Prior to joining the company, Haupt worked 20 years in customer service and sales in the welding industry.

NACE Officers Named for 2007–2008

NACE International, Houston, Tex., has announced its slate of officers to serve the 2007–2008 term beginning March 16. Named are **Louis D. Vincent,** president; **Robert W. Herbert,** vice president; **Phil Fouche,** treasurer; and **David Webster,** past president. Vincent is president of L. D. "Lou" Vincent PhD, Inc., and senior coating consultant for Corrpro Companies, Inc., Lafayette, La. Herbert is an independent corrosion consultant for Ashland Performance Materials, Dublin, Ohio. Fouche is owner of Quatro Paints Products, Odessa, Tex. Webster is manager of Corrosion and Integrity Services for Colt Engineering Corp., Calgary, Alberta, Canada.

NCCER Announces Board of Trustees Chairs

The National Center for Construction Education and Research (NCCER), Gainesville, Fla., has elected **Mark Small** chairman of its board of trustees. Small is senior vice president and CFO of Cleveland Construction, Mentor, Ohio. He succeeds **Ron McKenzie,** chairman and CEO of The Industrial Co., in Steamboat Springs, Colo. **Steve Halverson** will serve as vice chairman of the board. He is president and CEO of the Haskell Co., Jacksonville, Fla.

Bug-O Appoints Canada Sales Manager

Clay Cable

Bug-O Sytems Inc., Pittsburgh, Pa., a supplier of automated welding equipment, has appointed **Clay Cable** as its sales manager for Canada. Formerly, Cable served as an inside sales agent.

Gibraltar Industries Fills Two Key Posts

Andy Blanchard

Gibraltar Industries, Inc., Buffalo, N.Y., has appointed **Andy Blanchard** as president, processed metals group, and **Howard May** to vice president of operations for Alabama Metal Industries Corp., a division of Gibraltar Industries. Blanchard will oversee three steel processing facilities, SCM Metal Products, Hubbell Steel, and a materials management operation in the Detroit, Mich., area. Previously, Blanchard served for ten years in leadership positions at ESAB Welding and Cutting Products. May previously worked 12 years at Textron in various positions, most recently as senior vice president of operations for Jacobsen.

Obituaries

Robert W. Worden Jr.

Robert (Bob) W. Worden Jr., 62, a past chairman of the AWS Washington, D.C., Section, died February 28.

Mr. Worden taught welding at Northern Virginia Community College (NVCC) in Manassas, Va., for more than 20 years, and was active in the Washington, D.C., Section for 15 years. He held most executive posts in the Section, including student affairs coordinator, where he hosted numerous student welding contests, Section meetings, and demonstrations at the college. He is credited for developing and executing the welding program at NVCC and building it into one of the most successful programs in the area. He worked diligently with shipbuilders and other companies along the East coast to find good-paying jobs for his students. As a teacher, he had served as the Student Activity Coordinator his entire time. He worked with the Vocational and Industrial Clubs of America (VICA) programs, and coordinated welding contests between local institutions, and made technical presentations on how to train welders to take advantage of the local job markets.

Bob Worden

Born in Washintgton, D.C., his family moved to California when he was nine years old. He apprenticed with his father as a blacksmith through high school. Following graduation, he served in the U.S. Navy where he started welding in 1962. Subsequently, he worked in fabrication and production shops on the West and East coasts on structural steel buildings, bridges, stainless steel repairs, heavy equipment, and as a craftsman in his own welding business. He studied welding metallurgy and nondestructive evaluation at The Ohio State University College of Engineering in 1977.

Among his numerous awards and recognitions were the NVCC Provost's Award for Make-A-Difference (2000), Achievement in Technology Certificate (1998), and The Alumni Federation Award for Outstanding Service to Education (1998).

Mr. Worden is survived by his daughter, Carrie Worden Rossi, and grandchildren, Corinne and Roman.

Gordon E. Cossaboom

Gordon E. Cossaboom, 82, died January 10 in Jackson, Mich. He held a welding engineering degree from The Ohio State University, and worked for Westinghouse Corp. Mr. Cossaboom participated in AWS Section activities for 54 years. He was a member of the Detroit Section from 1970 to 1972 as technical representative, membership chair (1973–1974), vice chair (1974–1976), and chairman (1976–1977). Mr. Cossaboom then served the AWS Central Michigan Section as secretary (1981–1982 and 1992–2007), and chairman (1991–1992). He is survived by his wife Marian, a daughter, a son, three step daughters, nine grandchildren, and five great grandchildren.

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Conference on the Explosion of New Processes
San Diego • Doubletree Golf Resort
August 14-15, 2007

The welding industry is now in the midst of an explosion of new welding technologies, many of which have made quick passage from the research lab to the production line. This kind of activity has not been seen for decades. Presentations on many of these technologies will form the body of this first-of-its-kind conference. Two of the main thrusts will explore interesting variations and improvements on laser technologies and on friction stir welding.

Friction Stir Welding and Processing—An Update of Recent Developments
William J. Arbegast, Director, NSAF Center for Friction Stir Processing, and Director, Advanced Materials Processing and Joining Center, South Dakota School of Mines and Technology

The Deformation Resistance Welding Process
Menachem Kimchi, Technology Leader, Edison Welding Institute

A New Approach (Double Electrode) to High Productivity GMAW
Dr. YuMing Zhang, James R. Boyd Professor, Director of Graduate Studies, Center for Manufacturing, Department of Electrical and Computer Engineering, College of Engineering, University of Kentucky

Magnetic Pulse Welding Extends Its List of Applications
Erik de Jongh, Vice President, Sales and Field Operations, Pulsar Ltd.

The Fiber Laser Opens Up New Opportunities for Laser Welding
Bill Shiner, Director, Industrial Market Development, IPG Photonics Corp.

Ultrasonic Joining of Metals: Advances in Welding, Soldering and Brazing
Matt Short, Project Engineer, Edison Welding Institute

Friction Stir Welding and Processing of Advanced Materials—Advances and Challenges
Dr. S. A. David, Corporate Fellow and Group Leader, Materials Joining Group, Oak Ridge National Laboratory

Friction Stir Welded Components Are Headed to Mars
Mike Skinner, Business Development Manager, MTS Systems Corp.

Single-Sided Plasma Spot Welding and Plasma Brazing Process—A Review of Applications
R. V. Hughes, Technical Director, Camarc LLC

Laser Stir Welding of Aluminum Alloys
R. P. Martukanitz, Head, Laser Processing Division, Applied Research Laboratory, Pennsylvania State University; and Israel Stol, Senior Manufacturing Specialist, Joining and Assembly, Alcoa Technical Center

Novel Heat Source Enables Brazing at Room Temperature
Dr. Timothy P. Weihs, President, Reactive NanoTechnologies Inc.

CSC-Controlled Short Circuit Transfer—A New GMAW Process That Solves Old Weld Problems
Tom Rankin, Vice President and General Manager, ITW Jetline Engineering

A New Process (Ultrasonic Impact Treatment) for Improving Fatigue Strength of Welds
Sougata Roy, Research Scientist III, ATLSS Center, Lehigh University

Conference price is $550 for AWS members, $680 for nonmembers.To register or to receive a descriptive brochure, call (800) 443-9353 ext. 224, (outside North America, call 305-443-9353), or visit www.aws.org/conferences

American Welding Society

Friends and Colleagues:

I want to 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 July 1, 2007. The Committee looks forward to receiving numerous Fellow nominations for 2008 consideration.

Sincerely,

Nancy C. Cole
Chair, AWS Fellows Selection Committee

This month's AWS Foundation spotlights:

Spotlight on a scholar

"My name is Nathan Hoffman. While pursuing a bachelor's degree in Welding Engineering Technology at Ferris State University, I had the honor of receiving the William B. Howell Memorial Scholarship.

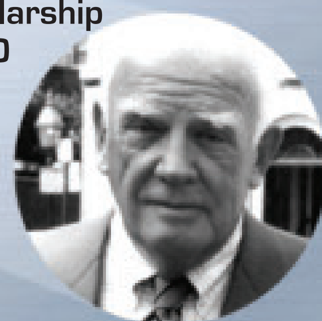
Receiving the scholarship not only assisted with the financial portion of attending college, but also inspired me to continue to pursue a career in the welding industry. As a result of the American Welding Society Foundation and the Howell family's generosity, I have been able to enjoy a successful career as a boiler system engineer in the electrical generation industry. I can't thank the AWS Foundation enough for their support of individuals such as myself."

Spotlight on a scholarship

The William B. Howell Memorial Scholarship honors an individual who spent his entire professional career actively participating in and promoting the welding industry. William B. Howell was a member of the American Welding Society for 50 years.

Mr. Howell retired from Hobart Brothers Company as executive vice president after 44 years of service. He also served as a member of the boards of directors of Hobart Brothers and the Hobart Institute.

The purpose of this scholarship is to provide financial assistance to a full-time undergraduate interested in pursuing a career in welding. Mr. Howell believed in helping people who were willing to help themselves. The scholarship was endowed in 2000 by his daughter, Deborah Kurd, and son, Robb Howell, to honor their father and the welding profession he loved.



The American Welding Society Foundation has helped thousands of students who otherwise would be unable to afford a welding education. We are proud of the fact that we help hundreds of welding students annually by providing them with funding towards their education. In fact, we are the only industry foundation set up specifically to further welding education and, in so doing, create the careers that sustain and grow our industry.

These funds are from your generous contributions. If you don't contribute, we will not be able to expand our work and our students' educations. And there is so much work to be done.

Please make a scholarship contribution, or set up your own Section, District Named, or National Named Scholarship. Contact the AWS Foundation at 1-800-443-9353, ext. 212.

AWS Foundation, Inc.

Building Welding's Future through Education

Welding for the Strength of America

The Campaign for the American Welding Society Foundation

Assuring Accurate Preheat Temperatures

Accurate preheating prior to welding reduces the chances of cracking and other problems

BY ROGER HORNBERGER

Checking the surface temperature of a custom alloy.

ROGER HORNBERGER is general manager, Tempil, an ITW Company, South Plainfield, N.J., www.tempil.com.

Welders know, and ASME codes reinforce, the need for preheating many ferrous metals prior to welding — Fig. 1. A successful weld unites the welding filler metal and the base metal into one entity; a good weld is at least as strong as the base materials being joined.

With many materials, bringing the base metal "up to heat" before welding improves the chances of achieving a successful weld by reducing the danger of crack formation and other problems. As a result, there is less need for factory rework, and performance of the finished piece is enhanced.

Cracks and How They Form

Weld cracking may occur due to thermal stresses imposed on the weld metal and adjacent heat-affected zones. In welding carbon and alloy steels, cracking often occurs in conjunction with the formation of hard, brittle areas — the result of rapid cooling during welding and the presence of hydrogen.

Weld metal shrinks as it cools, and this sets up stresses when the shrinkage is restrained by the surrounding colder metal. Also, the surrounding colder metal draws heat away from the weld zone. The rate of heat flow away from the weld is greater during welding of thick sections and in metals having a high thermal conductivity. In metals that are susceptible to quench hardening, such as high-carbon and alloy steels, the rapid extraction of heat from the weld area can result in the formation of hard, brittle regions.

Preheating can help to minimize the thermal gradients in the weld area, thereby reducing the resulting thermal stresses. Also, by reducing the cooling rate, preheating can prevent or minimize the formation of hard, brittle areas during welding of some types of steel.

Controlled preheating provides a simple and well-known solution to welding problems that may occur as a result of rapid postweld cooling. Preheat temperatures are based on the type and composition of the metal being joined, and in order to be effective, preheat temperatures must be properly controlled.

The Problem with Hydrogen

The presence of hydrogen greatly increases the possibility of cracking in the weld metal or heat-affected zone in welding carbon and alloy steels. Root cracks, toe cracks, underbead cracks, and transverse cracks are all common, given thermal stress and the presence of hydrogen.

In welding these materials, it is important to keep hydrogen away from the weld area. Hydrogen can come from electrode coatings, fluxes, base-metal contamination — even the atmosphere — and, in the case of a repair weld, from materials which were contained or handled by the

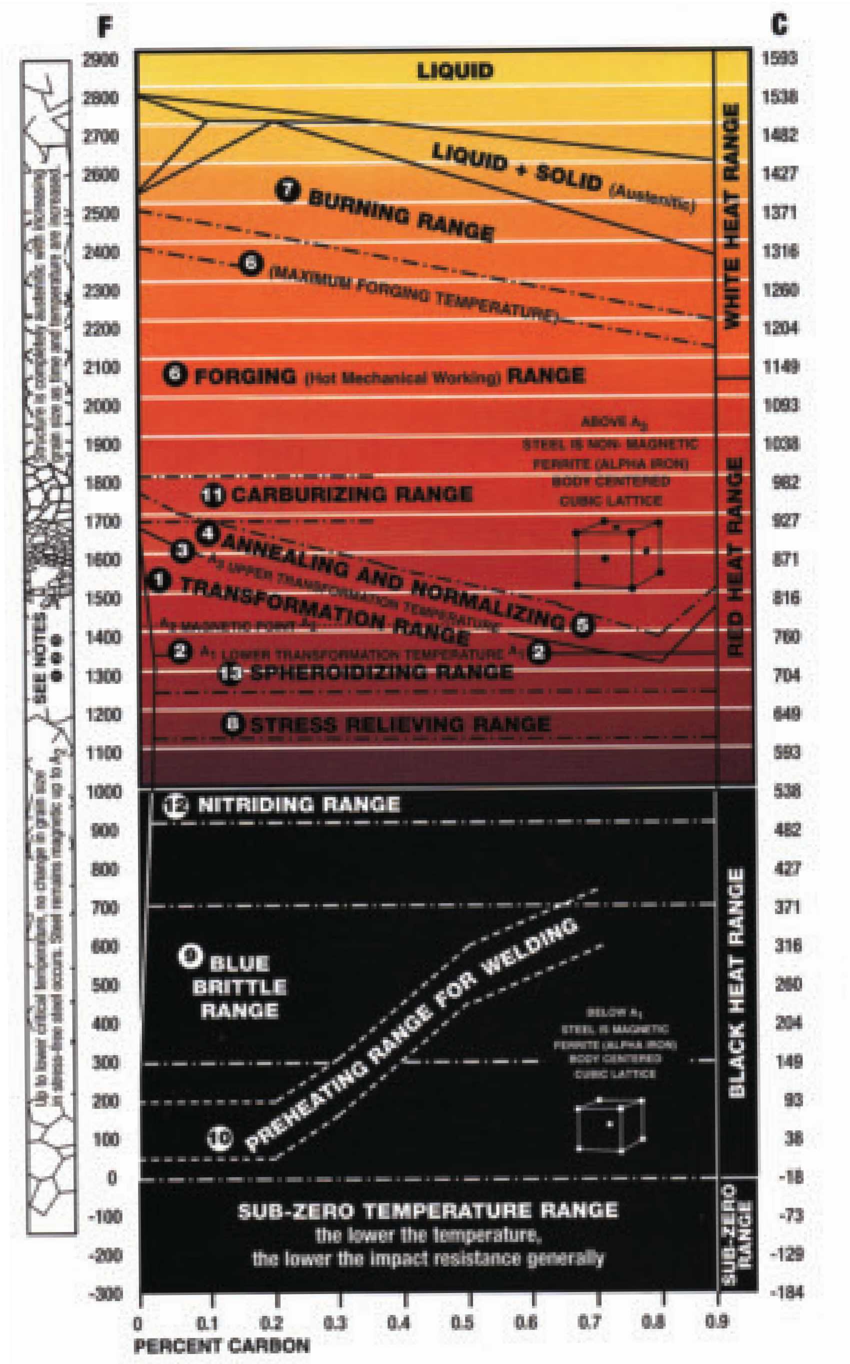


Fig. 1 — A basic guide to ferrous metallurgy.

*1. **Transformation Range**. In this range, steels undergo internal atomic changes that radically affect the properties of the material.*

*2. **Lower Transformation Temperture** (A_1). Termed Ac_1 on heating, Ar_1 on cooling. Below Ac_1 structure ordinarily consists of ferrite and pearlite (see below). On heating through Ac_1, these constituents begin to dissolve in each other to form austenite (see below), which is nonmagnetic. This dissolving action continues on heating through the transformation range until the solid solution is complete at the upper transformation temperature.*

*3. **Upper Transformation Temperature** (A_3). Termed Ac_3 on heating, Ar_3 on cooling. Above this temperature the structure consists wholly of austenite, which coarsens with increasing time and temperature. Upper transformation temperature is lowered as carbon increases to 0.85% (eutectoid point).*

*• **Ferrite** is practically pure iron (in plain carbon steels) existing below the lower transformation temperature. It is magnetic and has very slight solid solubility for carbon.*

*• **Pearlite** is a mechanical mixture of ferrite and cementite.*

*• **Cementite** or iron carbide is a compound of iron and carbide Fe_3C.*

*• **Austenite** is the nonmagnetic form of iron and has the power to dissolve carbon and alloying elements.*

*4. **Annealing,** frequently referred to as full annealing, consists of heating steels to slightly above Ac_3, holding for austenite to form, then slowly cooling in order to produce small grain size, softness, good ductility, and other desirable properties. On cooling slowly the austenite transforms to ferrite and pearlite.*

*5. **Normalizing** consists of heating steels to slightly above Ac_3, holding for austenite to form, then followed by cooling (in still air). On cooling, austenite transforms giving somewhat higher strength and hardness and slightly less ductility than in annealing.*

*6. **Forging Range** extends to several hundred degrees above the upper transformation temperature.*

*7. **Burning Range** is above the forging range. Burned steel is ruined and cannot be cured except by remelting.*

*8 **Stress Relieving** consists of heating to point below the lower transformation temperature, A_1, holding for a sufficiently long period to relieve locked-up stresses, then slowly cooling. This process is sometimes called process annealing.*

*9. **Blue Brittle Range** occurs approximately from 300° to 700°F. Peening or working of steels should not be done between these temperatures, since they are more brittle in this range than above or below it.*

*10. **Preheating For Welding** is carried out to prevent crack formation.*

*11. **Carburizing** consists of dissolving carbon into surface of steel by heating to above transformation range in presence of carburizing compounds.*

*12. **Nitriding** consists of heating certain special steels to about 1000°F for long periods in the presence of ammonia gas. Nitrogen is absorbed into the surface to produce extremely hard "skins."*

*13. **Spheroidizing** consists of heating to just below the lower transformation temperature, A_1, for a sufficient length of time to put the cementite constituent of pearlite into popular form. This produces softness and in many cases good machinability.*

*• **Martensite** is the hardest of the transformation products of austenite and is formed only on cooling below a certain temperature known as the M_s temperature (about 400° to 600°F for carbon steels). Cooling to this temperature must be sufficiently rapid to prevent austenite from transforming to softer constituents at higher temperatures.*

*• **Eutectoid Steel** contains approximately 0.85% carbon.*

*• **Flaking** occurs in many alloy steels and is a defect characterized by localized microcracking and "flake-like" fracturing. It is usually attributed to hydrogen bursts. Cure consists of cooling to at least 600°F before aircooling.*

*• **Open or Rimming Steel** has not been completely deoxidized and the ingot solidifies with a sound surface ("rim") and a core portion containing blowholes that are welded in subsequent hot rolling.*

*• **Killed Steel** has been deoxidized at least sufficiently to solidify without appreciable gas evolution.*

*• **Semi-Killed Steel** has been partially deoxidized to reduce solidification shrinkage in the ingot.*

*• **A Simple Rule:** Brinell Hardness divided by two, times 1000, equals approximate tensile strength in pounds per square inch.* (200 Brinell $\div$ $2 \times 1000 =$ approx. 100,000 tensile strength, lb/in.^{2}).

Fig. 2 — A temperature indicator is used to check the surface temperature on a gear.

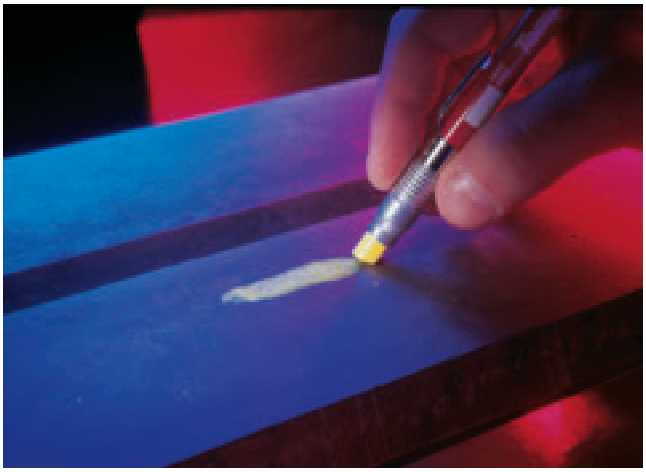


Fig. 3 — The melted mark left by a temperature crayon.

equipment being repaired.

Preheating can be very helpful in preventing hydrogen absorption because it allows the hydrogen to escape.

Moisture and Porosity

It's important to eliminate moisture during welding. Outdoors it's ever present. Even indoors, there's the problem of condensation from humidity, particularly if the metal is cold.

High welding temperatures will vaporize any surface moisture; the vapor can enter the weld pool, causing porosity in the completed weld, which reduces its strength and ductility.

Again, preheating is beneficial. Warming the metal prevents condensation. It also vaporizes any moisture already present before the weld process begins, so it will not be vaporized by the heat of welding and absorbed into the weld pool.

Cooling Slowdown

Preheating reduces the rate of heat flow away from the weld. This allows more time for redistribution of thermal stresses, thereby reducing the tendency for cracking. In some steels it helps to minimize the formation of hard, brittle areas in the weld and heat-affected zones, thereby promoting ductility and decreasing the risk of cracking.

Is Preheating Always Needed?

The need for preheating increases with these factors:

1. Thickness of parts being welded

2. Lower temperature of the pieces to be welded

3. Low atmospheric temperature

4. Lower heat input

5. Higher speed of welding

6. Higher carbon content of the steel

7. Higher alloy content of the steel

8. Difference in mass between the pieces being joined

9. Complicated shape or section of the parts.

ASME B31.1, *Power Piping*, lists preheat requirements. In general, as noted above, steels with higher carbon and alloy content, and greater thickness, need preheat. In some cases, the required preheat temperature is only 50°F, minimum — a consideration for outdoor applications, but usually not important indoors. In many cases, however, preheat temperatures ranging from 175° to 400°F are advised.

ASME B31.3 lists requirements for chemical plant and petroleum refinery piping. Recommended or required minimum preheat temperatures range from 50° to 300°F.

Preheating is not necessary for chrome-nickel stainless steels, nor for nonferrous metals such as nickel and nickel alloys (Monel®, Inconel®), or aluminum and copper alloys. However, warming up to 200°F may be desirable to remove moisture condensation. Preheat may be desirable for thick sections of high-conductivity metals such as aluminum and copper.

How to Preheat

Preheating is most commonly done using oxyfuel gas torches. Where more precise control of the preheat temperature is required, furnace heating, electric resistance heating blankets, or induction coils may be employed.

With local torch heating or other rapid heating methods, it is important to prevent overheating, and it is necessary to allow sufficient time to reach the desired uniform temperature throughout the thickness of the weld joint and surrounding metal. Also, in using gas torches it is important to prevent deposits of incomplete combustion products on joint surfaces or adjacent areas.

Determining the Proper Temperature

One method for determining that the joint has reached the desired preheat temperature is a simple one: a temperature indicator made of materials with melting points calibrated to a guaranteed accuracy of 1%.

The most common temperature indicator for welding purposes is the stick or chalk type, which is usually supplied in an adjustable holder with a pocket clip similar to that on a mechanical pencil — Fig. 2.

Temperature indicators are made of materials with calibrated melting points. An indicator is stroked on the piece as heating proceeds.

When the temperature rating of the

selected indicator is reached, the dry opaque mark undergoes a phase change to a distinct melted appearance — Fig. 3.

Phase-Change Accuracy

A wide variety of electric, electronic, infrared, and other instrumentation is available for temperature determination. However, none of these methods is widely employed in welding. Phase-change temperature indicators are preferred because they are accurate, simple to use, inexpensive, and make good thermal equilibrium with the surface to which they are in contact — Fig. 4.

Melting point, the temperature where phase change occurs, is a physical property of the raw material. It is not influenced by static electricity, ionized air, humidity, or being dropped on the floor — factors that can make electrical and electronic instrumentation function erratically. No setup time, calibration, and recalibration are required, and no operator training or experience are necessary. All the operator has to do is observe that the chalk mark has melted. The indicators are accurate within 1% of their stated temperature ratings measured in accordance with MTL-STD-45662. The materials used are calibrated on apparatus traceable to the National Institute of Standards & Technology.

Many practitioners consider welding an art as well as a science. Two or more pieces of metal are joined, with a bond that is as strong or stronger than the component materials. But in order to achieve this, weld quality must be good. Preheating is often necessary. With the ready availability of accurate, inexpensive temperature indicators, the correct preheat temperature can be assured.♦

Fig. 4 — A welder uses a temperature crayon to mark a piece close to a weld.

Understanding the New Hexavalent Chromium Standards

The answers to these questions will help you implement the requirements of the new hexavalent chromium standard

The new standard means that employers must reassess their respirator programs taking into consideration the lower exposure limit.

Prepared by the 3M Occupational Health and Environmental Safety Division (OHESD), Minneapolis, Minn.

For additional information, contact a local 3M OHESD sales specialist, the 3M OHESD Technical Hotline at (800) 243-4630, www.3M.com/OccSafety *or* www. hexchrome.com.

On February 28, 2006, the Occupational Safety and Health Administration (OSHA) published the final Hexavalent Chromium Cr(VI) standard. The new permissible exposure limit (PEL) for Cr(VI) is 5 µg/m³ (micrograms per cubic meter) as an eight-hour time-weighted average (TWA).

There are three standards for different industries — General Industry, Construction, and Shipyards. The respiratory protection requirements for the three standards are similar.

The standard requires the respiratory protection program, including respirator selection, to follow OSHA 1910.134 requirements.

For employers with more than 20 employees, the standard took effect November 27, 2006. Employers with 19 or fewer employees must be in compliance by May 30, 2007. Feasible engineering controls must be in place by May 31, 2010.

For a complete copy of the standard, visit OSHA's Web site at *www.osha.gov*.

Q: What is hexavalent chromium?

A: Hexavalent chromium, Cr(VI), is a metal particle that can occur naturally in rocks but is most commonly produced by industrial processes. It has the ability to gain electrons from other elements — it is a strong oxidizer — which means it can react easily to other elements. Because of its ability to react with other elements, it can produce hard coatings, which is why it is used in paints for cars, boats, and aircraft.

Q: What type of contaminant is hexavalent chromium?

A: Cr(VI) is a metal particle. It can be filtered with an N95 filter or an R or P95 filter if oil mist is present.

Q: What Cr(VI) exposures are covered in the standard?

A: Cr(VI) exposures from any source are covered except exposures from

- Portland cement.
- Applications of regulated pesticides such as treatment of wood with pesticides. Exposures resulting from sawing or sanding treated wood are covered by the standard.
- Where an employer has objective data demonstrating that a material containing chromium or a specific process, operation, or activity involving chromium cannot release dusts, fumes, or mists of chromium (VI) in concentrations of above 5 $\mu g/m^3$ in an eight-hour TWA under any expected conditions of use.

Q: What are the main industries affected?

A: The primary industries affected, according to OSHA, are stainless steel fabrication, heavy-duty coatings and paints, electroplating, and chrome-based pigment production.

Q: What are the main applications affected?

A: Welding (especially stainless steel), spraying heavy-duty coatings and paints, electroplating.

Q: When must I be in compliance?

A: Employers with 20 or more employees had to be in compliance by last November. Employers with 19 employees or fewer must be in compliance by May 30. Engineering controls, if they are determined feasible and/or necessary, must be in place by May 31, 2010. Until engineering controls are in place, respiratory protection must be used to help reduce exposure.

Q: How does this affect me?

A: Employers must reassess their respirator programs taking into consideration the lower exposure limit. More employers may have to provide respiratory protection to employees and assess the feasibility of engineering controls such as ventilation. If they have not already done so, employers in the affected industries should make an exposure determination to establish whether the new standard and its requirements apply and, if so, implement the necessary steps for compliance, including selection of proper respirators.

Q: How do I make an exposure determination?

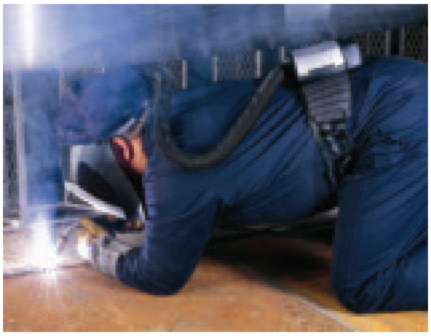
A: The standard permits exposure determinations to be done either through monitoring or by estimating exposures using any combination of air sampling, historical monitoring data, and objective data. If historical or objective data are used, they must reflect workplace conditions closely resembling the processes, types of materials, control methods, work practices, and environmental conditions in the customer's current operations.

Q: How do I monitor for Cr(VI)?

A: Monitoring is accomplished with a pump and filter — not a badge-type monitor. Refer to NIOSH Method ID-215. Consult an American Industrial Hygiene Association (AIHA) accredited laboratory for assistance in selection of the appropriate sampling and analytical method. To contact an AIHA-accredited laboratory or industrial hygienist to do the monitoring, go to *www.aiha.org* and select "consultants" or "laboratories."

Q: When are respirators required?

A: Respirators are required in the following situations when exposure levels exceed the PEL:



One situation that calls for the use of respirators is when employees are exposed above the PEL for fewer than 30 days per year and the employer has not elected to implement engineering and work practice controls.

- While engineering and work practice controls are being developed.
- During maintenance and repair activities for which engineering and work practice controls are not feasible.
- When all feasible engineering and work practice controls are implemented and are still not sufficient to reduce exposures to or below the PEL.
- When employees are exposed above the PEL for fewer than 30 days per year and the employer has not elected to implement engineering and work practice controls.
- Emergencies.

Q: Which respirator should I use?

A: Respirators should be chosen by the employer based on workplace conditions and contaminant levels.

- N95 filters may be used where no oil aerosols are present.
- R or P95 filters may be used where oil aerosols are present.
- Filtering-facepiece respirators, elastomeric half-facepiece respirators, and full-facepiece respirators, when qualitatively fit tested, may be used up to 10 × PEL with appropriate filters.
- Full-facepiece respirators may be used up to 50 × PEL when they are quantitatively fit tested and are equipped with appropriate filters.
- Loose-fitting facepieces may be used up to 25 × PEL.

Employers need to choose respirators based on workplace conditions and contaminant levels. Tight-fitting full facepieces, hoods, and helmets with supplied-air or powered air-purifying respirators such as is shown here may be used for up to 1000 times the PEL.

- Tight-fitting full facepieces, hoods, and helmets with supplied air or powered air-purifying respirators may be used up to 1000 × PEL.

Q: I have not had a respiratory protection program in the past. What information do I need to get started?

A: The standard requires the respiratory protection program, including respirator selection, to follow OSHA 1910.134 requirements.

3M provides resources and training materials such as the following:

- "Administrative Respiratory Protection Program" — basic program requirements. (Fax-On-Demand (800) 646-1655, enter document #2018)
- "3M Respirator Selection Guide" (*www.3M.com/OccSafety*)
- "On Line Fit Test Kit Training" (contact your 3M OHESD sales specialist)
- "Mail-in Medical Evaluation" (*www.respexam.com*)
- "Respiratory Protection eTraining" (*www.respexam.com*)
- "Select Software" and "Service Life Software" (*www.3M.com/OccSafety*)
- "3M Respirator Fitting Instructions" (*www.3M.com/OccSafety*) ♦


FABTECH
INTERNATIONAL
& AWS
WELDING SHOW
oto courtesy of Jason Bartholme, ©2006
CHICAGO 2007

College Program Grooms High Schoolers for Welding Careers

Through a special noncredit college program, high school students Ashley Kolarek and Molly Farrand have experienced the exciting fields of ironworking and welding

BY KRISTIN CAMPBELL

Fig. 1 — A — Ashley Kolarek (left) and Molly Farrand are sitting on I-beams and columns built into a structure. The setup simulates a real work site. They are attached to body harnesses and safety cables. B — Farrand practices gas metal arc welding on scraps of metal.

KRISTIN CAMPBELL (kcampbell@aws.org) *is assistant editor of the* Welding Journal.

Ambitious high school juniors Ashley Kolarek and Molly Farrand, both 16, are eager to learn and be successful in all they do. Currently, they are the only two females in the Ironworking and Industrial Welding program available through The High School Programs at Front Range Community College (FRCC) — Fig. 1A, B.

The two students attend the program at the FRCC Larimer Campus in Fort Collins, Colo. It is one of twelve different programs offered to juniors and seniors from public high schools in Larimer and Weld counties.

To get accepted, Kolarek and Farrand each had to fill out an application and be selected by their home high schools. They were each awarded a $2800 scholarship from the Poudre School District to attend the program.

Interest in the Field

Kolarek is originally from New York. Her mother Christine Nossoughi, a sculptor, used to take her to the foundry as a child.

"I would watch them pour the melted bronze into the sculpture molds and then weld together the pieces," Kolarek said. "I always had somewhat of an interest because to me it was so amazing to watch."

Kolarek moved to Fort Collins in 1999. She decided to pursue the Ironworking and Industrial Welding program because she thought welding would be a great skill to have and it would be a way to get more familiar with foundry work. At the time, her family had an 11-acre farm, so she thought knowing how to weld would be useful to help her fix items there.

On the other hand, Farrand is originally from Fort Collins. She has watched her father Greg Farrand, a large-animal veterinarian, weld items for his business, Northern Colorado Veterinary Services, and around the family's house, ever since she can remember.

"When I was little I loved just putting on a helmet and watching him work," Farrand said. "It looked like fun."

She wanted to get into the program because she thought welding was a skill that could come in handy later on in life.

Program Details

The Ironworking and Industrial Welding program started five years ago in response to a request from Rocky Turner, the president of LPR Construction Co. in Loveland, Colo. He came to The High School Programs with this idea because he was short on employees. Today, this company, along with many others, recruits students who have completed the program to work for them.

"We're preparing students to be able to put on their green hats, their hard hats, put on all their ironworking equipment, and be able to walk on the job with entry-level skills," Dr. Gary Cagle, executive director of The High School Scholarship Programs at FRCC, said.

The two-semester program takes place Monday through Friday from 8 to 10 a.m. (Mountain Time). Because it serves as an extension of the students' home high school experience, college credit is not received for finishing it.

Kolarek and Farrand started the program in August 2006, and when they complete it this May, they will receive a one-year completion certificate listing all the competencies they have learned.

Hands-On Experience

Students spend a majority of their class time at FRCC's 4600-sq-ft welding lab — Fig. 2. The lab underwent a $400,000 renovation, completed in September 2005; this included installing a new ventilation system and buying new machines. However, the lab's walls were not expanded, and the floor design did not change. "The state of Colorado does not allow you to do that," Cagle said.

The lab has twelve traditional shielded metal arc welding (SMAW) stations, twelve gas metal arc welding (GMAW) stations, and eight gas tungsten arc welding (GTAW) stations. Numerous brands of equipment are available for use here.

This particular program is limited to 20 students a year and can only be taken once. "We have a large waiting list," Cagle said. "We could probably double our enrollment if we had the space."

Ruben Vinton, Jason Walsh, and Keith Downey are the program's instructors. Kolarek and Farrand are glad for their guidance.

"They want to see all the students succeed in welding, so they do all that they can to make us excellent welders," Farrand said.

So far, Kolarek and Farrand have learned SMAW, GMAW, and GTAW. Primarily they weld on steel. They also have learned how to weld in different positions such as horizontal, uphill, and overhead.

"It's probably 95% hands on," Cagle said. Kolarek and Farrand really like this aspect of the program.

"I learn much better with getting out there in the shop and being able to go at my own pace learning from my own mistakes as well," Kolarek said.

In addition, they have learned to cut metal with an oxyacetylene torch using regular and scarfing tips, to use a track torch and cut with a plasma torch, and to use different machines to cut metal — Fig. 3.

Kolarek and Farrand have also gained an understanding for building steel structures. In fact, outside the welding lab there is a small-scale steel structure that is being expanded into a large steel structure.

In the classroom, they study modules on topics such as metallurgy.

They hope to become qualified soon and are working hard on perfecting their techniques. Kolarek and Farrand would both like to be qualified in overhead and uphill using SMAW.

Important Aspects

"We stress a work ethic here, which also makes us unique," Cagle said, referring to the Applied Work Ethics Program. This educates students in the importance of cultivating ten key traits, such as attendance, respect, and teamwork. They even get a grade for this course.

Safety is another area that is stressed. Students must wear the proper welding attire; understand fall-protection setup and inspection of fall-protection devices/systems; learn about the Occupational Safety and Heath Administration regulations; and participate in the CSU Challenge Course to develop coordination and physical stamina.

Thus far, 97 males and 3 females have completed this program. Based on follow-up surveys, when former students first came into this program, only about 30% wanted to go on to college or pursue additional postsecondary education. After completing the program, about 65% go on to earn a two- or four-year degree or join the military.

About one-third of the class immediately goes to work upon graduation. "I would say our success rate is about four out of every 20 make it a career pathway," Cagle said.

More information about The High School Programs can be obtained through FRCC's Web site at *www.frontrange.edu*.

Being a Female Welder

Kolarek and Farrand are not intimidated being the only two females in the program. They both think the males have the potential to become great welders.

"I look at it as competition for me to do my best and give it my all," Kolarek said. She mentioned the males give her and Farrand tips on how to weld better beads and offer encouragement.

"With these boys having so much talent in welding, it makes me strive to do my best," Farrand added. She said a lot of the males are helpful and supportive.

"I like being a woman welder," Kolarek said. "To me, it's no different except for the fact that I am barely 5 feet tall and am tiny for my age. The only challenge I have is being so small so I can't carry those huge tanks of gas or oxygen, but overall I am very strong for my size."

Farrand enjoys it, too. "Being a woman welder is not very different from anything else I do," she said. "I can't really think of any challenges that I have encountered. It is really easy being one of the only girls."

Fig. 2 — Ironworking student Andy Keirns from Loveland High School in Loveland, Colo., is performing a shielded metal arc qualification weld on an overhead V-groove with a backing plate.

Busy Schedules

After finishing the program in the morning, Kolarek goes to Rocky Mountain High School in Fort Collins

Fig. 3 — Farrand (left) and Kolarek are using the oxyacetylene cutting process to cut a 45-deg bevel on ⅜-in. plate. These plates are set up with a backing plate to practice welding on either uphill or overhead position.

and takes Spanish, English literature, and humanities.

Kolarek now lives on a three-acre farm, where she enjoys taking care of the family's pets, including four South African Boerboel dogs, two ponies, and three horses. In her free time she hangs out with friends, draws, and paints.

Farrand attends Fossil Ridge High School, also located in Fort Collins, in the afternoon. There she takes anatomy and physiology, math, U.S. literature, and U.S. history.

She loves spending time with her family, including her sister and two little cousins, working out, hanging out with friends, watching all kinds of sports, working a part-time job at Espresso Di Cincotta, a coffee shop, and helping her father work on animals.

Applying Welding to Real Life

Recently, Kolarek welded a steel plate using SMAW to cover a drainage hole in the warehouse of Poudre Pet & Feed Supply, where she holds a part-time job, that the forklift kept getting its wheel stuck in.

Her employer appreciates this. "It's been great ever since," Kolarek said. "We haven't had any problems because of it."

Farrand has helped her father weld items for his veterinary business. He has one GMAW and two SMAW machines. She has used GMAW to fix corrals, as well as repair chutes for the cattle and stalls for horses.

"He gets really excited when I can go out there and actually help him," she said.

Future Aspirations

For her senior year of high school, Kolarek would like to get into The High School Programs Industrial and Design Technology program.

For college, Kolarek would like to attend The Cooper Union for the Advancement of Science and Art in New York, N.Y. She is not really sure what kind of art-related career she wants to pursue, but she definitely wants a degree in business.

Afterward, she would like to come back to Fort Collins and start her own business to sell her art.

"I'd like to get into metal art," she said and work with aluminum, stainless steel, and bronze. "I think that would be really neat to do, now that I know how to weld."

She may even start working with a foundry. "Welding is a great skill and will come in handy throughout my entire life," Kolarek said.

Farrand wants to be in The High School Programs Med-Prep Certified Nurse Aide program her senior year of high school.

"In the near future, I hope to go to college and study nursing, specifically labor and delivery," she said. "I also am going to join the United States Air Force."

Farrand will not forget what she has learned in welding. "When I get older and can afford welding equipment, I hope to be able to make things for fun and maybe sell them somewhere," she said.

Farrand would like to use welding on the ranch she plans to have someday in Walden, Colo. "I am planning on using welding all through my life," she said. ♦

Antique Torch Comes Back Home

BY HOWARD WOODWARD

Elmer Smith started a design and manufacturing operation in his Minneapolis, Minn., garage in 1916. His fledgling business, named Smith Inventions, produced a line of oxyacetylene welding and cutting equipment. But welding torches were his primary product — Fig. 1.

That same year, Allen Verch was born in a small town in the Ottawa Valley in Canada. As an inquisitive nine-year-old lad, he was awestruck when he saw an electric light bulb for the first time, and two weeks later he tried to wire a light bulb for his mother with disastrous results. Verch said, "I got up on the chair and started connecting wires. All of a sudden the sparks flew, the light went out and the shock knocked me to the ground." Completely undeterred by this mishap, a few weeks later Verch got back on the chair and succeeded in lighting his family's home with electricity.

Fascinated with electricity, it became a part of his career as a welder and a salesman for Carter Brothers.

"It was pretty tough to get a job when I started looking in 1935," Verch recalled, "but my high school principal recommended me to Carter Brothers and I took to welding like a duck to water. We used bare stick electrodes, about fourteen inches long, and they stuck out about four inches from the holder. You would burn a couple inches off before you'd have to stop and adjust it."

Verch started his welding career working for 15 cents/hour, with a raise of 2½ cents every six months. Despite the low pay, he managed to save enough money to become one of the first Canadians to join the American Welding Society. He reveled when his first copy of the *Welding Journal* was delivered to his mailbox.

When Carter Brothers sold their distributorship to Canadian Oxygen in the early 1960s, they left behind a brand-new, albeit 46-year-old, Elmer Smith-built oxyacetylene torch. The new owners were about to throw the relic into the trash but Verch rescued it. He stored the torch on a shelf in his home where it remained, untouched, for 45 years.

During his many years at Canadian Oxygen until his retirement in 1981, Verch learned and performed most types of welding, brazing, and cutting. "I used to dream," he said, "of a machine that would keep feeding the wire so that we wouldn't have to stop and adjust the stick every few seconds."

Fig. 1 — Elmer Smith is shown, circa 1916, handcrafting an oxyacetylene torch in his Minneapolis, Minn., garage workshop.

Meanwhile, it was during the late 1950s that Elmer Smith made the decision to expand his business into markets outside the welding industry to include manufacturing high-pressure regulators. He changed the name of his company to TESCOM Corporation — an acronym for The Elmer Smith Company of Minnesota. Eventually, TESCOM evolved into four antonymous divisions, one of which was named Smith Equipment Manufacturing Co. Smith Equipment continued to grow, and in 1981, the company relocated its facilities to Watertown, S.Dak., where it currently has 165 employees.

Last year, Verch rediscovered the old torch, just gathering dust on the shelf. He decided to pack it carefully and send it to the Smith Equipment Manufacturing Co.

The precious package was received by Customer Service Manager Karen Hemiller and General Manager Ross Buckley — Fig. 2.

Fig. 2 — Holding the torch, still in mint condition after 90 years, are Smith Equipment Customer Service Manager Karen Hemiller and Ross Buckley, general manager.

Buckley said, "We were just floored when that package arrived. Inside was an antique torch in pristine condition with a note from Verch reading, 'This relic has finally returned home — I wish I knew more of its history. It is probably older than I am, and I'm 90 years old. Give it a good home.'"

Buckley said, "We had a hard time finding any record of this torch in our archives. That the torch has remained in such good condition this long, and that Mr. Verch would . . . send it to us, is just amazing. We'll be sure to give this torch as good of a home as Mr. Verch has for the last 45 years. The folks at Smith Equipment are grateful to Allen Verch for his token of kindness."♦

Western Area Career and Technology Center Employs Work-Based Learning Techniques

BY HOWARD M. WOODWARD

The Western Area Career and Technology Center (WACTC) is located in Canonsburg, Pa., about 25 miles south of Pittsburgh. The Center was created in 1967 when nine sending school districts were united. The districts include Avella, Burgettstown, Canon McMillan, Chartiers-Houston, Fort Cherry, McGuffey, Peters Township, Trinity, and Washington.

Overview of the Center's Welding Education Program

Tony Reis (Fig. 1) is the primary welding instructor, and Mario Colaizzo teaches the evening classes — Fig. 1. Reis, who is advisor for the Center's AWS Student Chapter, said his students are prepared for working with all of the basic welding and cutting processes — Fig. 2. Tenth- through twelfth-grade students learn the proper use of measuring instruments, hand tools, and portable grinders. They learn the basics of metallurgy, blueprint reading, electrical principles, layout and design, fabrication, and quality assurance methods. They also do practical math problems, prepare materials lists, and estimate costs. The bottom line is they learn all of the tools necessary to succeed in the real world of manufacturing.

Reis's successful students are given the opportunity to qualify to the requirements of AWS D1.1, *Structural Welding Code — Steel,* and AWS D1.5, *Bridge Welding Code.*

The numerous postsecondary training options include the Community College of Allegheny County, Hobart Institute of Welding Technology, The Lincoln Electric Co., Pennsylvania College of Technology, Triangle Tech, Inc., and Welder Trainer and Testing Institute, and the Center has articulation agreements with Millwright Union 2235, Community College of Allegheny County — Welding Technology, and Westmoreland County Community College — Welding.

Reis said, "I have been the welding instructor at WACTC for 18 years. During this time, I have seen the welding program grow from 15 students to well over 40 at times. The welding program is a three-year course incorporating 10th-, 11th-, and 12th-grade students. The students learn oxyfuel, shielded metal arc welding, gas metal arc welding, gas tungsten arc welding, flux core arc welding, plasma arc cutting, carbon arc, brazing, manual and automatic machine cutting, blueprint reading, and basic fabrication. On average, 90 to 100% of the graduating class students have jobs waiting for them upon graduation.

"Currently, the companies that employ my students are DBT, Multifab & Machine Inc., Heslin Steel, Barr Canon, Thermo-Electric Co., and C & J Metals, just to name a few."

The Welding Facilities

Reis's welding shop includes the traditional training equipment, plus a variety of specialized items, including a square wave gas tungsten arc welding machine, inverter technology for shielded metal arc and gas metal arc welding, an ironworking shear, and press and punch. The facility offers 17 different technical courses including Cooperative Education and Youth Apprenticeships. David Adamson of the cooperative education department said, "We can assist students in gaining employment and applying their skills to the real world of work. This is done with two work-based learning programs that are combined with the career and technical class areas. They are cooperative education and registered apprenticeships. These programs place students at work sites, filling both a need for the employer and student-learner. Western Area works hard to maintain and strengthen ties with business and industry through these programs."

Fig. 1 — Evening welding instructor Mario Colaizzo (left) and Tony Reis, daytime welding instructor, are shown in the WACTC workshop.

Dr. Joseph P. Iannetti, director of vocational education, said, "Manufacturing is still a viable industry and a major source of employment in our region. There just aren't enough welders being trained to meet industry needs. Tony Reis's welding

Fig. 2 — Shown are some of Tony Reis's welding students who also participate in the Western Area Career and Technology Center's Student Chapter.

students are succeeding in the workplace and his program is helping manufacturers by addressing the shortage.

The HSTW Initiative

"As the workplace becomes more competitive," Iannetti noted, "our completing students must have a variety of higher-order academic, technical, and workplace skills and the willingness to use them if they are to succeed. That is why," he said, "we have joined the High Schools That Work initiative."

High Schools That Work (HSTW) is a national effort to improve the way high school students are prepared for work and further education. It provides a framework of goals, key practices, and key conditions for accelerating learning and setting higher standards to meet the criteria for comprehensive school reform. The mission of schools in the HSTW network is to prepare high school students for both postsecondary education and a career by having students complete a solid academic core and either an academic, a career/technical, or a blended concentration. Pennsylvania has been affiliated with the HSTW initiative since 1991.

The Western Area CTC joined the initiative in 2002. The three major goals of HSTW are 1) to raise the mathematics, science, communication, problem-solving, and technical achievement of more students to the national average and above; 2) blend the essential content of traditional college-prep studies with quality career/technical studies; and 3) advance state and local policies and leadership initiatives necessary to sustain a continuous school-improvement effort for both academic and career/technical studies.

How WACTC Achieves These Goals

To do this, WACTC expects students to complete a challenging curriculum that focuses on raising academic and technical achievements and meeting the HSTW performance goals in reading, math, and science. To complete the recommended curriculum, each student takes at least four English courses geared to the standards of college-prep English. At least three math courses, including two courses with the content and performance standards for college-prep: algebra I and II, geometry, and trigonometry. At least three science courses including two courses with the content and performance standards of college-prep biology, chemistry, and physics or applied physics. At least three college-prep-level social studies courses, four courses in a planned career/technical concentration or additional course work in either math and science, the humanities, or a blended concentration. At least two courses in related academic and career/technical fields, including at least one-half credit in a basic computer course covering word processing, database entry presentation software, and use of the Internet and e-mail.

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Contact: Anthony Reis, areis@wactc.net; (724) 746-2890, ext. 151

Iannetti explained, "This data-driven program aimed at improving student achievement will enable us to identify our weaknesses while we focus our efforts toward those areas that require improvement. Already, we have worked to improve our integration and reinforcement of academic skill and the acquisition of new industry-recognized certifications for our technical students. We have opened the enrollment of our academic courses and improved our offerings. To serve a variety of student needs, we now offer online academic course work through the University of Nebraska."

The Tech Prep Program

The Center also participates in the Pennsylvania state-approved Tech Prep program. Tech Prep is a career and technical education program of study that consists of at least two years of secondary education, includes rigorous academic and technical components, and leads to admission into a two-year postsecondary certificate, associate degree, or registered apprenticeship with the intent of completing all requirements of the program consistent with the student's career objective.

Instructional support services are provided based on each student's individual needs to ensure his/her success. These services include assistance in math, reading, writing, technical skills, job seeking and keeping skills, communications, and interpersonal skills, and testing. Student counseling services include individual and group counseling, coordinating and consulting with students, parents/guardians, and assisting students in making decisions about education and career plans.

Additional Training Experiences

Student organizations are an integral part of the educational program at WACTC. These co-curricular experiences provide students with the opportunities to develop leadership skills and to participate in community service activities.

Students are also able to compete locally, regionally, statewide, and nationally in skills and leadership competitions in their occupational specialty. Students may participate in the following organizations: American Welding Society, Interact Community Service Club, National Technical Honor Society, SkillsUSA, and Family, Career, and Community Leaders of America.

Postgraduating Services

Based on the student's career goals, WACTC provides job placement services to meet his/her individual needs and interests. Placement rates for the school's graduates have been excellent and have historically exceeded 90% for those students who desire and actively pursue employment or college placement.

Adult Education Opportunities

Adult students are accepted into daytime programs as space permits. Opportunities exist for adult students to upgrade skills in their current positions, refresh skills for employment, or enter a new field. Adult students are offered individualized programs tailored to their needs and flexible scheduling. On-campus child care and placement assistance are available. Customized industry employee training programs are also offered. The tuition is $7.25/instructional hour. Adults interested in entering a training program should visit *www.wactc.net or* call (724) 746-2890 for complete information. ♦

Equations for Estimating the Direct Costs of Arc Welding

The table below presents suggested formulas for estimating arc welding costs. Cost factors of weldments for a proposed project or product should be researched and verified to assure actual costs are known. Be aware, for any formula, the accuracy of the input data influences the estimate.

Overhead could include expenses such as employee benefits, rent, depreciation of facilities and equipment, taxes, utilities, maintenance costs, and supporting services. Usually, management has determined a fixed factor for this to be incorporated into an estimate for manufacturing costs.

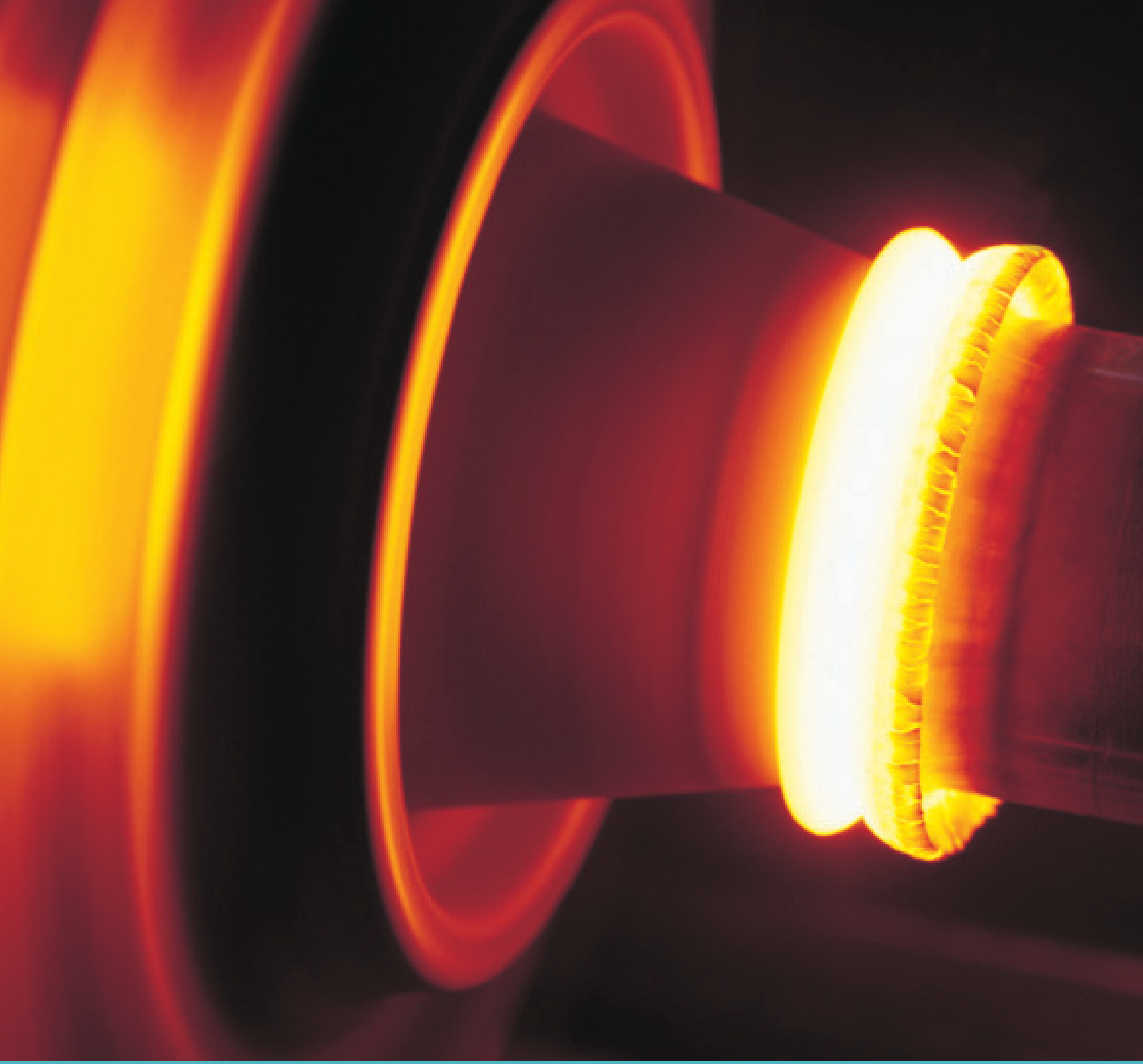
Suggested Equations to Estimate the Direct Costs of Arc Welding

Cost	Equation
Gas cost per unit weight of deposited metal, \$ per lb (\$ per kg)	$\text{Cost}_{\text{Gas}} = G \times F / D$
Power cost per unit weight of deposited metal, \$ per lb (\$ per kg)	$\text{Cost}_{\text{Power}} = P \times V \times A / 1000 \times D$
Cost of materials per unit weight of deposited metal, \$ per lb (\$ per kg)	$\text{Cost}_{\text{Materials}} = M / E$
Labor rate per unit weight of deposited metal, \$ per lb (\$ per kg)	$\text{Cost}_{\text{Labor}} = L \times K / D \times 100$
Overhead cost per unit weight of deposited metal, \$ per lb (\$ per kg)	$\text{Cost}_{\text{Overhead}} = O / D \times (k / 100)$
Total cost of weld per unit of deposited metal, \$ per lb (\$ per kg)	$\text{Cost}_{\text{Weld per unit length of deposited metal}} =$ Sum of Equations 1 through 5
Total cost of weld per unit length of joint, \$ per ft (\$ per m)	$\text{Cost}_{\text{Weld per unit length of joint}} = \text{Cost}_{\text{Weld per unit length of deposited metal}} \times S$
Total cost of weld, \$	$\text{Total cost}_{\text{Weld}} = \text{Cost}_{\text{Weld per unit length of deposited metal}} \times W$, or $7 \times N$
Total welding time, hours	$T = W / (D \times K)$
Total weight of weld metal, lb (kg)	$W = S \times N \times C$
Welding time per unit length for a specific joint	$T_{\text{Joint}} = W + (D \times K)$
Total consumables required	Electrode or wire (lb [kg]) = $W + E$ SAW flux (lb [kg]) = $1.5\ W / E$ Gas (ft^3[m^3]) = $F \times T / E$

Key:
A = amperes
C = specific gravity of metal, lb/in.^{3} (kg/m^3)
D = deposition rate, lb/h (kg/h)
F = flow rate, ft^3/h (m^3/h)
G = unit cost of gas or flux by volume, \$/ft^3 (\$/mm^3)
E = deposition efficiency, %
K = operator factor, %
L = labor rate, \$/h
M = cost of materials, \$/lb (\$/kg)
N = length of specified weld, in. (mm)
O = overhead rate, \$/h
P = power cost, \$/kWh
W = total weight of weld metal lb/ft (kg/m)
(steel weighs 0.283 lb/in.^{3} (7.8×10^{-6} kg/mm^3))
S = cross-sectional area of weld joint, in.^{2} (mm^2)
T = total welding time, h
V = volts

Average operating factors: SMAW 30%; GMAW 50%; FCAW 45%
Average deposition efficiencies: SMAW 65%; GMAW 95%; FCAW 85%

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



Arc Cutting and Gouging

Fumes and Gases

Arc cutting and gouging produce fumes and gases that may be hazardous to your health. The fume and gas byproducts usually consist of the oxides of the metal being cut, ozone, and oxides of nitrogen, including nitrogen dioxide. Phosgene gas could be present as a result of the thermal or ultraviolet decomposition of chlorinated hydrocarbon cleaning agents.

The metal fumes generated by the arc cutting processes can be controlled by natural ventilation, local exhaust ventilation, and respiratory protective equipment as described in *Safe Practices in Welding, Cutting, and Allied Practices*, ANSI Z49.1. The concentration of ozone usually increases with an increase in current and when cutting or gouging aluminum. Tests have shown high concentrations of nitrogen dioxide close to the arc. Cutters should keep their heads out of the fumes whenever possible. With some applications this might not be possible. In such instances fumes must be removed at the source by using an exhaust system or respiratory equipment should be used.

Recommended Eye Protection for Plasma Arc Cutting and Air Carbon Arc Cutting

	Minimum Shade	Suggested Shade
Plasma Arc Cutting Current (A)		
Less than 300	8	9
300 to 400	9	12
400 to 800	10	14
Air Carbon Arc Cutting Current (A)		
Less than 500	10	12
500 to 1000	11	14

Protective Apparel

The arc emits intense ultraviolet and infrared radiation that is potentially harmful to the eyes and skin. Operators should wear adequate eye and face protection. A standard welding helmet fitted with filter glass (see table) appropriate to the current used is sufficient. Heavy gloves should be worn as gouging radiates a significant amount of heat. Exposed areas of skin should be covered, and heavy, flame-retardant clothing should be worn to protect against molten metal. Leather and wool clothing that is dark is recommended to reduce reflection.

Fire Hazards

Fire prevention measures are necessary for all cutting and gouging operations. Cutting and gouging processes produce significant heat, metal sparks, and hot spatter, all of which create a fire hazard. Personnel should wear fire-retardant clothing and fire extinguishers should be readily available near the cutting or gouging operation.

Air carbon arc cutting or gouging require special fire prevention precautions because of the nature of the removal process. All combustibles within 35 ft (11 m) of the work area should be removed. Protection such as metal screens should be placed in line of the hot metal ejected by the compressed air stream if ample room for dissipation is not available. Additional information on this topic is presented in *Fire Prevention during Welding, Cutting, and Other Hot Work*, NFPA 51B.

Electrical Hazards

Electric shock can be fatal. Safety precautions for all cutting and gouging processes include the following:

1) All electrical circuits must be kept dry, as moisture can provide an unexpected path for current flow. Equipment cabinets that contain water, as well as gas lines and electrical circuits, should be checked periodically for leaks.

2) Equipment must be properly grounded and connected as recommended by the manufacturer.

3) All electrical connections should be kept mechanically tight, as poor electrical connections can generate heat and start fires.

4) High-voltage cable must be used, and cables and wires must be kept in good repair. The manufacturer's instructions should be consulted for the proper cable and wire sizes.

5) Personnel must not touch live circuits. Equipment panels must be kept in place, and access doors must be kept closed.

6) Only trained personnel should be permitted to operate or maintain the equipment.

The risk of electrical shock is probably the greatest when replacing used torch parts. Operators must make sure that the primary power to the power sources and the power to the control circuitry is turned off when replacing torch parts. Operators and maintenance personnel should be aware that plasma arc cutting equipment presents a greater hazard than conventional welding equipment because it uses higher voltages. The voltages used in plasma arc cutting equipment range from 150 to 400 V DC.

Emergency first aid should be readily available. Prompt, trained emergency response may reduce the extent of injury in the event of electrical shock. Additional information can be found in the *National Electrical Safety Code*, ANSI C2. ♦

Excerpted from *Welding Handbook*, Vol. 2, Welding Processes, Part 1.

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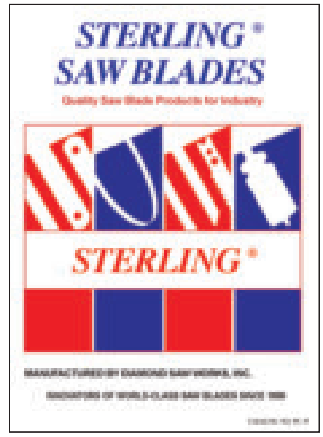

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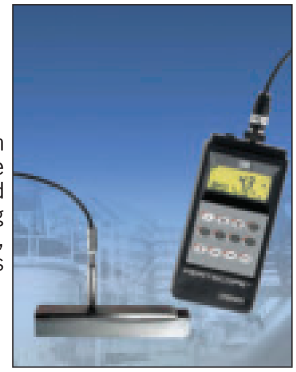

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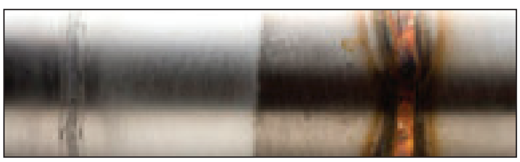

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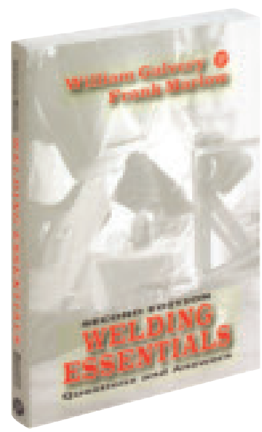

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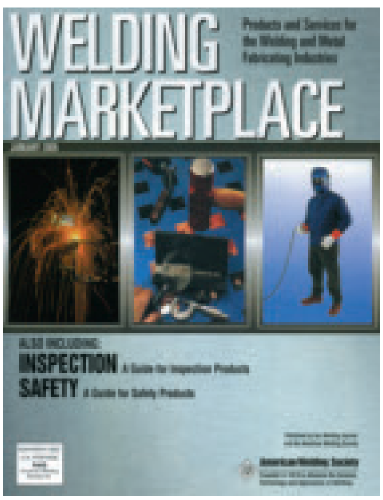

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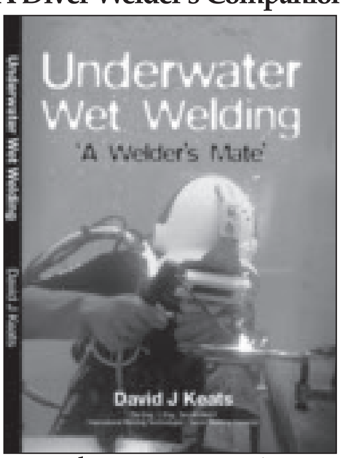

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SUPPLEMENT TO THE *WELDING JOURNAL,* APRIL 2007
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Effects of Sheet Surface Conditions on Electrode Life in Resistance Welding Aluminum

The surface of aluminum sheet was cleaned with three different methods, then each surface was tested as to its effect on electrode life

BY Z. LI, C. HAO, J. ZHANG, AND H. ZHANG

ABSTRACT. The relatively short electrode life in welding aluminum sheets has been a bottleneck for large-scale production of aluminum vehicles. The rapid deterioration of electrodes during resistance welding aluminum is the collective consequence of high pressure, high temperature, and a rapid metallurgical (alloying) process. This study systematically investigated the effects of sheet surface conditions on electrode life. Using 2-mm 5A02 aluminum sheets, a schedule conducive to electrode life was used for testing the effects of sheet surface conditions. A three-phase, direct-current pedestal-type resistance spot welding machine was used, and the electrodes lasted for about 200 welds for sheets with untreated or original surfaces, up to 1700 welds when they were electric-arc cleaned, and more than 2000 welds if the sheets were degreased or chemically cleaned. This investigation also shows that the appearance of an electrode after a small number of welds provides useful information on the electrode life using the same welding schedule.

Introduction

With the advantages of high specific strength, low density, high corrosion resistance, and low-energy formability, aluminum has been widely used in almost every aspect of daily life. The constantly increasing demands in weight reduction for fuel economy, and emission control have led to a wider application of aluminum sheets in automobile manufacture. Many automakers have attempted to replace steels with aluminum. For instance, Audi has successfully produced all-aluminum Models A2 and A8 cars.

Resistance spot welding has been the major joining process in automotive body construction because of its low cost, robustness, and many other advantages. However, the experience obtained in welding steels is not readily transferable to welding aluminum, mainly due to the significant physical and metallurgical differences in both the bulk material and surfaces. Because aluminum has higher electrical and thermal conductivities than steels, high electric current and short weld time have to be used in welding aluminum alloys. For example, a current of about 10,000 A may be needed to weld a 2-mm to 2-mm steel sheet combination, but more than 40,000 A are usually required to weld similar combinations of aluminum sheets (Ref. 1). Such a high current produces high temperature in the weldment and at the interfaces between aluminum sheets and copper electrodes. This greatly affects the electrode life considering the metallurgical reaction between aluminum and copper. Aluminum has a high chemical affinity for copper to form a brittle alloy (bronze) with lower electrical and thermal conductivities than copper. The oxide layer, which is inherent to aluminum sheets, also plays an important role. An Al_2O_3 layer on the surface of an aluminum sheet at the as-fabricated state is usually not uniform and may break under an electrode force during welding. As a ceramic, Al_2O_3 is highly insulating with a high melting temperature. A nonuniform or broken Al_2O_3 layer on a sheet surface results in uneven distribution of electric current, with very high electric current density at low resistance locations, and produces significantly localized heating or even melting on the surface (Refs. 2, 3). The electrode face deteriorates rapidly due to alloying and material depletion under high pressure (electrode force) and high temperature. In a continuous welding process, a repeated and accelerated (due to accumulative alloying and material depletion) deterioration of the electrode surfaces makes electrode life so short that such electrodes and sheets cannot directly be used in automated, large-volume automotive production.

Controlling aluminum sheet surface conditions is the key to increasing electrode life as it determines the heating of the interface between a copper electrode and an aluminum sheet. A surface without the Al_2O_3 layer is preferred concerning electrode life. Or, if that is difficult to achieve, a thin, uniform layer can be tolerated as it will result in a uniform heating. According to the German Standard DVS 2929 (Ref. 4), a stable welding process with uniform weld nuggets can be achieved if the sheet-sheet contact resistance is controlled between 20 and 50 μΩ. Such contact resistance can only be achieved if the sheet surface is properly

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KEYWORDS

Aluminum
Resistance Weld
Electrode Life
Surface Condition

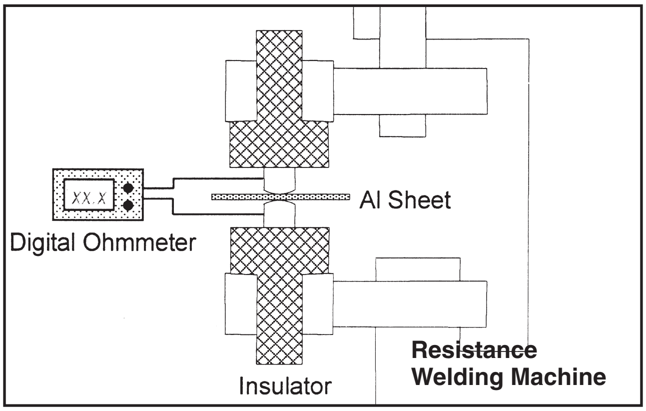

Fig. 1 — Setup for contact resistance measurement.

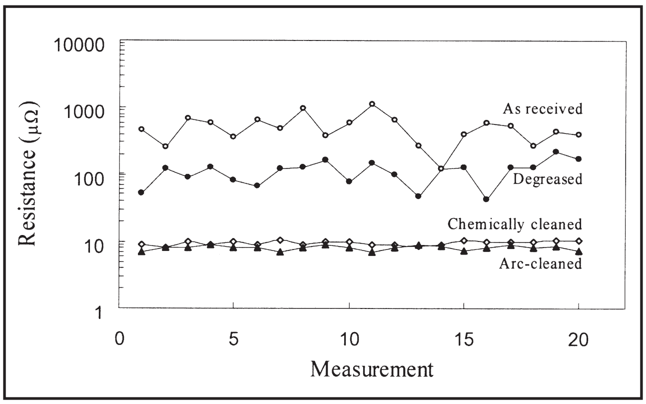

Fig. 3 — Resistance measurement of various surface conditions.

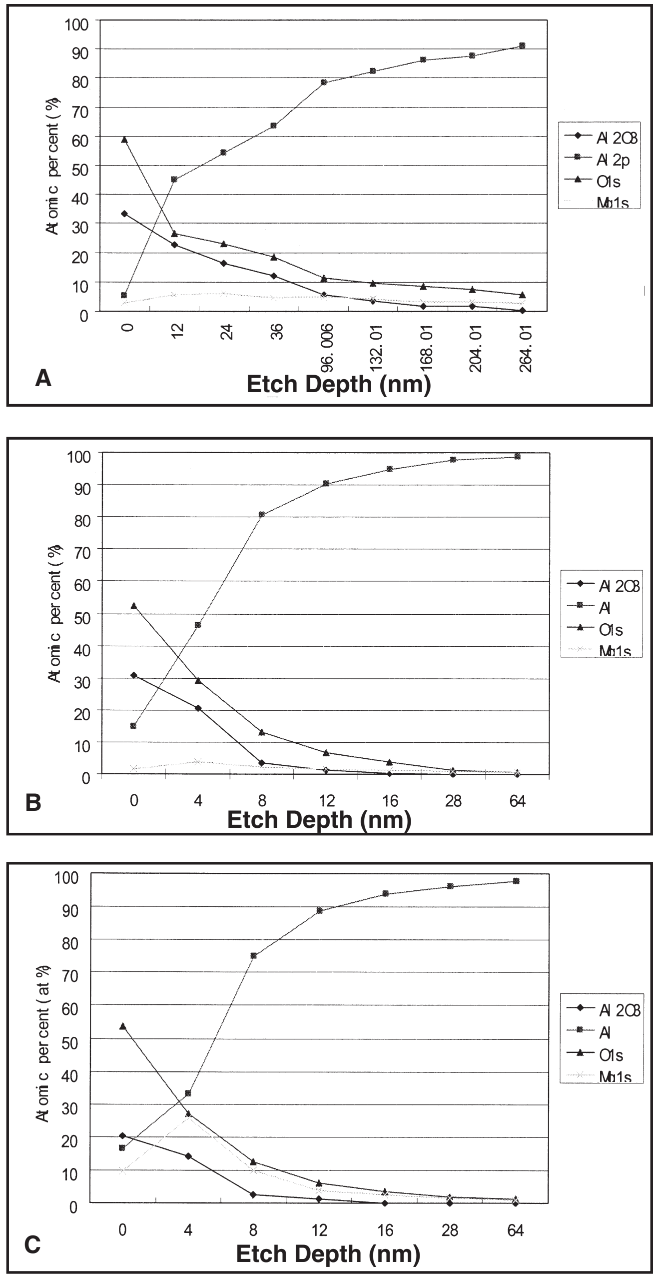

Fig. 2 — Profiles of atomic-percent of various elements in the surface layers after cleaning. A — Degreasing; B — chemical cleaning; C — electric-arc cleaning.

Table 1 — Chemical Composition of 5A02 Aluminum Alloy (wt-%)

Si	Fe	Cu	Mn	Mg	Ti	Al
0.40	0.40	0.10	0.25	2.5	0.15	balance

treated. An early representative work performed by Patrick et al. (Ref. 3) has revealed that different outer and inner surfaces (sheet-electrode and sheet-sheet interfaces) are needed for optimal welding. It is reported that when the inner surface is conversion coated (using a chromium phosphate to achieve uniform resistance and chemical stability) and the outer is arc cleaned, an electrode life of more than 7000 welds can be achieved. This research highlighted the importance of surface conditions in affecting electrode life, although such conditions are difficult to achieve in production. Differential surfaces were also proposed and investigated by Leone and Altshuller (Ref. 5). A parabolic relationship between the number of welds and differential oxide thickness was established, and a differential of about 400 Å in oxide thickness produced the highest number of welds.

Thornton and Newton's experimental study revealed that an electrode life of up to 1000 welds can be achieved if the sheets are properly degreased or chemically cleaned when welding a 2-mm sheet (Ref. 6). A similar electrode life was obtained using aluminum sheets covered by a specially designed thin film (Ref. 7). An electrode life of more than 2000 welds without dressing has been the target for many industrial practitioners.

The electrode degradation was characterized in four steps prior to eventual failure: aluminum pickup, electrode alloying with aluminum, electrode tip face pitting, and cavitation (Ref. 8). In that work, detailed investigation of the metallurgical interactions between the copper electrode and aluminum alloy sheets was carried out with a focus on electrode pitting in welding aluminum sheets. Pitting can be controlled, and electrode life extended, if aluminum pickup and alloying are limited.

The objective of this work is to understand how electrode deterioration is affected by aluminum sheet surface conditions, and therefore, to determine electrode life for welding aluminum sheets.

Experiment

The material selected for this study was 2-mm 5A02 aluminum alloy sheets. 5A02 is nonheat treatable with a composition similar to AA5754. The as-received sheets were in H1 temper condition, with the chemical composition listed in Table 1. Commercially available, dome-shaped Cu-Cr-Zr (Cr: 0.25~0.65%; Zr: 0.08~0.20%; Cu: balance) electrodes of face radius of 100 mm, and 20 mm in diameter were used for contact resistance measurement and for welding. The electrodes had a hardness of HRB = 75, electrical conductivity ≥ 45 MS/m, and a heat treatment of 950°C for 2 h and 500°C for 1 h. The electrodes were (room temperature) water-cooled during testing. A 300 kVA, three-phase DC pedestal welding machine was chosen for this study. A Hobart Cyber-Wave 300S arc welding machine was used for electric arc surface cleaning. The sheet surface contact resistance was measured using a setup as shown in Fig. 1 with a digital micro ohmmeter.

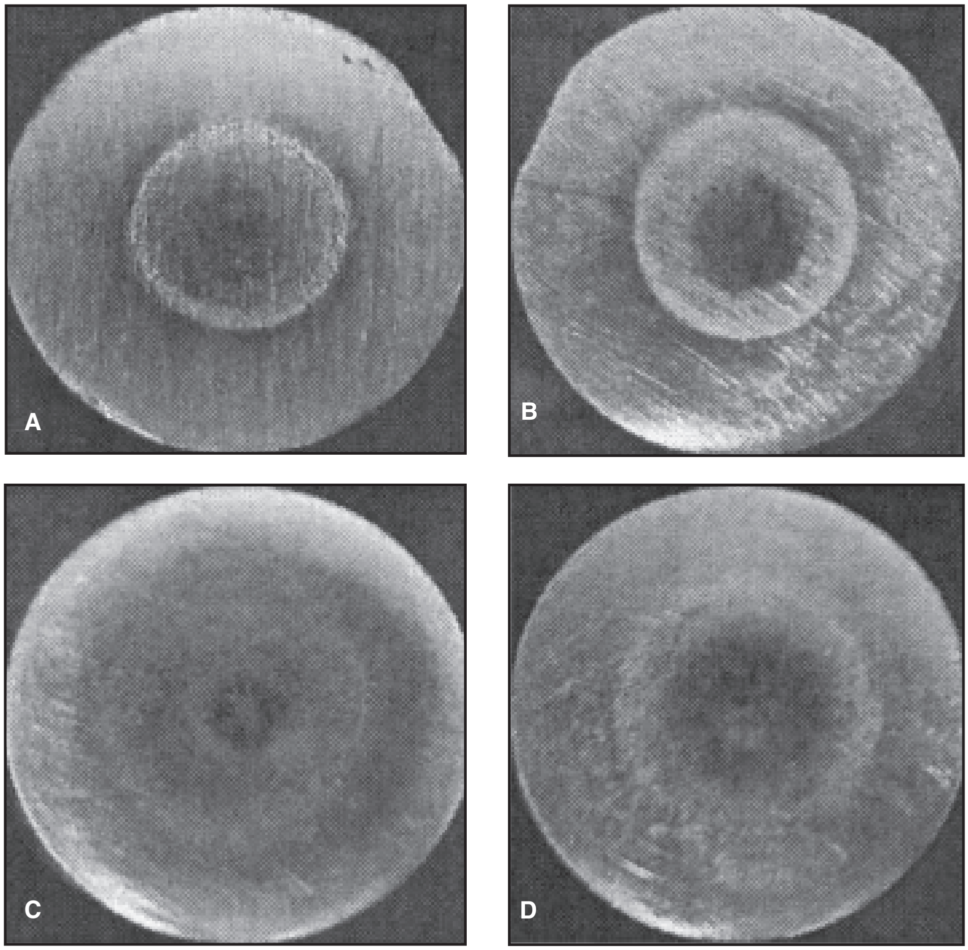

Fig. 4 — Electrode surfaces after making 60 welds on sheets of different surface conditions. A — Chemically cleaned; B — degreased; C — electric-arc cleaned; D — untreated.

Surface Cleaning

Three types of surface cleaning methods were employed to create sheets with different surface conditions. They were degreasing, chemical cleaning, and electric-arc cleaning. Untreated sheet surface condition was considered in the experiment to provide a baseline comparison.

1) *Degreasing*. Aluminum sheets were soaked in a water solution of a metal degreasing detergent for five minutes, wiped using cotton, and then water-rinsed three times. The sheets were air-dried afterward.

2) *Chemical cleaning.* Sheets were cleaned first following the degreasing procedure as described in 1. Then they were soaked in a water solution of 5%NaOH at 60°C for four minutes. After being water-rinsed for three times, they were soaked in 30%HNO_3 for two minutes at room temperature, then water rinsed three times before being air dried.

3) *Electric-arc cleaning.* The cleaning was performed manually using a Hobart Cyber-Wave 300S arc welding machine with a tungsten electrode. An electrical current of 30 A and 26 V was applied for 10 s to create a cleaned surface of about 15 mm in diameter. Two different types of cleaning were made for contact resistance measurement and for electrode life tests. For contact resistance measurement, the single sheet used was cleaned, using the arc welding machine on both sides, which were to contact with the electrodes. A circular area of about 15 mm in diameter was cleaned on each side. For the sheets used for welding, only the side of a sheet that was to be in contact with the electrode during welding was cleaned. The sheet-sheet interface was not cleaned as it was found in a preliminary experiment that the welding quality was not consistent when both sides of a sheet were cleaned. Care was taken during cleaning to avoid melting the Al sheet surface.

Surfaces cleaned by these three methods were then characterized using X-ray photoelectron spectroscopy (XPS, ESCALAB 250 by Thermo Scientific), similar to the analysis conducted by Leone and Altshuller (Ref. 5). Using a specimen of $10 \times 10 \times 2$ mm in size, the probe detected the atomic count of each element, and therefore, revealed the composition of the surface. In addition, the probe depleted the surface layer at an etching speed of 0.2 nm/s, providing the distribution of elements through the thickness of a surface layer.

Contact Resistance Measurement.

In Al welding, it is widely believed that an interface generates more heat due to the contact resistance, which is significantly higher than that of the bulk Al. Therefore, the deterioration of electrodes due to alloying between Cu and Al is largely affected by the contact resistance at the electrode-sheet interfaces. The experimental setup, using a resistance spot welding machine, for contact resistance measurement is shown in Fig. 1. The measurement followed German Standard DVS 2929 (Ref. 4) using an electrode force of 7.5 kN. The same electrodes were used for measurement and for welding. The measurement order was randomized with 20 measure-

Table 2 — Welding Schedules for Rapid Electrode Life Determination

Surface Condition	Untreated	Degreased	Electric-arc Cleaned	Chemically Cleaned
Welding Time and Current	4 cycl. 27.21 kA	4 cycl. 29.1 kA	6 cycl. 34.3 kA	5 cycl. 32.7 kA

Note:Electrode force was 9 kN for all welding tests.

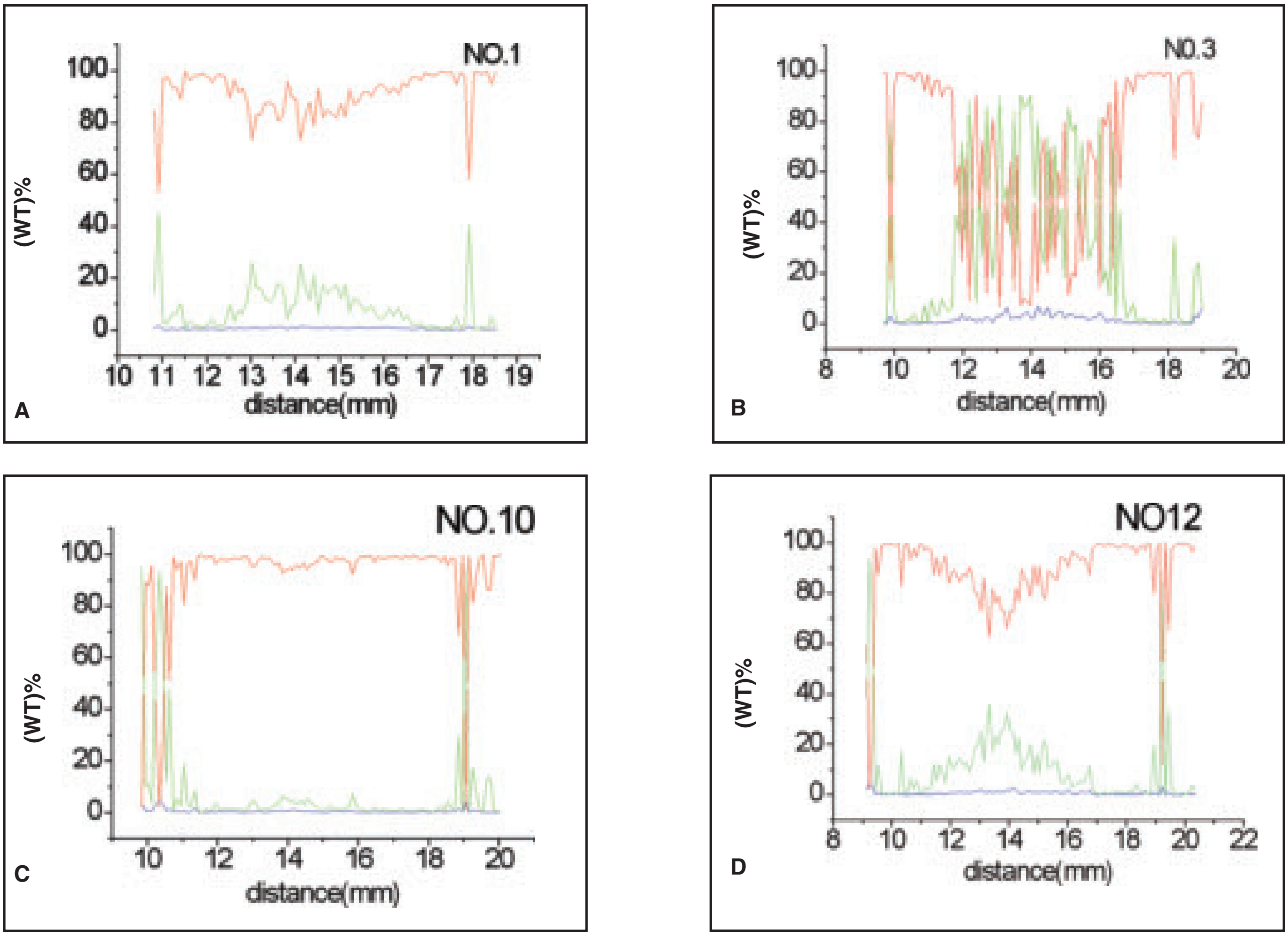

Fig. 5 — Composition profiles of electrode surfaces after 60 welds using the schedules of A — F = 4.5 kN, τ = 60 ms; B — F = 4.5 kN, τ = 180 ms; C — F = 9.0 kN, τ = 60 ms; D — F = 9.0 kN, τ = 180 ms. The red line is for Cu, green is for Al, and blue is for Mg.

ments taken for each surface cleaning condition. In order to make consistent measurements, the electrodes were cleaned after each measurement using the same grit sandpapers.

Rapid Electrode Life Determination

Before conducting electrode life tests, a set of electrodes was used to make a small number of welds, i.e., 60 welds under each of the four surface conditions. The electrodes were then compared with those tested for life, and such a comparison may provide a possibility of determining electrode life after making 60 welds only.

An electrode life is closely related to the welding parameters used. For instance, high electric current or long welding time generates more heat at the electrode-sheet interface, and promotes the formation of bronze through the accelerated diffusion between Cu and Al, and therefore, shortens electrode life. However, such unfavorable conditions cannot be avoided in spot welding aluminum as a certain level of welding current and welding time is necessary to produce an acceptable weld nugget. An experiment was conducted first to determine appropriate welding schedules, as listed in Table 2, with the minimum weld size of $5\sqrt{t}$ (t is Al sheet thickness in millimeters) maintained for each surface condition during the first 60 welds. The unit of welding time was 50 Hz cycles, i.e., 1 cycle = 20 ms. An identical electrode force of 9 kN was used for all welding, and welding times of 4, 5, or 6 cycles were chosen with appropriate welding current levels in order to achieve stable and sizeable weld nuggets.

Electrode Life Tests

Using the same schedules as listed in Table 2, electrode life tests were conducted on sheets with four different surface conditions. The test coupon size was 40×500 mm. All welds were peel-tested to measure the weld size. A "failure" was defined as when there is no weld or a weld produced is smaller than $3.5\sqrt{t}$. When 5% or more of 100 welds failed, the end of an electrode life was reached. For specimens of chemically cleaned, electric-arc cleaned, and degreased, one of every 100 welds was tensile-shear tested, and one of every 50 welds was tested on specimens with untreated surfaces.

Results and Discussion

The various surfaces were characterized first by their composition, depth, and contact resistance. The electrode life was then evaluated through measuring the quality of the welds on the aluminum sheets with various surfaces. The surface features of the electrodes were linked to the measured electrode life in order to predict electrode life by making a small number of welds.

Surface Layers after Cleaning

The profiles of atomic-percent measured by XPS are shown in Fig. 2A–C. The thickness of a surface layer after cleaning can be easily determined in Fig. 2 through

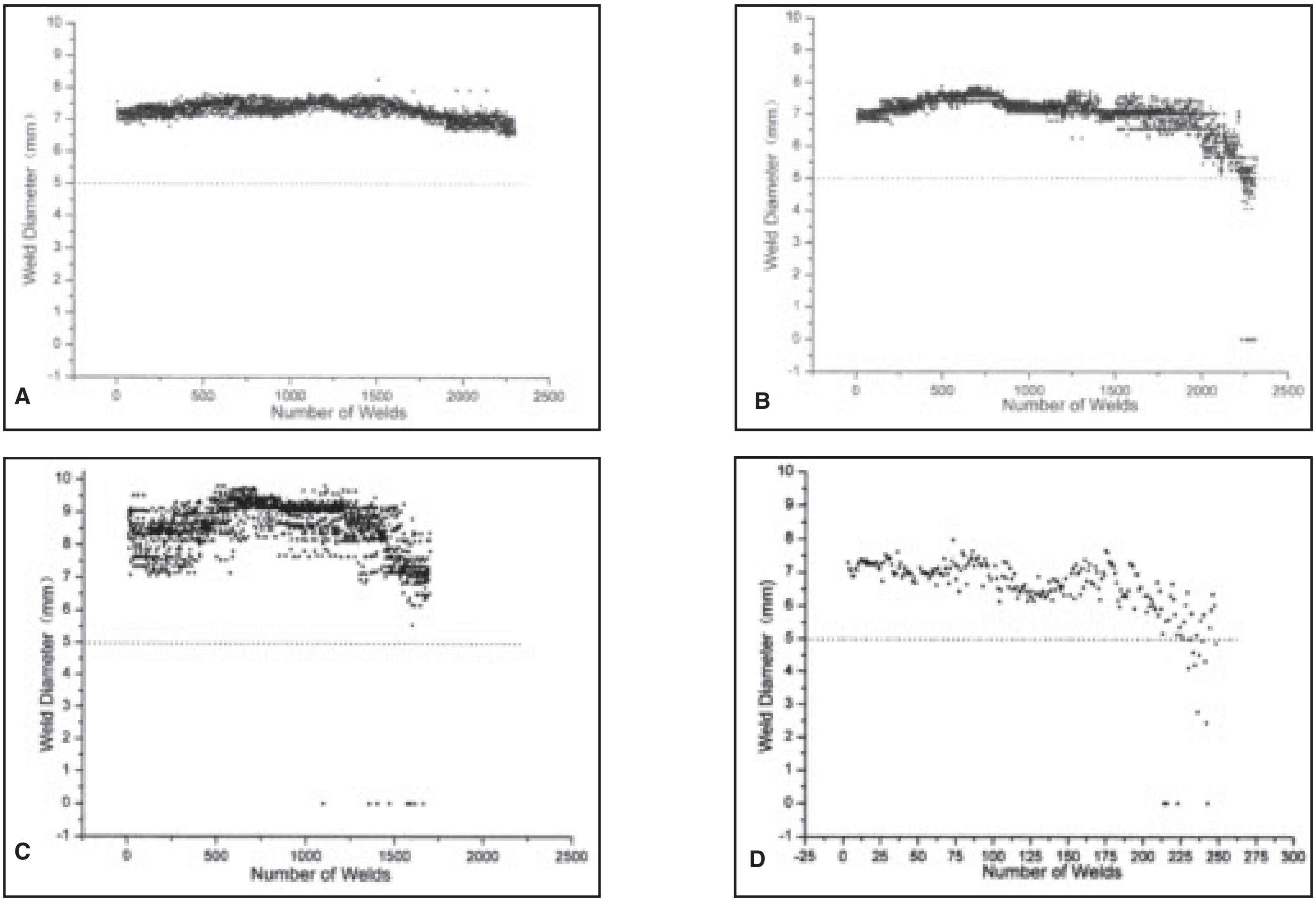

Fig. 6 — Electrode life testing results. A — Chemically cleaned; B — degreased; C — electric-arc cleaned; D — untreated surfaces. The dashed lines represent the minimum weld diameter ($3.5\sqrt{t}$) for the sheets.

the changes in atomic-percent of Al_2O_3 along the etching depth. The thickness of the Al_2O_3 layer is estimated around 170 nm for the degreased surface, and it is about 12 nm for both the chemically cleaned and electric-arc cleaned. It can be seen that the percent of aluminum increases approaching the base metal as the amount of Al_2O_3 decreases with depth. The amount of oxygen changes in a similar manner as Al_2O_3. However, oxygen also exists in Mg oxides, in addition to Al_2O_3, although at a much smaller portion. In general, the chemically and electric-arc cleaned surfaces have much thinner and more uniform Al_2O_3 layers than a degreased surface does. The uniformity of aluminum oxide layers was tested by measurements at different locations on a treated surface.

Contact Resistance

The measured resistances of various surface conditions are plotted in Fig. 3, using a setup as shown in Fig. 1. As shown in the figure, there is a significant difference in contact resistance among the sheets of different surface conditions. Electric-arc cleaning resulted in the lowest contact resistance, possibly due to the fact that the layer of grease and oxides on the surface was burned off under the intensive heat of the electric arc. The base metal was exposed and little oxidation occurred after cleaning as the cleaning was performed under the protection of Ar gas. The time elapsed between cleaning and measurement (and welding for the tests on electrode life) was a few hours in which only a thin layer of Al_2O_3 was expected to form as revealed in Fig. 2A–C by XPS measurement. Softening of the base metal in the cleaned surface area occurred under the electric-arc heat. In fact, measurements showed that the hardness of an electric-arc-cleaned surface (Vickers hardness of 60) is about two-thirds of that of a degreased surface (Vickers hardness of 90). This makes the contact area between the electrode and sheet larger than would be for untreated sheets or treated by other means.

The resistance of chemically cleaned surfaces is fairly uniform with a magnitude slightly higher than those electric-arc cleaned. Degreased surfaces have a higher contact resistance, which is still significantly lower than that of untreated surfaces. The contact resistance of degreased and untreated surfaces is not as uniform as those chemically or electric-arc cleaned. The resistance values for chemically cleaned, degreased, and untreated surface conditions are consistent with those published in literature.

Rapid Electrode Life Evaluation

The electrode faces after 60 welds using the schedules listed in Table 2 on four different surface conditions are shown in Fig. 4. The upper and lower electrodes after 60 welds under each condition had very similar appearances, and therefore, only the upper electrodes were used to characterize the influence of surface conditions on electrodes, as shown in the

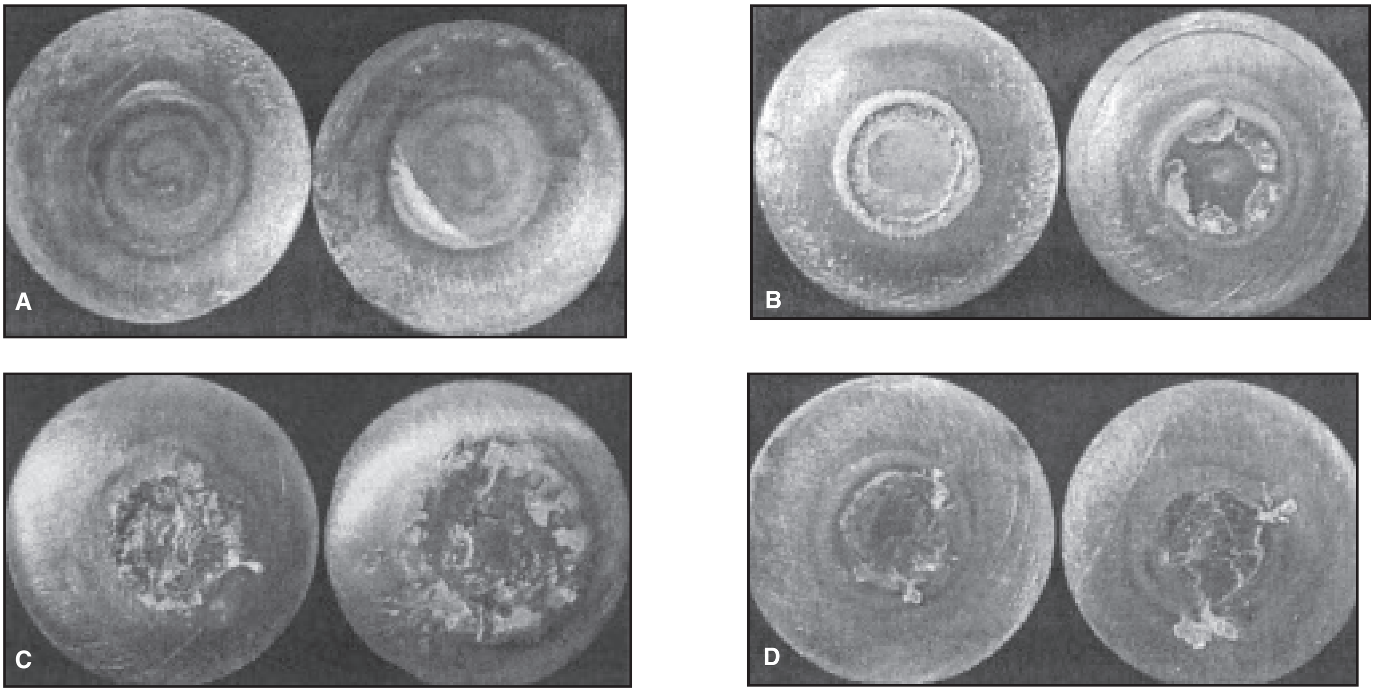

Fig. 7 — Electrode surface morphology after life tests. A — Chemically cleaned; B — degreased; C — electric-arc cleaned; D — untreated aluminum sheets. The electrodes on the left side are from the lower arm of the welding machine (negative), and those on the right side are from the upper arm (positive).

figure. These electrodes show a clear region of metallurgical changes on their faces, due to an intensive heating and a pressurized contact with the Al sheets. In such a zone, a silver-colored ring of aluminum pickup is visible on all electrodes. However, the appearance of such a ring is different in the four electrodes used to weld the sheets with four different surface conditions. The ring is thin and clear with the chemically cleaned surfaces, thicker, yet still clear, with the degreased. The ring becomes blurry and thicker for electric-arc cleaned, and very fuzzy and thick for that with untreated condition. The change of the electrode surface is a direct result of metallurgical reactions occurring during welding, and therefore, the appearance provides a possibility of understanding the metallurgical processes and the trend of electrode deterioration if the electrodes are to be used for more welding using the same schedule. A thick and blurry ring of Al pickup may represent an unstable electrode-sheet contact during a continuous welding process, as resulting from alloying between Cu and Al and removing the resultant bronze from the electrode surface at many locations.

On the other hand, a clearly defined and narrow silver band may be the result of a consistent contact between the electrode and the sheets, with a lesser amount of material removed from the surface. Oxidation of Cu is also observed on the electrode faces. Fig. 4A and B appears less oxidized than Figure 4C and D. The surfaces of the electrodes show a significant roughening (in the form of small craters) on those using untreated and electric-arc cleaned sheets, while the electrodes used on chemically cleaned and degreased sheets are much smoother.

Figure 4 clearly shows that welding using sheets of different surface conditions creates distinctively different appearances of electrode faces. Recognizing such differences may help in predicting electrode life after making only a small number of welds. This is possible by linking the features of these electrodes to their respective electrode lives produced in electrode life tests.

Effect of Welding Schedules

The alloying between copper electrodes and aluminum sheets is also influenced by electrode force and welding time. As shown in Fig. 5, the profiles of Cu, Al, and Mg along a line through the electrode center, measured through a line scanning of chemical composition, depend on both factors. Low electrode force (4.5 kN) and long welding time (180 ms) generate more heat at the electrode-sheet interface, and therefore a larger amount of alloying with Al and Mg (Fig. 5B) than with a shorter welding time — Fig. 5A. A similar effect of welding time is also observed with higher electrode force (9.0 kN, as in Fig. 5C, D), but the severity of alloying is significantly lessened with high electrode force, as can be seen by comparing Fig. 5A with 5C, and 5B with 5D. A large electrode force creates low contact resistance, and therefore less heat generation and alloying at the electrode-sheet interface. Thus, a large electrode force is preferred for electrode life.

Effect of Surface Conditions on Electrode Life

The electrode lives determined by welding using sheets of four different surface conditions are shown in Fig. 6. In welding chemically cleaned sheets more than 2300 quality welds were produced; the electrodes were slightly worn and they were still far from the end of their lives as shown in Fig. 6A. Electrodes used to weld degreased sheets have a life of more than 2000 welds — Fig. 6B. In this case, the variation of weld diameters grows large at the end of the electrode life, but is significantly smaller than those for electric-arc cleaned and untreated sheets — Fig. 6C, D. As shown in Fig. 6C, the electrode life is about 1700 welds when sheets were electric-arc cleaned. When untreated sheets were used, the electrode life is about 200 welds, which is significantly

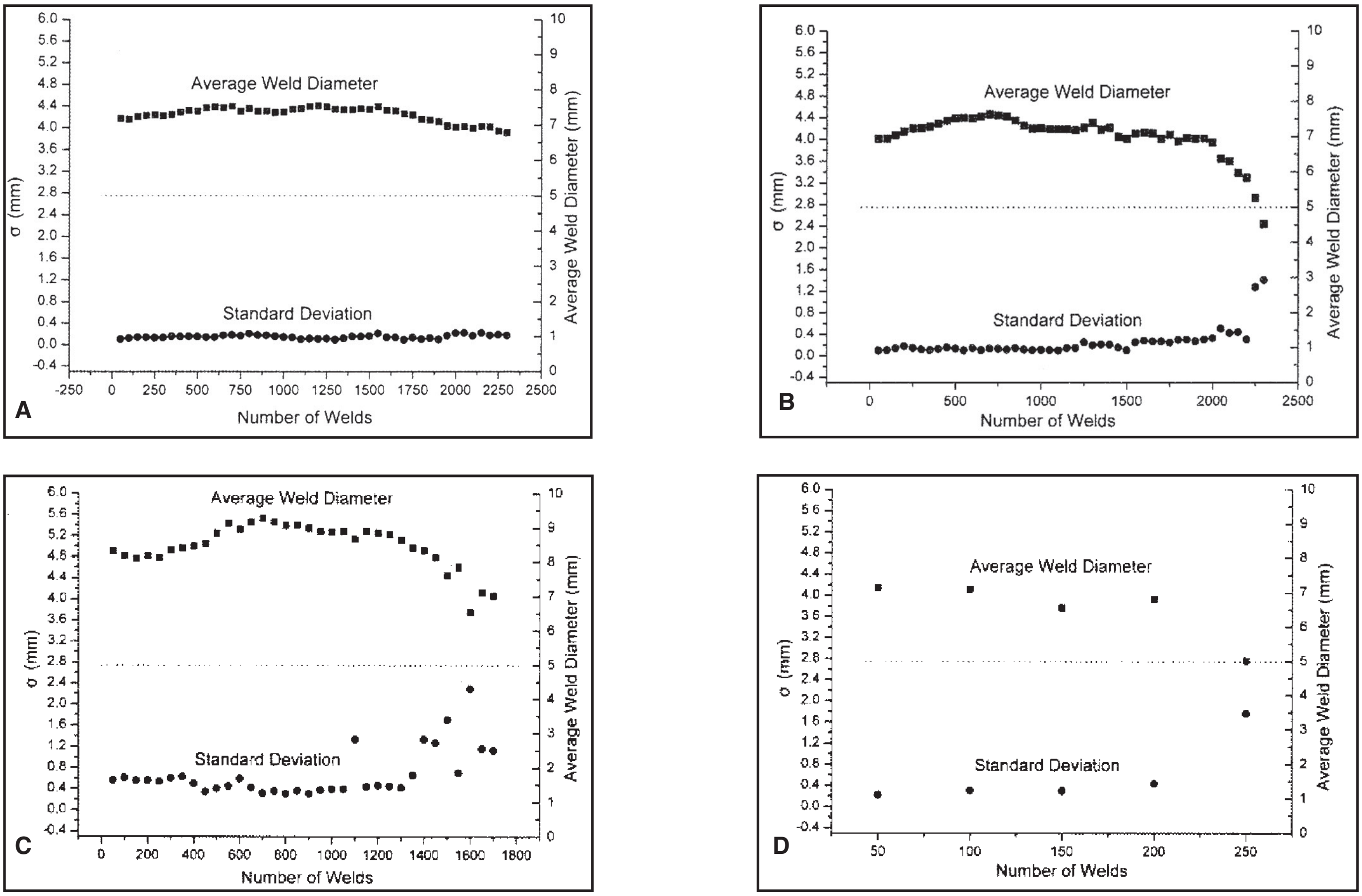

Fig. 8 — Average diameters and standard deviations of welds. A — Chemical cleaning; B — degreasing; C — electric-arc cleaning methods; D — untreated sheets.

shorter than any of those treated sheets. Therefore, the surface condition of sheets plays a key role in determining electrode life in welding Al..

The faces of electrodes after electrode life tests using various surface conditions are shown in Fig. 7, arranged in the same order as their electrode lives — Fig. 6. The electrodes used in welding untreated sheets (Fig. 7D) appear less worn than others. However, they were used to make only about 200 welds, while the others made 1700 welds (electric-arc cleaning, Fig. 7C) or more than 2000 welds (chemical cleaning, Fig. 7A; and degreasing, Fig. 7B).

The effects of surface conditions on electrode life can be evaluated by considering the magnitude and uniformity of contact resistance between the electrode and sheet. The contact resistance can be directly measured, or it can be indirectly estimated using the linear relationship between the contact resistance and oxide thickness established by Leone and Altshuller (Ref. 5). Chemically cleaned surfaces have the thinnest oxide layer (Fig. 2), and therefore, the lowest contact resistance, as shown in Fig. 3, and they produced the longest electrode life. On the other hand, untreated sheets exhibited the highest contact resistance and yielded the shortest electrode life.

The impact of contact resistance is clearly shown by the appearance of the electrodes at the end of their respective lives in Fig. 7. Low contact resistance benefits the electrode life primarily due to less oxidation and alloying, which results in less heating at the contact interface and long electrode life. The electrodes used to weld chemically cleaned sheets have slight alloying and oxidation on the surface after the life test, and those for degreased sheets have craters due to depletion of bronze, and a large area of Cu-Al alloying. The electric-arc cleaned sheets deteriorated the electrodes the most, as evidenced by the large number of craters and Al pickup/alloying on the electrode surfaces.

The consistency and uniformity of electrode-sheet contact play an important role in determining electrode life. As discussed in previous sections, nonuniformly distributed contact resistance on a sheet surface induces uneven, localized heating between the sheet and a Cu electrode during welding. Severe oxidation and alloying may occur at these locations, resulting in a nonuniform distribution of surface resistivity on the Cu electrode face, which in turn, affects subsequent welding. Oxidation and alloying occur on the electrode surface during every welding cycle. An accumulative effect of such a process is the continuous deterioration of the electrode surface. As a result, the current distribution changes from weld to weld and produces inconsistent welds if the electrode surface damage is severe enough.

Although Fig. 3 shows that electric-arc cleaned sheets have a lower, and more consistent contact resistance than degreased sheets, it is not always possible to create a uniform and consistent surface by electric-arc cleaning, especially when it's performed manually while trying to achieve sufficient cleaning without melting the surface. The rough surface of the electrode after 60 welds shown in Fig. 4C may be the result of the inconsistently arc-cleaned sheet surfaces. This explains that electric-arc cleaning produces lower contact resistance but shorter electrode life

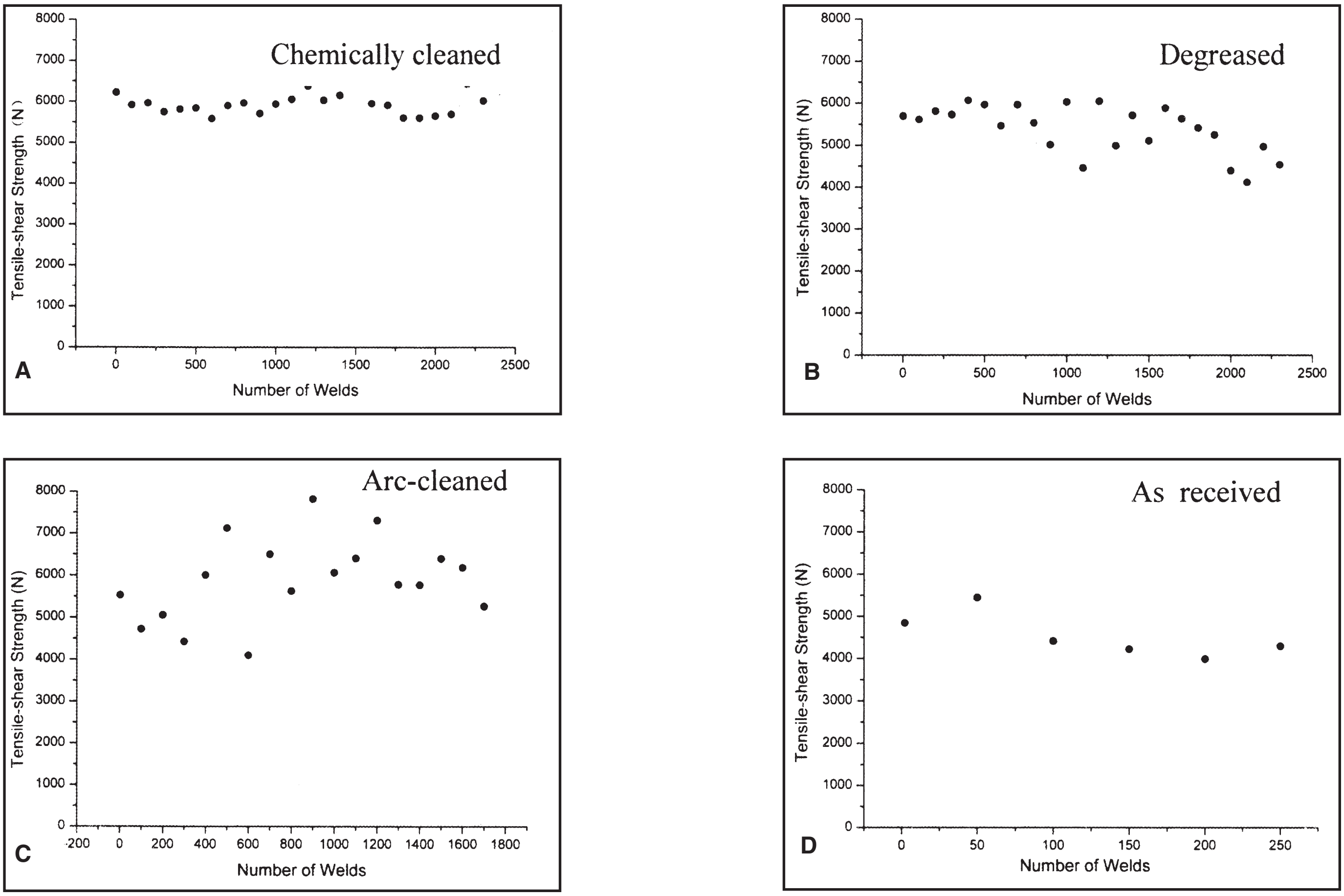

Fig. 9 — Tensile-shear strengths of welds. A — Chemically cleaned; B — degreased; C — electric-arc cleaned; D — untreated sheets, taken during electrode life tests.

than degreasing. Another possible reason is that the thin aluminum oxide layer remaining on the sheets after degreasing would serve as a protection layer, which prohibits the interdiffusion between Cu and Al, while not producing much localized heating in the contact area.

The modified surface properties of the electric-arc cleaned sheets may be responsible for the relatively short electrode life. The surface of such a treated sheet is softened by electric-arc heating, which results in a large contact area between the electrode and the sheet under an electrode force of 9 kN. Therefore, welding such sheets needs high electric current in order to achieve a minimum current density for making a weld. As shown in Table 2, welding electric-arc cleaned sheets requires the highest welding current and longest welding time among all surface conditions. The surfaces of the electrodes used to weld electric-arc cleaned sheets in Fig. 7 have significantly more damage than those using other cleaning methods. There are many large and deep craters, large area of Al deposit, and the contact area appears significantly larger than others. When intensive alloying and alloy depletion from an electrode surface occur, the effective contact area between the electrode and a sheet surface becomes unstable — it can be small at one weld and result in a large current density, and it can be large at the next weld and result in very low electric current density producing low weld penetration or an undersized weld. Such changes in contact area are random and produce large variations in the welds created.

Electrical polarity appears to have some effects on the electrode deterioration. Similar effects were discussed by Lum et al. (Ref. 8). In Fig. 7, for each pair of electrodes, the one on the left side was taken from the lower or negative electrode arm. These electrodes appear less damaged than those on the right side, which were taken from the upper, or positive electrode arm. This phenomenon might be explained considering the micro morphology of the contact interface and the dynamics of resistance heating, and is not a subject of this study.

The variability of weld quality in a welding process is an important index in production. It may also provide a useful indicator for electrode life, as a large variability indicates that the welding process becomes unstable, and it may be close to the end of electrode life. In order to understand the influence of surface conditions, both average weld diameters and standard deviations are plotted in Fig. 8. These quantities were calculated on every 50 welds in the electrode life tests. Welding chemically cleaned sheets produced fairly consistent welds and a small, but almost constant standard deviation — Fig. 8A. It can be seen, when welding under other surface conditions, that accompanying a drop in the average weld diameter when an electrode life approached its end, the standard deviation of diameters increased dramatically. From the figure, it can be seen that an increase of about 300% in standard deviation is observed for all surface conditions when the electrode life was reached. The standard deviation before the sudden increase is about 0.4 mm, and it jumps to about 1.4 mm or more, accompanied by a visible drop in weld diameters when it's close to an electrode life. In the case of electric-arc cleaning, the first such increase in standard deviation doesn't correspond to an average weld diameter falling below the desired value. However, this occurrence is fairly close to the end of the electrode life. Therefore, the change in standard deviation of weld diameters during welding can be a useful index for electrode life.

Tensile-shear strengths of the welds of various surface conditions are shown in Fig. 9. One of every 100 welds during electrode life tests was tested, except for untreated sheets for which one of every 50 welds was tested. Chemical cleaning again produced the highest strength with the least variability. Degreasing has lower strength and larger variability, and electric-arc cleaned is quite unstable, similar to those observed in Fig. 6 for measured weld sizes. Such differences can be attributed to the magnitude and distribution of contact resistivity of the sheets cleaned using different methods.

Relation between 60-Weld Electrodes and Electrode Lives

As seen in Fig. 4, the electrodes used to weld sheets of different surface conditions have distinctively different characteristics. The subsequent electrode life tests proved that the electrode lives are different. Therefore, it is possible to predict the electrode life for a particular stack-up of sheets and welding schedule, only after a small number of welds, such as 60 welds, as in this study. By analyzing the features shown in Fig. 4 and linking them to the corresponding electrode lives, the following observations can be made:

1) The border of the reaction area on the electrode face. An electrode of long life tends to have a small, thin, yet clear silver band on the surface after a small number of welds. Such a band indicates a stable contact between the electrode and the sheet. On the other hand, a large, thick, and fuzzy silver band may indicate a short electrode life, as in the cases of electric-arc cleaning and untreated sheets because of the repeated alloying and removal of the alloy.

2) Black oxidation (burning) marks at the center of an electrode face. Inside the silver band there is usually an area of oxidation that is directly related to the cleanness of the electrode-sheet interface. Greases and other organic compounds at the interface may be burned under the intensive heating during welding. As such reaction is due to low conductive or even insulating substances at the interface, it directly reflects the contact resistivity or resistance. Therefore, it affects the deterioration of electrodes and electrode life. By comparing Figs. 4 and 6, it can be seen that small and light burning marks on the electrode face after 60 welds indicate a long electrode life, and large and dark burning marks correspond to a short electrode life.

Such an understanding may help predict the electrode life for a combination of sheets, electrodes, and welding parameters by conducting a small number of welds that produce visible characteristics on the electrode faces, as observed in this study. However, a detailed and quantitative relationship between electrode surface features and electrode life needs a more thorough and well-designed investigation to develop.

Summary

In this study, the effects of sheet surface conditions on electrode life have been investigated. Using four types of surface treatments, namely, chemical cleaning, degreasing, electric-arc cleaning, and original (untreated), drastically different electrode lives were obtained. The effects of surface conditions on electrode life can be attributed to the influences of the magnitude and distribution of surface resistivity, as summarized in the following.

Chemical cleaning. It produced the thinnest and most uniform layer of Al_2O_3 on sheet surfaces. The greases on surfaces are also largely removed in the process. As a result, very little alloying and oxidation occur during welding, yielding a long electrode life (more than 2300 welds, yet far from the electrode life).

Degreasing. It did not change the thickness or the uniformity of Al_2O_3 on sheet surfaces. Welding using degreased Al sheets can produce an electrode life of more than 2000 welds in this study.

Electric-arc cleaning. It produces similar contact resistance compared with chemical cleaning, and a significantly longer electrode life (about 1700 welds) than untreated surfaces. However, electrode life shorter than those using the degreasing cleaning method, which has a higher surface contact resistance.

Original surface. The untreated sheets have both greases and oxides on the surfaces, and the electrode life in welding such sheets was about 200 welds.

In general, the surface condition of Al sheets plays an important role in affecting the electrode life. From this study it can be concluded that welding untreated sheets without dressing the electrodes is not practical. The electric-arc cleaned surfaces produced a shorter life than degreased, and therefore, a low-contact resistance doesn't guarantee a long electrode life. Although chemical cleaning produced desirable electrode life, it is costly, time-consuming, and environmentally unfriendly. Degreasing is more practical than other cleaning methods and it may be adopted in large-volume production, such as automobile manufacture.

The tensile strength of welds tested during electrode life tests shows a similar trend as the weld diameter. This study also shows that together with the average weld diameter, the change in standard deviation of weld diameters provides a feasible indication of electrode life. The rapid electrode life determination method using only 60 welds provides a possibility of selecting appropriate welding schedules, sheet stackups, and surface conditions for prolonged electrode life.

Acknowledgment

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A Wavelet Transform-Based Approach for Joint Tracking in Gas Metal Arc Welding

A new system was developed for joint tracking and control of the GMA welding process based on CCD sensors without an external light source

BY J. X. XUE, L. L. ZHANG, Y. H. PENG, AND L. JIA

ABSTRACT. Effective tracking of the weld joint is crucial to the development of a high-performance control system for the gas metal arc welding (GMAW) process. This paper presents a new approach to effectively track weld joints based on charge coupled device (CCD) sensors. Due to the presence of spatter, dust, and strong arc noises in welding environments, it has proved to be difficult to detect the weld joint from the CCD images captured in real time. In order to improve the robustness of weld joint tracking, this paper presents a novel approach, based on the Bubble and M-band wavelet transform, for detecting the image edge of molten weld pools from the images captured during GMAW. The experimental results show that the effectiveness of the proposed method in detecting the edges of molten weld pools and identifying weld joints even when the welding images are presented with much noise. Based on the weld joint identification, a PID control approach is employed to manipulate the welding gun in order to produce a desired weld joint. The control experiments demonstrate that, based on the proposed joint tracking, the control of an S-shaped weld joint has been effectively delivered with good precision.

Introduction

Extensive research has been performed for developing efficient and effective techniques for tracking and controlling the welding process. Many systems have been developed in research laboratories; however, they are still challenged by a variety of uncertainties and complexities when used in industrial environments. The objective of this research is to develop effective and efficient algorithms for the online identification of weld joints, based on the processing of the molten pool images and to facilitate the intelligent control of the welding process (Refs. 1–4). For the development of systems with great value for industrial applications, it is desired to develop approaches capable of tracking the weld joint without using an additional light source (i.e., directly using the light produced by the welding arc) in order to reduce the cost, although it would increase the complexity and difficulty of weld joint tracking.

Most of the existing techniques have been developed for tracking and control of the gas tungsten arc (GTA) and gas metal arc (GMA) welding processes. The arc sensing method is an effective technique that can identify weld defects and track weld joints exactly through arc scanning. Based on this, many joint tracking systems have been developed and practically applied for gas metal arc and CO_2 welding. In practice, the arc sensor requires a set of weaving arc devices, which has a complex structure and is more easily implemented with a welding robot. It is restricted on the aspect of mechanism and its weaving frequency is rather low, so it is only suitable for bevels, corner joints, lap joints, etc., and is not effective for high-speed and sheet joint tracking of butt joints. Vision sensor methods can directly observe the area of the weld joint to facilitate artificial intelligence (Refs. 5–7). In the GMAW process, the molten pool images are presented with much noise (such as bright spots and lines due to spatters). As a result, the weld joint is usually very difficult to identify in real time. Kim et al. (Ref. 8) developed a robot visual tracking system for arc welding in which a CCD sensor is used to capture the positional information of the joint. In this system, an additional laser light was used. Gao et al. (Ref. 9) developed a fuzzy logic controller for a welding robot. Tao and Levick (Ref. 10) developed a method to assess the feedback variables for arc joint tracking in a robotic GMAW system. They investigated the use of a welding power source for feedback control of welding current and voltage. Cheng et al. (Ref. 11) developed an image processing algorithm for joint detecting and tracking in a pulse GTAW process. Their algorithm has been tested when the current waveform was controlled under a strictly level (the molten pool image was presented with very little arc noise). Recently, Kim et al. (Ref. 12) and Matsui et al. (Ref. 13) developed a three-dimensional sensor system for the recognition of operating conditions and weld joint tracking. Matsui's GMAW system has been tested on thin steel sheets.

For effective identification of the weld joint, this paper proposes a new approach to detect the edge of molten pools from the images obtained during the GMAW process by applying wavelet transform techniques to extract the space and frequency information of the images. Based on the excellent capability of extracting the space-frequency information from images (Refs. 14, 15), the arc welding image signals with strong noise can be depicted with the wavelet coefficients through the process of multiresolution decomposition. On the other hand, the image noise can be eliminated according to the signal energy estimated based on the associated wavelet coefficients.

In this study, a Windows®-based system has been developed for joint tracking control of the GMAW process, in which a high-performance A/D image converter and a novel edge detection algorithm are embedded. The wavelet transform algorithm is

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KEYWORDS

Gas Metal Arc Welding
Joint Tracking
Process Control
Process Monitoring
C-Mn Steels

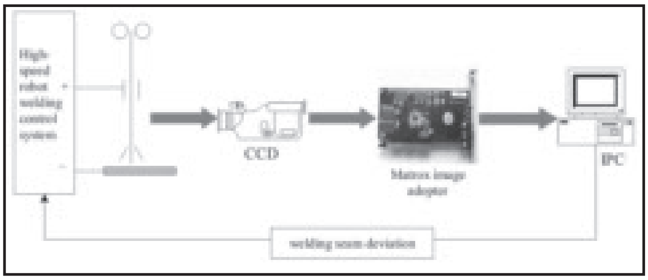

Fig. 1 — The developed intelligent weld tracking and control system.

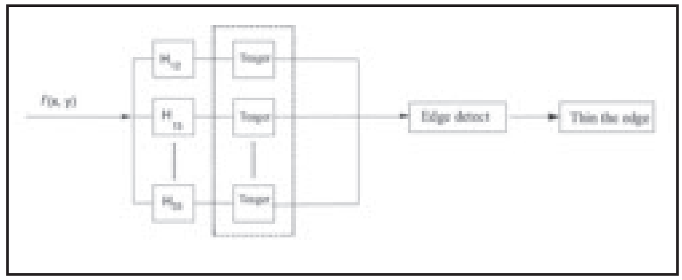

Fig. 3 — The image edge detecting flow with M-band wavelet transform.

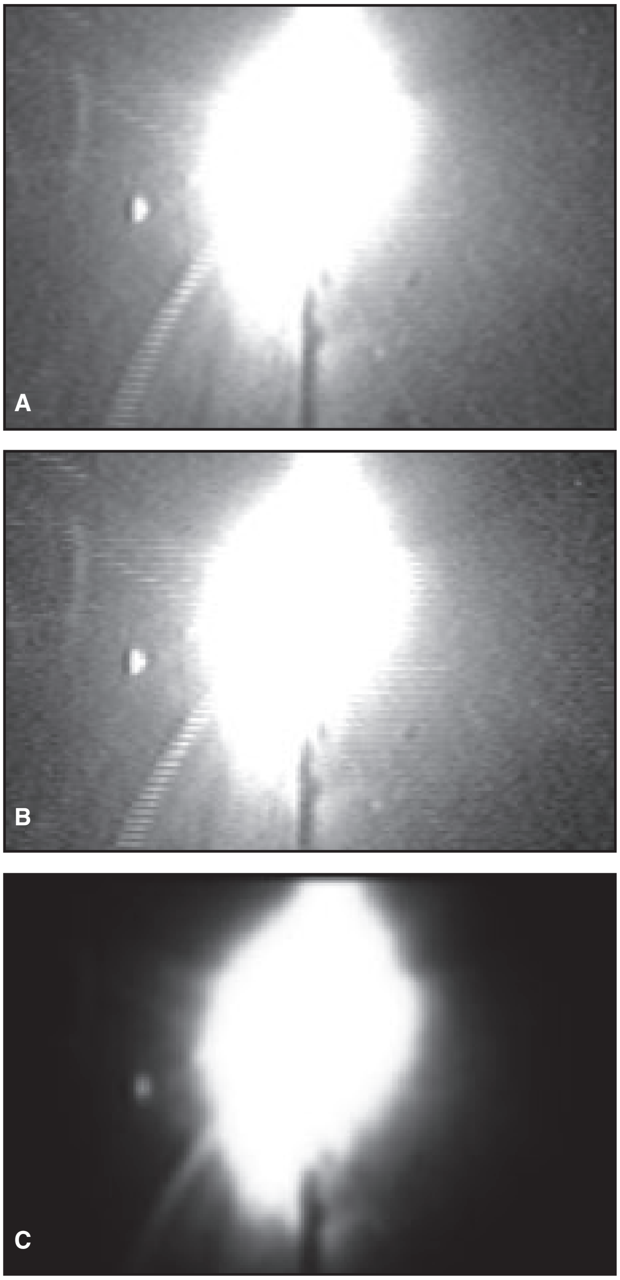

Fig. 2 — Result of image preprocessing: filtering and squaring. A — The original welding image; B — the result after median filtering; C — the result after filtering and squaring.

modified so as to fulfill the requirements of precision, speed, and noise elimination needed for real-time tracking and control of a GMAW joint. The system can automatically track and control the weld joint after the starting point of the welding process is given.

As shown in Fig. 1, this system consists of five steps:

1. A CCD sensor system is used to capture the original images of the weld joint and the foreside of the molten pools;
2. A high-resolution A/D converter is employed to digitalize the original image;
3. The digital images are then processed to detect the edge of the molten pools, for which a novel algorithm based on wavelet transform is proposed in this paper;
4. The central track of the weld joint is estimated based on the edges of the molten pools;
5. Finally, a PID controller is applied to deliver the control signal to the three-dimensional servo system to manipulate the welding gun to produce a weld joint close to the desired track as accurately as possible.

Edge Detection with M-Band Wavelet Transform

M-Band Wavelet Transform

The region of the image captured by CCD is 640 × 480 pixels. To ensure the controlling effectiveness, only the central image of the molten pool, which was sized 90 × 120 pixels, was processed. Conventional approaches to applying wavelet transform techniques for the detection of image edges are to use dyadic wavelet transform to decompose the image and then to detect the object edge with Mallat Scheme of Local Modulus Maxima. These conventional approaches have been applied successfully for general image processing (Refs. 16–21). However, the conventional dyadic wavelets transform is not suitable for processing narrowband and high-frequency signals (Ref. 22). The orthogonal dyadic wavelets can only have either compactly supported property or linear-phase (except Harr wavelet, as concerning real filter) (Ref. 23), which are

Table 1 — Four-Band Wavelet Taper Decomposed Structure

LL	H_1L	H_2L	H_3L
LH_1	H_{11}	H_{21}	H_{31}
LH_2	H_{12}	H_{22}	H_{32}
LH_3	H_{13}	H_{23}	H_{33}

Table 2 — Filter Coefficients

h_n	g^1_n	g^2_n	g^3_n
0.114701	0.026913	0.135299	–0.076641
0.385299	–0.326641	–0.218254	0.076641
0.576641	–0.488852	–0.326641	0.114701
0.576641	0.135299	0.680194	–0.385299
0.385299	0.680194	–0.135299	0.576641
0.114701	0.326641	–0.488852	–0.576641
–0.076641	–0.218254	0.326641	0.385299
–0.076641	–0.135299	0.026913	–0.114701

Table 3 — Experimental Parameters of Tracking Control

Maximum horizontal tracking error	0.29 mm
Maximum vertical tracking error	0.58 mm
Maximum tracking error	0.40 mm
Average tracking error	0.27 mm

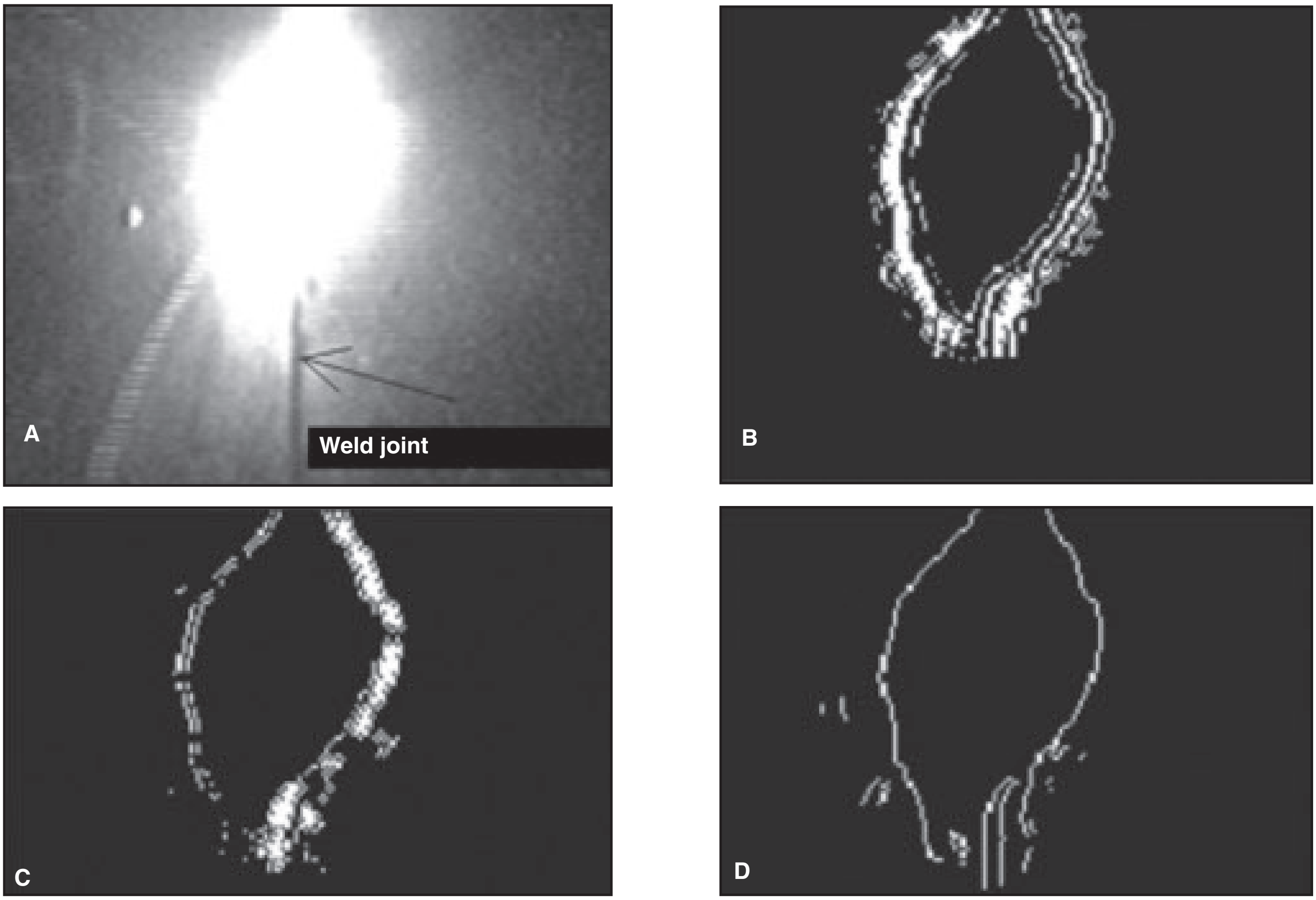

Fig. 4 — The results of molten pool image edge detection with M-band wavelet transform. A — Molten weld pool; B — horizontal result; C — vertical result; D — synthetic result.

both useful properties for image processing so as to ensure not distorting the quality of images. M-band wavelet transform, compared to dyadic orthogonal wavelet transform, has three useful merits, which can be used effectively in image edge detection (Ref. 22): 1) it has a narrower frequency band at the high-frequency band; 2) its energy is more concentrated; 3) an orthogonal M-band wavelet can be a compactly supported and linear-phase one.

The construction of the M-band discrete wavelet is similar to that of the dyadic wavelet (Refs. 24, 25), which is derived from a two-scale equation as:

$$\phi(x) = \sum_{n \in Z} h_n \phi(Mx - n) \quad (1)$$

where M is an integer $M \geq 2$, and $\phi(x)$ is called as a scale function, h_n are the scale coefficients. If $\phi(x)$ is known, (M-1) wavelet could be generated by

$$\psi^i(x) = \sum_n g_n^i \phi(Mx - n), \quad i = 1,2,\ldots,(M-1) \quad (2)$$

where $\{g^i_n\}$ are $(M–1)$ groups of wavelet decomposition coefficients. Usually, the relation between $\{g^i_n\}$ and $\{h_n\}$ is unknown. Let us define the scale functions as

$$\phi_{m,n}(x) = M^{-m/2}\phi(M^{-m}x - n), \quad \psi^i_{m,n}(x) = M^{-m/2}\psi^i(M^{-m}x - n). \quad (3)$$

For a discrete signal $f(x)$, its wavelet transforms are

$$Sf_{m,n} = \langle f(x), \phi_{m,n}(x)\rangle, \quad Df_{i,m,n} = \langle f(x), \psi^i_{m,n}(x)\rangle, \quad (4)$$

then the $Sf_{m–1,n}$ and $Df_{i,m–1,n}$ can be calculated by the recursions as follows:

$$Sf_{m-1,n} = M^{-1/2}\sum_n h_n Sf_{m,n}, \quad Df_{i,m-1,n} = M^{-1/2}\sum_n g^i_n Sf_{m,n}, \quad i = 1,2,\ldots,M-1 \quad (5)$$

Therefore, for a signal $f(x)$, we can obtain the associated multiscale decomposition and reproduction of M-band wavelet transform. For processing two-dimensional images, M-band wavelet transform is performed based on M^2 filter-pairs. The M^2-channel separable wavelet transform can be obtained by the tensor product of M-band one-dimension wavelet filters, which are denoted by $\phi_{m,n}$. The results obtained by these M^2 filter pairs contain useful edge characteristics defined at different scales. In this paper, $M=4$ is used, namely an image is decomposed into 16 sub-bands accordingly. As shown in Table 1, each sub-band is

$$LL = \varphi_{m,n}\varphi_{m,n}, LH_j = \phi_{m,n}\psi^j_{m,n}, \quad H_iL = \psi^i_{m,n}\varphi_{m,n}, H_{i,j} = \psi^i_{m,n}\psi^j_{m,n}, \quad i,j = 1,2,3 \quad (6)$$

The M^2 filter-pairs used in this paper are from 8-tap 4-band discrete wavelet transform (Ref. 26). Table 2 shows the associated coefficients.

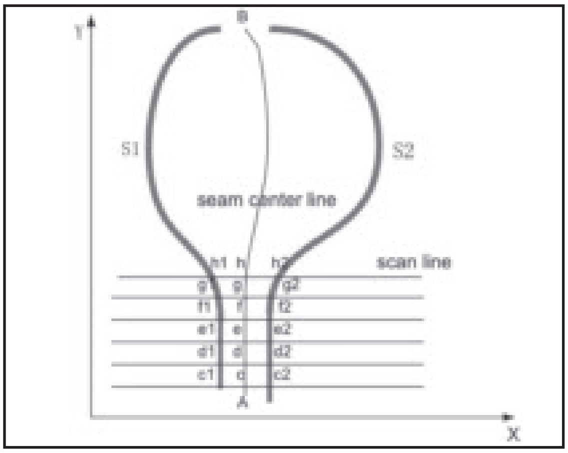

Fig. 5 — The method for detecting welding joint center.

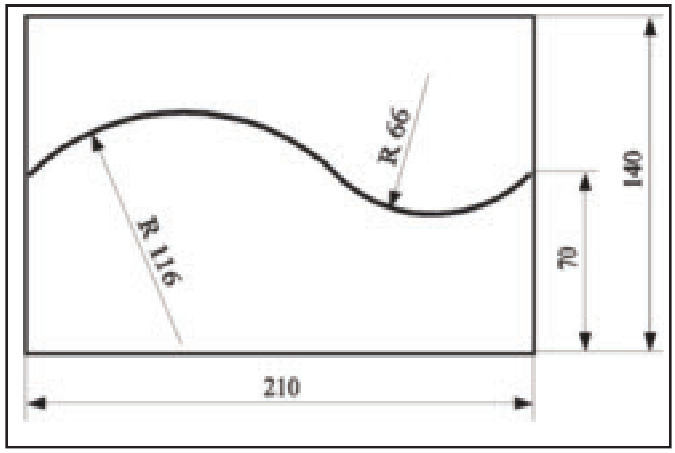

Fig. 6 — The geometry chart of the weld joint.

The Proposed Edge Detection Algorithm

The image decomposition needs to be modified in order to fulfill the computation requirement in real-time applications. In this study, an image is processed in the horizontal and the vertical directions separately. This simplification facilitates the use of a one-dimensional filter to process the image serially, and enables the edge detection to be performed online.

In principle, the frequency response perpendicular to the edge direction is the strongest, whereas the more parallel to the edge direction, the smaller is the frequency response (Refs. 27, 28). This inspired us to use a high-pass filter along the edge direction, and to use the low-pass filter upright the edge direction. Furthermore, as only the results of the high-pass filter make sense for edges detection, the results produced by the low-pass filter can then be ignored.

In order to achieve robust edge detection, the noise and pseudo-edges are eliminated in a preprocessing step. In this study, the Median filter (Ref. 29), which is a well-known nonlinear approach in image processing, to eliminate noise while protecting the edges from being blurred. Particularly, the median smoothing mask in a 3 × 3 neighborhood is used in this study:

$$\frac{1}{10}\begin{bmatrix} 1\,1\,1 \\ 1\,2\,1 \\ 1\,1\,1 \end{bmatrix}. \qquad (7)$$

After applying the median filter, it is seen there is still halation around the molten pools, which affects the effectiveness of the edge detection, as illustrated in Fig. 2B. To eliminate the halation, we square the grey value for each pixel:

$$f'\left(x,y\right)=\left[f\left(x,y\right)\times f\left(x,y\right)\right]/255, \qquad (8)$$

where $f(x,y)$ denotes the gray level of the image pixel located at (x, y). Figure 2C shows the preprocessing result of one image, which shows the noise and halation have been effectively eliminated and the molten pool is clearly reveled.

After preprocessing the image, the edge of a molten pool is detected based on the Teager's energy operator (Refs. 30, 31) defined on the decomposition of an image. The one-dimensional form of the Teager's energy is

$$T\left[f\left(t\right)\right]=\left(\frac{df\left(t\right)}{dt}\right)^2-f\left(t\right)\frac{d^2f\left(t\right)}{dt^2} \qquad (9)$$

while in discrete domain, it becomes

$$T\left[f\left(n\right)\right]=f^2\left(n\right)-f\left(n+1\right)f\left(n-1\right). \qquad (10)$$

As stated previously, an image is processed by one-dimensional wavelet transform, respectively, in each direction. After decomposing an image $f(x,y)$, a total of $M \times M$ different sub-band components are produced. By applying the Teager operator to calculate the energies of these sub-band components, the associated edge can then be detected in terms of the energy of the sub-band components. The components having high energy are considered as edge whereas the components having low energy are considered as the pseudo-edge or noise. The image edge detecting flow chart with M-band wavelet transform is shown in Fig. 3, which particularly consists of the following steps:

1. Given an image $f(x,y)$, the median filter (Equation 7) and the square operator (Equation 8) are used to preprocess the image;

2. The wavelet operators LH_j, H_{ij}($i \neq j$, $i, j=1,2,\ldots M-1$), as shown in Equation 6 are used to decompose it in the horizontal direction;

3. Apply the Teager operator to calculate the energy of each sub-band, and select an appropriate threshold to eliminate the noise components;

4. Extract the maximum wavelet transform coefficients and add them up to achieve the high-pass filtering and form wavelet transform maximum in the horizontal direction, from which the image edge information in horizontal direction is thus extracted;

5. The similar steps of numbers 2–4 are used to process the image $f(x,y)$ to extract the edge information in the vertical direction, but the wavelet operators are changed as H_iL, H_{ij} ($i \neq j$, $i, j=1,2,\ldots M-1$);

6. The transformed results in both the horizontal and vertical directions are then combined;

7. The outputs of step 6 are then compared with a predefined threshold t_0. The points with values bigger than t_0 are considered as edge points, and are connected to generate the image edge;

8. If the edges generated by step 7 are a little thick, it is necessary to thin them in order to estimate the position of the weld joint more accurately. To do so, we set a smaller detecting range $[t_1, t_2]$ of pixel values. All the edge pixels generated by step 7 are scanned again with this range. By marking and connecting these pixels whose values are in the range, a final and effective edge of the molten pool is then produced.

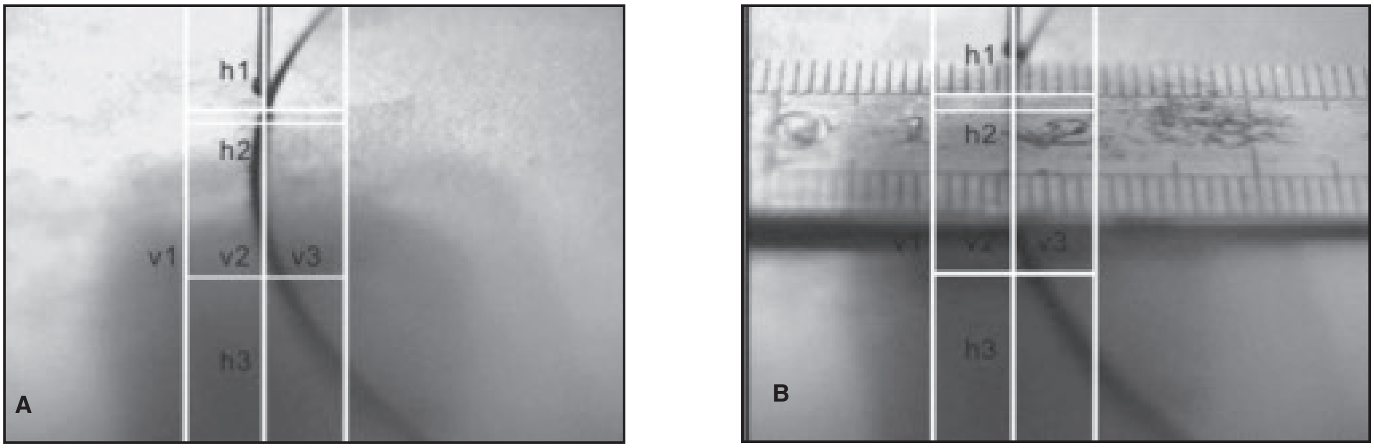

Fig. 7 — Pictures of the following: A — Original position of the weld joint; B — the calibration.

Fig. 8 — The front photo of the practical joint tracking.

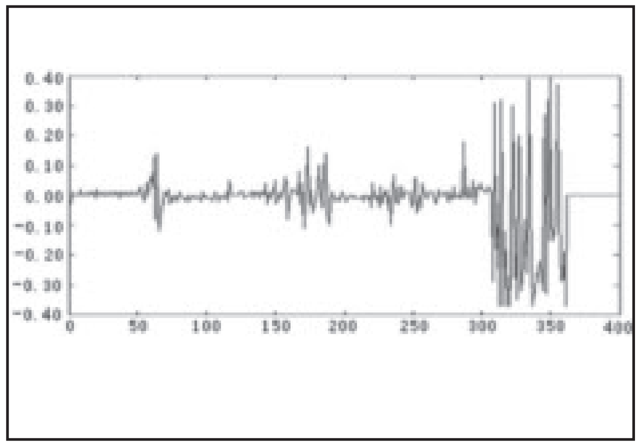

Fig. 9 — The curve of tracking deviation.

Joint Tracking and Control of GMAW

Joint Tracking Based on Molten Pool Edge Detection

The procedure of the proposed edge detection algorithm for weld joint tracking is illustrated by the example shown in Fig. 4. Figure 4A shows the original image of a welding molten pool and the weld joint. Figure 4B and C show, respectively, the results of the edge of the molten pool detected in horizontal and vertical directions. Both of them are produced by combining the results of three sub-band components with the highest Teager energies. It is shown that the joint edge detected in the horizontal direction is clearer than the edge detected in the vertical direction (which is not so obvious in many ranges).

As the orthogonal M-band wavelet transform has a linear phase, the results of the edge detected in different directions can be added up directly, without any positional deviation. Figure 4D is the synthetic result based on combining the results obtained in horizontal and vertical directions. Comparing Fig. 4D with the results of Fig. 4B and C, the result of edge detection is significantly improved. These results demonstrate that the edge information obtained in the vertical and horizontal directions can well complement each other, and the proposed method is able to improve obviously the detection of edges of molten pools.

Based on the detected edge of molten pools, the weld joint track, defined by a set of central points of molten pools, can then be determined. To do so, the CCD scans successively along the X-axis with a distance of three pixels. As illustrated by Fig. 5, based on the detected edges of a molten pool (denoted by curves S1 and S2), each scan line generates a pair of characteristic points such as c1, c2, and d1, d2, and so on, and the associated central points, such as points *c* and *d* defined by c1, c2, and d1, d2. The weld joint track is then obtained by connecting all these central points, such as the curve AB shown in Fig. 5.

Control of Weld Joint

In our system, the control variable is the positional deviation of the welding torch, which is measured at the upright to the weld joint's direction. When the weld joint has been identified by means of the edge detection algorithm, the position of welding torch is adjusted by a PID close control loop. The controller adjusts the torch movement in real time according to the positional deviation, in order to produce a weld joint as close as possible to the desired weld joint. The PID controller used a discrete form as

$$u(t) = k_p e_k + \frac{Tk_p}{T_i} \sum_{j=1}^{k} e_j + \frac{k_p T_d}{T}\left(e_k - e_{k-1}\right) \tag{11}$$

where $K_p = 0.6$, $T_i = 0.25$, $T_d = 0.05$, $T = 0.1$.

Experimental Results

Experimental Condition

A 2-mm-thick Q235 steel workpiece with a narrow joint was used in our experiments to make the tracking method more fit for industrial practice. The weld joint is shown in Fig. 6. The setup of the welding experiment conditions was as follows:

Shield gas: 80%Ar+20%CO_2
Gas flow: 15 L/s
Welding speed: 5 mm/s
Arc voltage: 18.5–19 V
Welding current: 90–110 A
Welding gun type: vertical gun
Wire type: CHW-50C6
Wire diameter: ϕ0.8 mm
Power source: NB200B-IGBT inverter
Load duty: 60%.

The CCD sensor-based image-collection system is configured by a Pentium® IV CPU, a 256M memory, a Matrox image adopter, and a PIH-7912 camera with collecting image rate 30 frames/second. From the hardware point of view, we used a color filter to eliminate arcs of a specific wavelength. The main parameters of PIH-7912 are as follows:

Effective Pixels: 795 (H) × 596 (V) [NTSC];
Resolution: 600 TV lines
Shutter: 1/60 to 1/10000 s (auto).

The CCD visual sensor is rigidly fixed on the welding gun and adjusted as parallel as possible to the welding gun so that the gun would not cover the weld joint during operation. This setup helps to reduce the influence of the welding gun, and enlarge the welding image's visual field. However, because of a fixed gun with the certain angle, there inevitably exists distortion in the collected image including the shape of the weld joint and molten pools. The distortion caused extra deviation in welding control, but the associated deviation was a systemic static error and thus can be determined through off-line experiments.

Image Calibration

In joint tracking and control, it is necessary to determine the starting point of the joint curve and initialize the welding gun position. The method used in this study is illustrated in Fig. 7. First, the welding wire was moved to a predetermined starting point of the joint (as denoted in Fig. 7A). The horizontal angle of the CCD was adjusted so that it superposes the welding wire with the vertical datum line (v2) as shown in Fig. 7. Two vertical lines (v1, v3) were then marked beside v2 with a distance of 50 image pixels. The CCD was then adjusted to focus on the areas between v1 and v3. Second, two horizontal lines (h1, h2) were marked with a distance of ten image pixels beside the starting points. The CCD was adjusted in the vertical direction so that the terminal of the welding wire was seen between the lines of h1 and h2. Referring to another horizontal line (h3) under h2 with a distance of 100 image pixels, the CCD was adjusted to focus on the area between the lines h1 and h3. As a result, the section of v2 between h1 and h2 is almost coincident with the weld joint. In this way, the original position of the weld joint can be estimated accurately.

The physical distance associated with every pixel point was calibrated in the way shown in Fig. 7B. Using a ruler to measure the distance between v1 and v3 (as shown in Fig. 7B, the distance is 10 mm). Dividing this distance by the number of pixels between v1 and v3 (100 pixels for the case shown in Fig. 7B), then we can get the calibrating distance of every pixel point. For the case shown in Fig. 7, the calibrating distance is 0.1 mm per pixel.

Experimental Results of Tracking and Control

In our experiment, the range of identified weld joint widths was 0.1–0.5 mm. By changing the CCD focus or adopting the sub-pixel identifying technique, the identification precision can be further improved. In practice, the weld joints are usually wider than 0.1 mm, which means our method can satisfy practical requests. Figure 8 shows tracking and control results for the desired weld joint shown in Fig. 6, and tracking accuracy follows in Table 3.

Figure 9 shows the curve of tracking deviation produced by the PID control system. The deviation is calculated indirectly according to the revolution of the step motor. The Y-axis denotes the revolution of the motor, each revolution corresponding to 1 mm in the Y-axis. The X-axis denotes the times of sample (the sampling period is 100 ms particularly). Figure 9 indicates that the deviations vary from region to region. In detail, the deviations in the second half curve are bigger than those in the first half curve, especially during the last 50 sampling periods. The main reason of aforementioned situation is the breadth change of joint caused by thermal deformation in the welding process. Furthermore, deviation is also obvious between two joint arcs (from 16 to 18 s). The reason is that the big curvature increases the adjusting force of the mechanism.

Conclusions

This paper presents a new system for joint tracking and control of the GMA welding process based on CCD sensors without an external light source. An integrated software and hardware system has been developed for image collection and processing, and weld joint tracking based on wavelet transform. Based on the experimental results, we summarize the following important conclusions:

1. A novel method based on the median filter and square operation was developed for the preprocessing of molten pool images of GMAW in order to eliminate the noise caused by the strong arc and the spatters.

2. An effective M-band wavelet transform-based approach was developed for the edge detection of the molten pools and the weld joint.

3. The experiments on S-shaped weld joints demonstrated the effectiveness of the tracking and control system. The system is capable of detecting and tracking the weld joint automatically in real time.

4. One further development for this system is the enhancement of the system performance, for example, to reduce the error of weld joints and the improvement of system reliability. In addition, we will attempt to use a fuzzy control system to replace the PID controller in order to develop an intelligent system able to address various uncertainties presented in the industrial environments.

Acknowledgments

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Correction to Article Titled 'Fabrication of a Carbon Steel-to-Stainless Steel Transition Joint Using Direct Laser Deposition — A Feasibility Study,'

by J. D. Farren, J. N. DuPont, and F. F. Noecker

This article was published in the March 2007 edition of the Welding Journal and utilized the WRC Constitution Diagram as an aid to interpreting microstructures that formed between a transition joint. The transition joint had carbon steel on one end and stainless steel on the other end. The diagram appears in Figure 9A, and experimental composition measurements were plotted directly on the diagram. In this diagram, the lines of constant ferrite contents were mistakenly labeled as percent ferrite. The WRC Diagram uses Ferrite Number, not percent ferrite. Thus, the percent values labeled on the diagram are incorrect, and the values actually represent Ferrite Number.

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A Look at the Statistical Identification of Critical Process Parameters in Friction Stir Welding

To analyze the effects of nine friction stir welding input parameters on measured process outputs, a 16-run fractional factorial experiment was used

BY J. H. RECORD, J. L. COVINGTON, T. W. NELSON, C. D. SORENSEN, AND B. W. WEBB

ABSTRACT. Many fundamental physical relationships governing the friction stir welding (FSW) process remain largely unexplored. Recent studies have aided in the discovery and clarification of many process fundamentals. A 16-run fractional factorial experiment was used to analyze the effects of nine FSW input parameters on measured process outputs. It was confirmed that the most significant input parameters are spindle speed, feed rate, and tool depth. In addition, the distance between the weld and side of the plate had a significant effect on measured Z-force and shoulder depth, and thus should be considered in future studies.

Introduction

Friction stir welding (FSW) is a solid-state joining process having many desirable attributes. It involves forcing a rotating cylindrical tool with a protruding pin into the joint to be welded. Once submerged in the material, the tool is advanced along the joint line. Frictional heating is sufficient to locally soften the workpieces and the rotating motion of the tool 'stirs' the workpieces together. The result is a fully consolidated weld with superior quality and properties to those of traditional arc welds.

There are three primary control parameters available in FSW: spindle speed, feed rate, and tool vertical position. During the FSW process, a number of other variables can be measured, including motor power, tool temperature, and forces. The relationships between the fundamental control parameters and the measured process variables have never been completely explored. The relationship between the inputs and outputs is shown in Fig. 1.

For efficient application of FSW, it is desired that all important process parameters that affect a weld outcome be identified and the sensitivity of operating conditions to these process parameters be characterized. In addition to the three most fundamental parameters, it is believed that there are 'environmental' variables that may need to be controlled. Environmental variables are those not readily controlled during a weld as opposed to variables such as spindle speed that are easily controlled. Perhaps a model similar to that shown in Fig. 1 with the addition of environmental variables is a better representation of the FSW process. The environmental variables may have an impact on the process and affect the final weld quality and performance.

Researchers have previously studied various 'input' control parameters and their relation to many 'output' responses. Their objectives all differ but the underlying purpose is to further analyze fundamentals of the FSW process and explore the relationship between inputs and outputs.

Nishihara and Nagasaka (Ref. 1) varied spindle speed and feed rate and were able to measure tool and anvil temperatures. Nishihara and Nagasaka (Ref. 1) along with Lienert et al. (Refs. 2–4) included tool temperatures as a response, which has not been common during experimentation. Tang et al. (Ref. 5) varied welding load (Z-force), spindle speed, and tools with or without a pin in an effort to investigate the workpiece temperature distribution and heat input. Jandric et al. (Ref. 6) studied the effects of spindle speed and feed rate on weld quality and temperature distribution. Colligan et al. (Ref. 7) investigated the effects of pin design, spindle speed, and feed rate on specific energy, power, plunge force, torque, and X- and Y-forces. Johnson (Ref. 8) varied different plunge depths, feed rates, and spindle speeds to explore their effects on forces and torques. Others have included workpiece alloy as part of their studies (Refs. 2, 8, 9). From these studies and others, a wealth of information is acquired that aids in further studies and in understanding the FSW process.

To date, no known study has taken a statistical approach to accomplish the task of relating inputs and outputs. As previously discussed, there was a need to identify and study primary variables that affect welds. Thus, in the current study, a screening design of experiments was chosen to identify the effect of various weld inputs on selected outputs in an effort to identify critical process parameters.

A screening design of experiments (DOE) is a statistical method used to study many variables simultaneously and quantify their effects on a given response relative to each other. By identifying which variables have a large effect on a response, one can conclude which variables are key input parameters.

This paper utilizes a 16-run screening DOE to analyze the effects of nine inputs on selected outputs. No duplication of experiments is used because the intent is to identify the largest effects and not to com-

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**The opinions and conclusions expressed herein are solely those of the author and do not necessarily reflect those of Lockheed Martin.*

KEYWORDS

Friction Stir Welding (FSW)
Main Effects
Process Parameters
Design of Experiments (DOE)

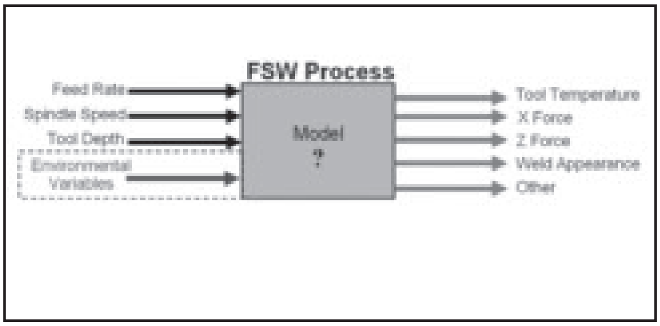

Fig. 1 — Possible relationships describing inputs and outputs of the FSW process.

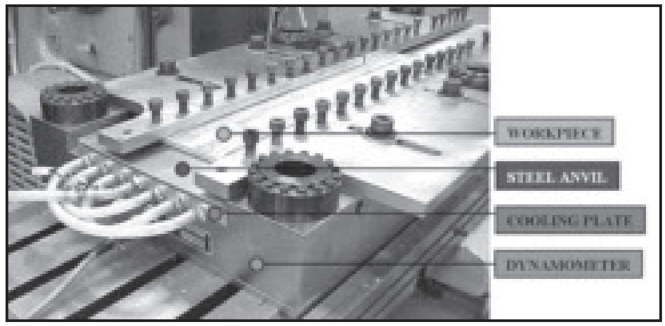

Fig. 2 — Setup of the dynamometer, cooling plate, and workpiece mounting.

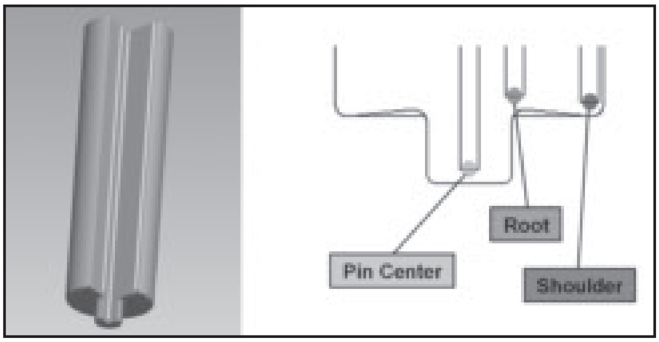

Fig. 3 — Thermocouple locations in the tool. Note: Threads are omitted for simplicity.

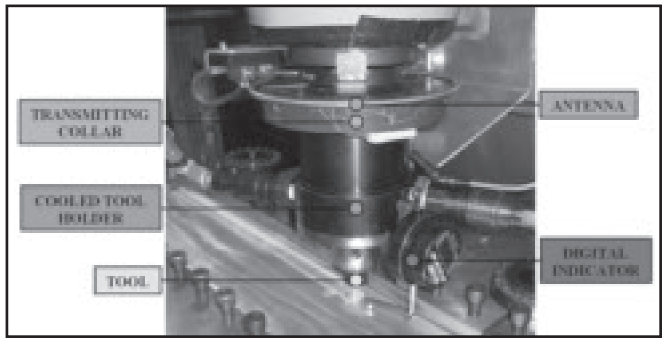

Fig. 4 — Cooled tool holder and electronic indicator used to measure shoulder depth.

pletely explore process relationships. The results aid in understanding process fundamentals and in further investigation of input/output relationships.

Experimental Approach

Design of Experiments

Initial setup of the DOE was done by creating a list of all possible process inputs (factors) and narrowing the list to nine. Factors were eliminated from the list by weighing feasibility and probability of significance based on previous studies (Ref. 10). The three most fundamental factors were included along with six environmental factors. These are detailed in Table 1.

The factors pin length and plunge depth are related. The objective of using plunge depth as a factor is to control the depth of the shoulder relative to the workpiece surface. Since the Z-position of each tool is zeroed on the top surface of the workpiece, different pin lengths (PL) must be accounted for in the plunge.

It was determined that a 16-run screening DOE would best analyze the effect of each factor. Factor levels were chosen from within a known operational window that yielded satisfactory welds. Factor levels were also chosen so the effect would be as apparent as possible. Following statistically sound practices, weld order was randomized. The parameters and levels for each weld are given in Table 2.

Although the FSW machine automatically measures many variables throughout the course of a weld, only eight were utilized as ‘responses’ in the analysis. These are X-force, Y-force, Z-force, pin center temperature, root temperature, shoulder temperature, shoulder depth, and motor power. Shoulder depth is actually a derived response (measured digital depth – pin length) and equates to the distance of the shoulder above or below the top surface of the workpiece. Motor power refers to the amount of power required by the FSW machine to turn the spindle under

Table 1 — Factor Descriptions and Units Used

Factor	Unit	Description
Spindle speed	rev/min	Revolutions per minute of FSW tool
Feed rate	mm/min	Speed of tool advancing through workpiece
Plunge depth	mm	Total distance tool is plunged (pin length + factor value)
Pin length	mm	Distance between outer edge of shoulder and tip of pin along tool axis
Weld cooling	n/a	Coolant circulation in cooling plate during weld
X start distance	mm	Location of plunge relative to edge of workpiece in X-direction
Weld location	n/a	Location of weld relative to edge of workpiece in Y-direction
Preweld cooling	Celsius	Amount of cooling before each weld, measured as the difference between the inlet and outlet temperatures of the cooling plate
Dwell time	seconds	Time between plunge sequence and weld traverse sequence

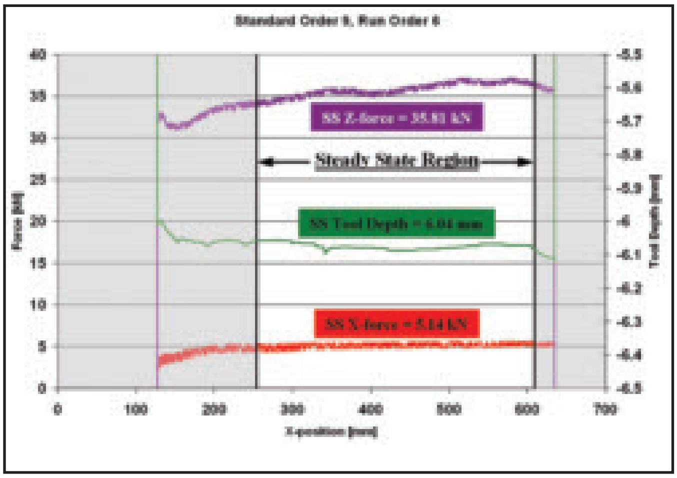

Fig. 5 — *Definition of steady-state region used. Responses were averaged over this region.*

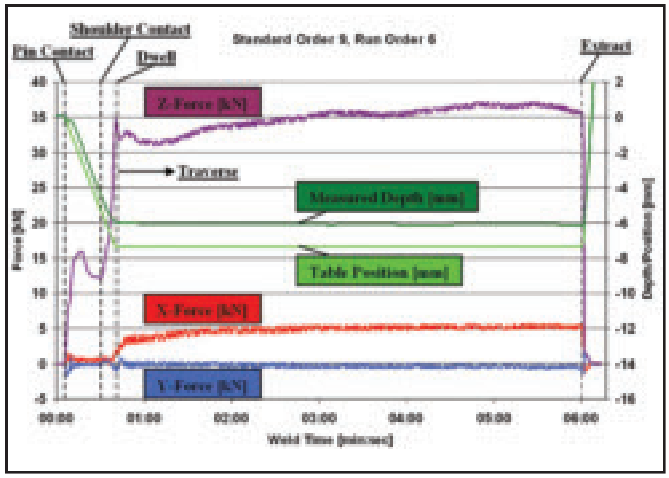

Fig. 6 — *Representative plot of weld depths and forces.*

load, which includes the power required to overcome frictional losses.

Equipment

Plates were friction stir processed (bead on plate) on a retrofitted Kearney & Trecker knee mill with a PLC/PC controller and data acquisition system. The machine is capable of performing welds over 1000 mm in length and has a maximum travel speed of approximately 790 mm/min. Both Z-position and Z-load control are available. Each axis (X, Y, and Z) is servo-driven and the position and velocity of each axis is monitored and recorded at a frequency of 2 Hz during any weld. The power required by the 22.4-kW spindle motor as well as all other measured parameters discussed hereafter are also recorded at 2 Hz. The spindle has a maximum speed of 1500 rev/min.

Mounted to the bed of the mill is a 1219-mm-long dynamometer capable of sensing forces up to 45 kN in the X-direction, 45 kN in the Y-direction, and 90 kN in the Z-direction with a resolution of 0.004 kN. The maximum possible workpiece width is approximately 305 mm. Fixtures for clamping the workpiece are mounted to the upper surface of the dynamometer.

Conditions unique to the current experiment required that the initial thermal condition of the workpiece and fixtures before each run be controlled. A 15.9-mm-thick liquid-cooled aluminum cooling plate was fabricated. A mixture of ethylene glycol and distilled water was pumped through the plate from a chiller and entered the plate at approximately 20°C. The flow to the plate could be stopped any time by a valve. Coolant inlet temperature, outlet temperature, and a calculated temperature difference (outlet – inlet) for the plate were continually monitored and recorded. A 4.8-mm-thick steel anvil was placed on top of the cooling plate for protection and to give a solid backing surface for the workpiece as shown in Fig. 2.

The material used in this study was AL 7075-T7351 with a thickness of 9.5 mm. The plates were sheared to the nominal dimensions of 680 × 222 mm. The oxide layer was removed with a portable disc sander and the surface was cleaned with methanol prior to processing. The thickness of the plate was predetermined so that only partial penetration welds would be run, eliminating any possible interaction that could exist between the tool and the anvil.

Tools were made from heat-treated H13 tool steel. Key tool dimensions include a shoulder diameter of 25.4 mm, pin diameter of 7.9 mm, and shoulder concav-

Table 2 — Factors and Factor Levels in Screening Design

Standard order	Run order	Spindle speed [rev/min]	Feed rate [mm/min]	Plunge depth [mm]	Pin length [mm]	Weld cooling	X start distance [mm]	Weld location	Preweld cooling [°C]	Dwell time [s]
1	14	300	102	PL + 1.14	4.8	No	25	Edge	3.5	10
2	4	500	102	PL + 1.14	4.8	Yes	25	Center	6	2
3	3	300	203	PL + 1.14	4.8	Yes	127	Edge	6	2
4	15	500	203	PL + 1.14	4.8	No	127	Center	3.5	10
5	5	300	102	PL + 1.40	4.8	Yes	127	Center	3.5	2
6	8	500	102	PL + 1.40	4.8	No	127	Edge	6	10
7	1	300	203	PL + 1.40	4.8	No	25	Center	6	10
8	7	500	203	PL + 1.40	4.8	Yes	25	Edge	3.5	2
9	6	300	102	PL + 1.14	6.4	No	127	Center	6	2
10	9	500	102	PL + 1.14	6.4	Yes	127	Edge	3.5	10
11	12	300	203	PL + 1.14	6.4	Yes	25	Center	3.5	10
12	13	500	203	PL + 1.14	6.4	No	25	Edge	6	2
13	16	300	102	PL + 1.40	6.4	Yes	25	Edge	6	10
14	2	500	102	PL + 1.40	6.4	No	25	Center	3.5	2
15	10	300	203	PL + 1.40	6.4	No	127	Edge	3.5	2
16	11	500	203	PL + 1.40	6.4	Yes	127	Center	6	10

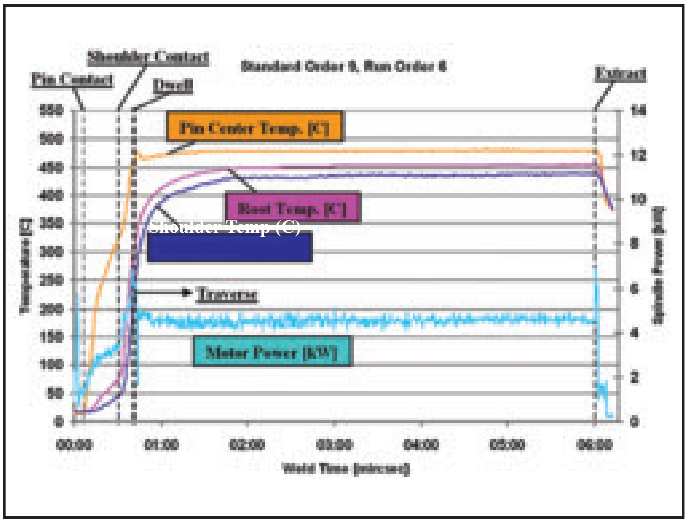

Fig. 7 — Representative plot of tool temperatures and motor power.

ity angle of 6 deg. The pins were threaded with a pitch of 0.91 mm. Pin lengths were 6.4 and 4.8 mm. The tool was used at a tilt angle of 2.5 deg.

Tools were modified to accommodate Type K thermocouples for temperature measurement at three locations within the tool. An EDM drill was used to cut long, straight, squared-bottomed holes to accommodate 1.59-mm-diameter stainless steel sheathed thermocouples at the locations defined in Fig. 3. The titles of each location should be noted (pin center, root, and shoulder). The distance between the thermocouple and tool/workpiece interface at each location was less than 1.27 mm.

A liquid-cooled tool holder was used to minimize heat flow into the machine head, as seen in Fig. 4. The coolant flow rate was approximately 1.9 L/min and is such that while welding there was typically less than 1°C rise in coolant temperature from the inlet of the tool holder to the outlet. Access holes near the top of the tool holder allowed the tool thermocouples to be inserted through the back of the tool.

A transmitting collar assembly is clamped to the rotating portion of the tool holder and houses RF transmitters, which broadcast the thermocouple readings as FM signals. The signals are captured by the receiver by way of a stationary loop antenna. The data are then transferred to the data-acquisition system.

Mounted to the tool holder is an electronic digital indicator for tool depth measurement. It has a range of 25.4 mm and a resolution of 0.02 mm. An extension adapter is connected to the indicator so that weld depth is measured as close to the tool as possible to account for any local changes in tool depth. Readout error associated with attaching such an adapter is estimated to be 0.03 mm or less. The indicator readings are transferred to the data acquisition system throughout the weld.

This digital indicator is used to measure the actual plunge and weld depth as seen in Fig. 4. Due to machine deflection, the programmed plunge depth will not actually be achieved. Thus, it is important to measure the actual tool depth throughout the weld. The indicator is zeroed when the tip of the pin comes into contact with the workpiece.

Friction Stir Processing Procedure

Plates were friction stir processed (FSP) in the following manner. A plate was secured at a predetermined location on the anvil. Preweld cooling was performed to meet the condition specified in the DOE. The plunge sequence was performed at 500 rev/min and at a plunge rate of 12.7 mm/min to the specified depth. The spindle speed during the dwell remained at 500 rev/min. After the dwell, the spindle speed was adjusted to the value dictated by the DOE and the tool began to traverse at a rate of 51 mm/min. The feed rate was then increased at a constant acceleration over a distance of 76 mm until the desired feed rate was obtained. No adjustments in load control or tool depth control were made throughout the processing. Each extract sequence was performed at a spindle speed of 500 rev/min.

Upon completing the 16 welds, the raw data were plotted and organized using a spreadsheet. For each weld, a steady-state (SS) region was identified starting at 127 mm into the weld and ending at 25.4 mm from the end of the weld. For each response of interest, values were averaged over that steady-state region for use in further analysis. This steady-state region, along with the averaged values for three selected responses, is shown in Fig. 5 for the weld listed as standard order 9 (see Table 2).

All extracted data were analyzed using *Minitab*, a statistical software package capable of DOE factorial design analysis. The principal effects of all nine input factors were calculated, and a Pareto chart was created for each given response. This method of analysis shows graphically which factors are most important and significant in reaching a desired response. Conclusions were drawn from the Pareto charts.

Table 3 — Measured Responses Shown in Standard Order (nonrandomized order)

Standard order	SS X-force [kN]	SS Y-force [kN]	SS Z-force [kN]	SS pin center temp. [°C]	SS root temp. [°C]	SS shoulder temp. [°C]	SS motor power [kW]	Shoulder depth [mm]
1	4.942	–0.813	36.453	483	455	446	4.5	0.242
2	4.956	0.089	37.168	515	481	476	5.7	0.200
3	5.558	–0.024	33.719	457	437	435	4.6	0.282
4	7.699	0.542	36.750	503	471	466	5.9	0.336
5	5.320	–0.692	41.987	487	461	454	4.8	0.133
6	4.423	0.155	37.597	515	479	475	5.7	0.073
7	6.518	–0.660	43.879	477	455	447	5.2	0.157
8	7.361	–0.164	44.434	511	478	474	6.4	0.236
9	5.137	–0.374	35.812	480	453	435	4.6	0.276
10	5.394	1.021	33.295	507	470	459	5.6	0.261
11	7.060	0.290	37.617	465	447	438	5.0	0.291
12	8.390	1.115	36.949	501	468	460	6.0	0.305
13	5.371	–0.540	36.218	478	454	440	4.6	0.247
14	6.103	0.956	39.995	513	475	469	5.9	0.084
15	7.237	–0.019	40.560	468	449	439	5.1	0.273
16	8.246	1.219	42.572	506	472	464	6.4	0.174

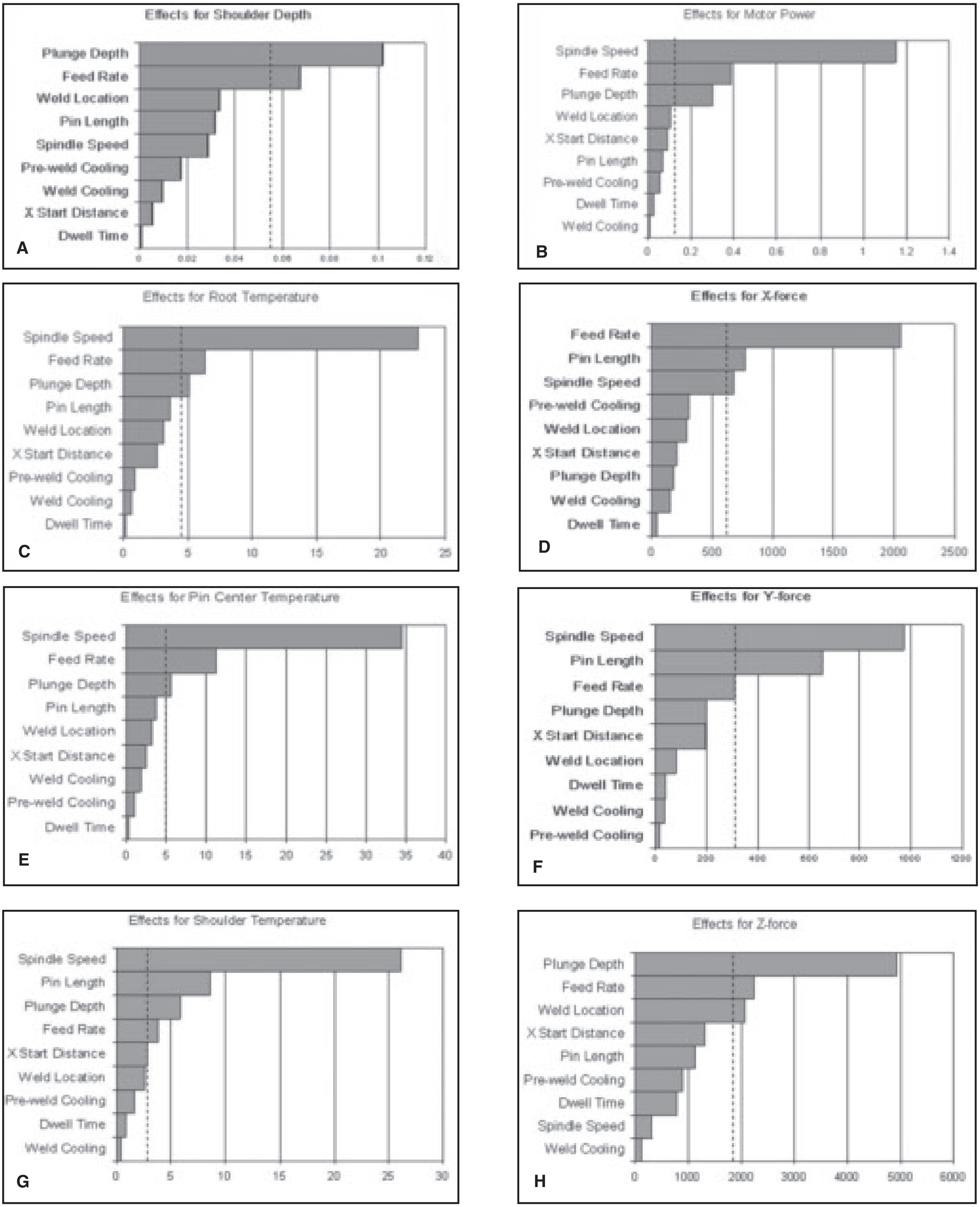

Fig. 8 — Pareto charts of effects of inputs on (A) shoulder depth, (B) motor power, (C) root temperature, (D) X-force, (E) pin center temperature, (F) Y-force, (G) shoulder temperature, and (H) Z-force.

Table 4 — Ranking of Significant Factors for Each Response, One Being the Most Significant

Factor	X-force	Y-force	Z-force	Pin center temp.	Root temp.	Shoulder temp.	Motor power	Shoulder depth
	Responses							
Spindle speed	3	1	–	1	1	1	1	–
Feed rate	1	–	2	2	2	4	2	2
Plunge depth	–	–	1	3	3	3	3	1
Pin length	2	2	–	–	–	2	–	–
Weld location	–	–	3	–	–	–	–	–

Results/Discussion

Temporal Raw Data

Figures 6 and 7 are plots of raw data obtained for the weld listed as standard order 9 and are chosen as representative plots for this study (see Table 2 for input parameters). As noted in the figures, seven of the eight responses and two additional variables (measured depth and table position) are plotted vs. weld time. Measured depth is the actual depth of the tool as measured with the digital indicator and is used to calculate the response shoulder depth. Table position, which is synonymous with plunge depth, is the vertical distance the table travels as dictated by the servomotor. After the plunge sequence, table position and plunge depth are identical in value and do not change until the extract sequence. It should be remembered that these plots are only representative and that each processing run will have its own unique set of values. A brief discussion of these responses as they follow the weld sequence is given below.

As the pin is forced into the material the Z-force increases to approximately 16 kN, then decreases slightly until the shoulder contacts, resulting in the final rise to 35 kN. X- and Y-force traces after shoulder contact are explained in light of the tilt angle of the FSW tool. The rear edge of the shoulder is the first to contact, which, with a counterclockwise rotation in the current setup, produces a negative Y-force. As the pin plunges into the workpiece, the pin center temperature increases, followed by the root and shoulder locations. A more significant rise in temperature at both the root and shoulder locations occurs after the shoulder cavity fills with softened aluminum and as the shoulder comes into intimate contact with the workpiece. As the workpiece material softens during the dwell, the power required by the motor decreases.

No adjustments, load control, or tool depth control were made throughout the processing, which is apparent in the table position trace. The measured depth, however, does not remain constant as it accounts for 0.12 mm of change. The X-force makes an initial jump as the tool begins to traverse and then climbs steadily throughout the traverse, reaching a steady-state value of approximately 5 kN. The Z-force oscillates about a gentle rise throughout the weld, but always remains within 6% of the 35.8 kN steady-state average. The pin center temperature decreases slightly until rising to a steady-state value. The decrease in temperature most likely can be attributed to changes in the spindle speed (this particular weld was reduced to 300 rev/min) and the tool traversing into 'colder' material.

It is notable that the highest measured temperature is at the pin center. This result is consistent for each run in this study. This result is interesting since many analytical approximations for the heat input for FSW attribute maximum heat generation to the outer edge of the shoulder, i.e., at the maximum tool radius (Refs. 11–19). It has been reported that this may also correlate to the location of the maximum tool temperature (Ref. 20). It can be noted that maximum workpiece temperatures have been reported at or near the joint line (Refs. 12, 15, 18, 19, 21, 22). Some have also predicted a maximum temperature near the bottom of the pin when both frictional heating and plastic work are taken into account (Ref. 23). The power required by the spindle remains constant throughout the entire traverse.

Statistical Analysis

A summary of the steady-state averages for each of the chosen eight responses is given in Table 3. The results of the statistical analysis include which 'input' exercises a considerable influence on a response. An effect can be thought of as a proportionality constant relating an input and output. If an equation were to be written, the 'effect' β relates the inputs to a response in the following manner:

$$y = y_o + \frac{1}{2}[\Sigma \beta_i X_i]$$

where y represents the response, y_o is the average response, and β_i is the effect that input parameter X_i has on the response. Thus, the larger an effect is, the greater influence it has in determining the response. The form of this equation is assumed to be linear since there is not enough information in the data to predict any other form.

Figure 8 contains Pareto charts that show the absolute value of the effect, on the x-axis, ranked in decreasing order. The dotted line represents a certain level of significance described by α, which was set to 0.1, a commonly used value. The value α is the probability that the statistical analysis will claim an insignificant effect to be significant. The factors whose effects extend beyond the dotted line are primarily responsible for changes in a given response with a 90% (1- α) confidence level, and are deemed significant.

As α decreases, the dotted line moves to the right, which effectively eliminates more factors but identifies significant factors with a greater certainty. It can be seen that there are only two to four significant factors for each response. Effects may not be compared from one plot to the next in Fig. 8. Table 4 contains a ranking of significant effects (numbered, so "1" is the largest effect) for each response.

Spindle speed, plunge depth, and feed rate are generally the most significant factors that affect the FSW process as confirmed in Fig. 8. The assumption that these factors are the most fundamental is now strengthened. Spindle speed and plunge depth are significant in six of the eight responses. Feed rate is significant in seven of the eight responses. Significant influences of operating parameters on response variables will now be discussed.

Shoulder depth should be affected by plunge depth. This is confirmed in Fig. 8A. Feed rate is also significant as expected. As the feed rate increases, the incoming material will deflect the shoulder so the tool is effectively shallower.

Spindle speed, feed rate, and plunge depth are the three most significant factors in determining motor power as shown in Fig. 8B. Pin length was not shown to be significant, which may be surprising. This may indicate that the shoulder dominates in required motor power, not the pin. Because this study varied the pin length over a small range, the pin length could be significant under other experimental conditions. It is important to note again that motor power in this study is not tool power because it includes losses from friction and the gear train. However, these losses have been quantified through free-wheel experiments to be 1 kW or less for the spindle speeds used in this study.

Common among X- and Z-forces is the significance of feed rate. The most important factors for X-force are feed rate, pin length, and spindle speed as shown in Fig. 8D, 8F, and 8H. The faster a tool is driven through the workpiece and the longer the pin, the larger the required force. It is interesting that plunge depth is not significant for X-force because it has been observed that there is an effect of depth on X-force. Again, there is a heavy dependence of these results on the ranges of parameters used and experimental conditions.

Factors affecting Z-force include plunge depth and feed rate. An unexpected significant effect is weld location. This is likely a good candidate to further consider as an 'environmental' variable that needs to be considered more closely in future studies. It is noted that in welding applications, weld location cannot be controlled. Another unexpected result is that for Z-force, spindle speed has no significant effect as it does for X-force.

For all three thermocouple locations in the tool, spindle speed was the most significant factor in determining temperature. Also common at all three locations is the effect of plunge depth and feed rate. It might be speculated that significant effects for all three temperature locations would be the same. However, this is not the case. Unexpectedly, pin length was a significant factor for the shoulder temperature (Fig. 8G) but not for the pin center and root temperatures.

It is essential to note that this study does not clarify interaction effects between factors. There may be important interactions that are not elucidated here. The screening experiments used in this study do not fully explore all relationships, but only allow identification of the most important ones. Therefore, no conclusion may be made regarding complete relationships. Also, it is vital to note that the significance of these factors is true only for the conditions of this study. For example, a dwell time of 60 s could affect some responses but this study only included 2 and 10 s dwell times.

Weld location and pin length are good candidates to be further controlled as the 'environmental' variables that need to be considered more closely in future studies because of their effect on responses.

This research was performed to provide basic information. It does not seek to comment much on its findings as compared to previous research or to fully explore parameter relationships. This is because results have been contradictory at times. The authors' intent is to 1) identify critical process parameters through a statistical study, 2) present the results publicly, and 3) provide information that other studies may use to fully explore process parameter relationships.

Conclusions

This study used statistical experimentation to study important process parameters and the sensitivity of operating conditions to these process parameters. It is concluded that for the conditions of this study (tool, material, methods, levels, etc.):

- Spindle speed, feed rate, and plunge depth are the three most significant factors of the FSW process.
- Z-force is most affected by plunge depth; feed rate and weld location had secondary effects.
- Spindle speed had no effect on Z-force.
- X-force is most affected by feed rate, followed by pin length, and spindle speed.
- Shoulder temperature is most affected by spindle speed, followed by pin length, plunge depth, and feed rate.
- The location of the weld relative to the sides of the plate affects Z-force.
- The tool temperature at the axis near the end of the pin is higher than the temperature near the root of the pin and at the outside edge of the shoulder.

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Examination of Crater Crack Formation in Nitrogen-Containing Austenitic Stainless Steel Welds

Cracking sensitivity in 317L and 904L was evaluated for welds introduced with nitrogen up to 5 vol-%

BY D. D. NAGE AND V. S. RAJA

ABSTRACT. A systematic study of the effect of nitrogen addition on the crater cracking tendency of 317L and 904L austenitic stainless steel welds was carried out. To conduct the experiment, nitrogen content of the welds was altered during welding by introducing various levels of N_2 (up to 5 vol-%) into the argon shielding gas. Crater cracking tendency was determined using FISCO test setup. The extent of solidification cracking was determined by using the hot cracking sensitivity factor, f_s. In the case of 317L welds, no appreciable rise in hot cracking sensitivity was noticed until 3 vol-% N_2 was added to the shielding gas. In the case of the 904L weld, crack sensitivity initially decreased for an addition of 0.5 vol-% N_2 and then increased gradually with further N_2 addition. The explanation for this observed behavior is discussed in this paper.

Introduction

Welding is a commonly adopted technique for joining austenitic stainless steel components. Solidification cracking or hot cracking due to welding is a major concern of these materials. It is known from the literature that hot cracking can be avoided if the weld solidifies by primary ferritic mode (requiring $Cr_{eq}/Ni_{eq} > 1.5$) (Refs. 1–6) and if the trace impurities like P and S are controlled (such that P+S remains lower than 0.02 wt-%) in the weld (Refs. 2, 7–11). Unfortunately, ferrite is not desirable for some process applications, as it may be subjected to preferential attack. Also, in high-temperature services, ferrite may transform into embrittling sigma and intermetallic phases. Hence, to attain fully austenitic welds, nitrogen, an austenite stabilizer, is introduced through the shielding gas.

The role of nitrogen toward hot cracking is controversial. There is no firm evidence supporting the advantages of nitrogen in preventing hot cracking. Many investigators have found nitrogen additions to be undesirable against hot cracking, as nitrogen makes δ ferrite unstable (Refs. 5, 11–14), and a few have found nitrogen to be beneficial toward hot cracking resistance (Refs. 8, 15, 16). It is well known that nitrogen influences weld microstructure, decreasing its delta ferrite contents, changing the solidification mode, and decreasing the secondary dendrite arm spacing.

Matsuda et al. reported that nitrogen additions up to 0.2 wt-% in 304 stainless steels made it resemble 310 welds, which solidify by the fully austenitic mode. This leads to segregation of trace impurities like S and P, enhancing hot cracking tendency (Ref. 17). Shankar et al. reported that interaction between P and nitrogen is deleterious for hot cracking resistance and the presence of Nb enhances the detrimental effects of N (Refs. 8, 11). On the contrary, Lundin et al. found that nitrogen had relatively little effect on fissuring even when the Ferrite Number (FN) was reduced to 0.5 from 5 (Ref. 15). Ogawa and Tsunetomi also found addition of nitrogen to decrease the crack length for 1 to 10% strain rate than those welds prepared without nitrogen in Ar shielding gas (Ref. 11). In 316L welds, nitrogen actually reduces cracking susceptibility accompanied by refinement of solidification substructure (Refs. 8, 18). A few authors have even indicated that the γ/γ interfaces act as sinks for harmful impurities (Refs. 8, 16). Similarly, Borland and Younger reported that 0.05–0.06 wt-% N in 18:8 stainless steel welds does not exhibit harmful influence on cracking in absence of Nb (Ref. 18). One reason for reduction in hot cracking tendency is that nitrogen inhibits Si at grain boundaries (Ref. 11).

It must be noted that a weld discontinuity termed as crater crack is found at the end of the solidifying weld pool in those welds that are said to be free from solidification cracks. The examination of craters would be interesting because the length of the craters when exceeding a certain minimum length, is termed a hot crack or solidification crack. The present paper examines the effect of nitrogen addition on the crater cracking tendency of 317L and 904L welds, which solidify by primary delta ferrite and primary austenite mode, respectively. These filler metals were welded onto a 316L base plate.

Experimental

Stainless steel 316L sheets of 200-mm length, 100-mm width, and 3.15-mm thickness, and 317L and 904L welding wires of 3.2 mm diameter were used in the present study. The nominal chemical compositions of the base metal and filler metal are given in Table 1. The edge preparation was a U geometry made at the center, along the length of the plate. A sectional view of this U-groove, giving various dimensions, is shown in Fig. 1. U edge preparation over commonly used V edge was preferred as the former gave rise to lower weld dilution (~60%) than the latter (90%) under the present welding conditions. The dimensions of the U-groove allowed the welding wire to fit very well in it. Welding was carried out using an automatic Transarc 500 (Fronius) gas tungsten arc (GTA) welding machine with direct current electrode negative (DCEN) polarity. Argon gas at a flow rate of 8 L/min was used as a shielding gas. Nitrogen was also introduced into the Ar shielding gas. For this, the nitrogen

KEYWORDS

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Hot Cracking Sensitivity
Nitrogen

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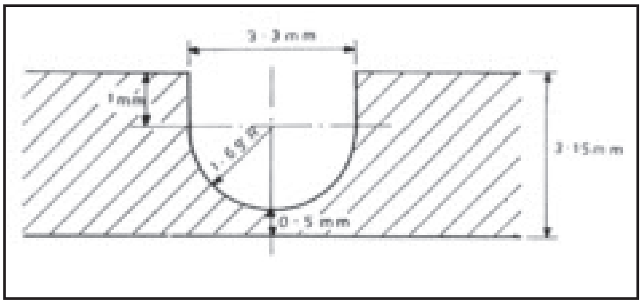


Fig. 1 — Dimensions of U-groove used for welding.

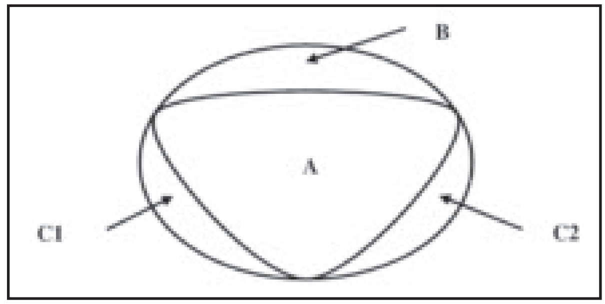


Fig. 2 — A schematic of short-transverse section of weld nugget indicating various regions of weld bead denoted by alphanumerics. This pictorial view is used for calculating percentage dilution using a mathematical equation.

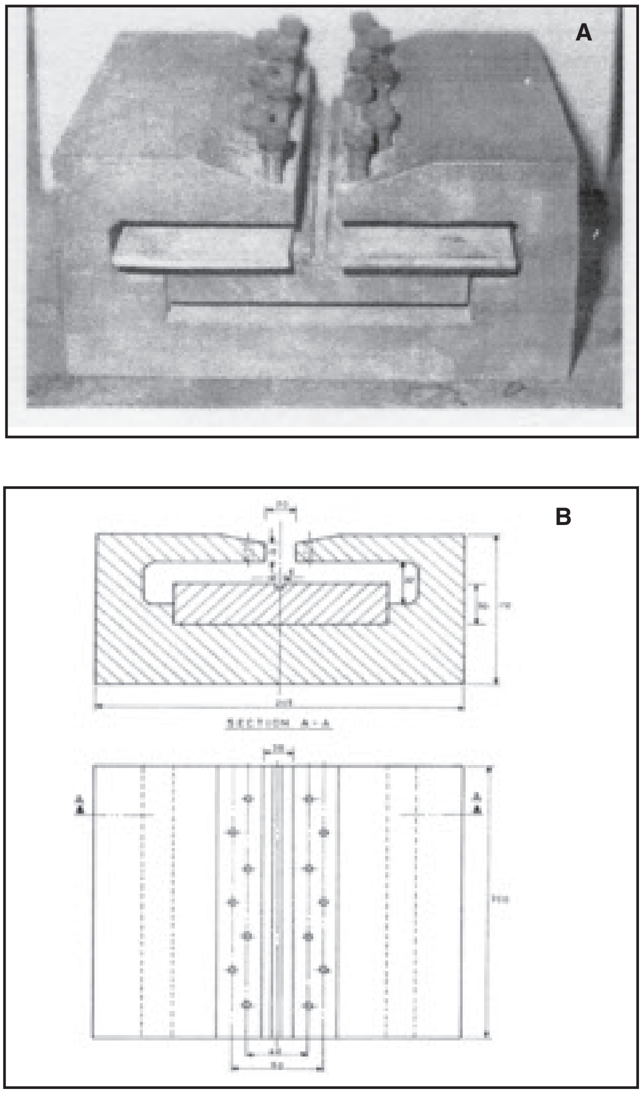


Fig. 3 — Details of FISCO apparatus. A — A photograph of FISCO apparatus; B — schematic drawing.

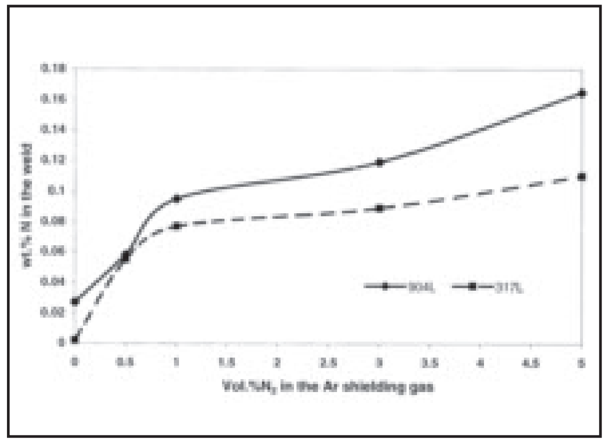


Fig. 4 — Variation of nitrogen contents in welds as a function of nitrogen in the Ar shielding gas.

was mixed with Ar in a specially designed mixing chamber, after it was sent through a rotameter to fix its levels in the shielding gas.

The volume percentages of nitrogen were 0, 0.5, 1, 3, and up to 5 in Ar shielding gas. The welding parameters, like the welding current and welding speed, were standardized with many welding trials. The optimized weld parameters were as follows:

- Welding speed of 4.3 mm/s,
- Heat input less than 0.3 kJ/mm
- Distance between electrode tip and the top surface of the base plate maintained to 4.5 mm.
- The welding currents optimized for 317L and 904L were 145 and 160 A, respectively, for the welds produced without nitrogen in the shielding gas. Upon introducing nitrogen in the shielding gas, the current values were reduced to 140 and 155 A, respectively. This is because nitrogen leads to weld penetration and concavity (Refs. 19, 20).

The present current levels are higher than that used in our previous work (Refs. 21, 22). This was because the delta ferrite content of the weld significantly varied from the root to the crown of the weld at low heat input values. Such a variation can alter various properties of the weld from the root to the crown, making it difficult to examine only the effect of nitrogen. This becomes even more important when the welds are examined for their stress corrosion behavior, which is the main theme of our work (Refs. 23–25).

The Ferrite Number (FN) of the welds was measured by means of a calibrated Fischer Fe-8 Feritscope® (DIN 50981 or ISO 2178) along the length of weld. The calibration was carried out using zero setting and a setting foil of closely controlled thickness over a ferromagnetic material. The average of about 8 to 10 readings obtained over the weld is given as the FN of the weld. The FN was cross-checked by quantitative metallography in terms of

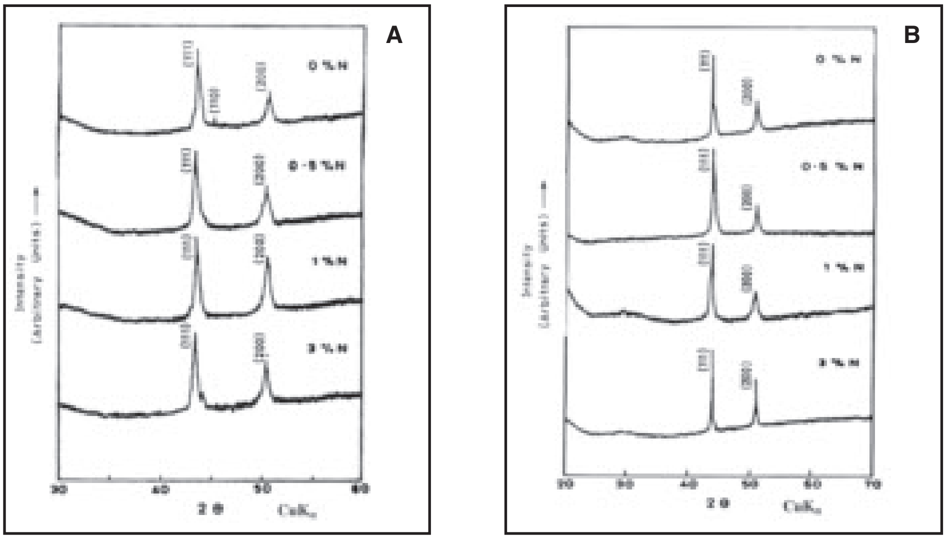


Fig. 5 — X-ray diffraction patterns. A — 317L welds; B — 904L welds with different nitrogen contents. The peaks (111) and (200) correspond to austenite, and (110) corresponds to ferrite phase. It is clear from 317L patterns that with nitrogen addition the (110) peak disappeared. This is because the ferrite transforms to austenite completely with nitrogen addition.

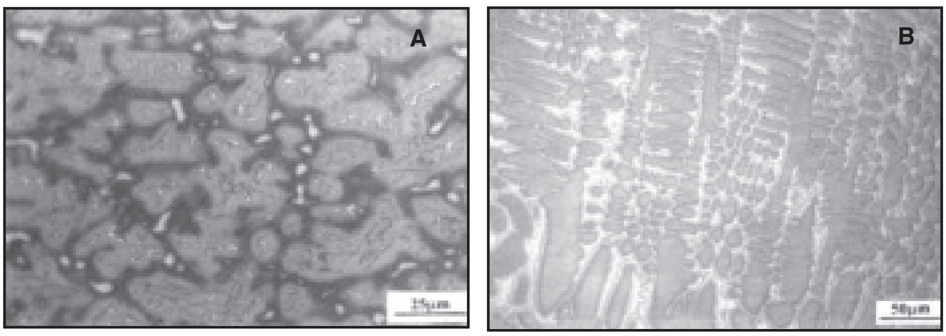


Fig. 6 — Color optical micrographs of 317L welds shown in grey scale. A — With 0 vol-% N_2, showing vermicular delta ferrite (bright contrast) in the center of austenite dendrites (darker) and interdendritic regions (dark contrast) with bright contrast; B — 1 vol-% N_2 in the Ar shielding gas, showing the absence of δferrite in the austenite dendrites (dark contrast). The interdendritic regions are light in color indicating high Cr contents, which are possibly secondary austenite transformed from delta ferrite and/or eutectic mixture.

volume fraction and was found to be in agreement for a weld having 8 FN. The nitrogen content of the weld was analyzed from the chips of weld fusion zones by LECO test. The percentage dilution (%D) of the welds was calculated as per Equation 1 given below.

%D = (C1+C2) / (A+B+C1+C2) (1)

The details of various abbreviations used in this equation are delineated in Fig. 2, where A = area of the U groove, B = area of reinforcement of the weld, C1 and C2 = area of diluted regions of the weld nugget.

Percent dilution was calculated by taking a short transverse section of the weld and subjecting it to polishing and etching. This was then projected over profile projector and the above parameters were measured.

For microstructural studies, various sections of the weld fusion zones were cut, polished to mirror finish, and color etched using modified Beraha's reagent (Refs. 26, 27). These samples were then observed over a Riechert MeFe3 microscope. X-ray diffraction (XRD) studies were carried out on the weldments in the range of 20 to 70 deg glancing angles at a scan rate of 1 deg/min, using Philips PW 1820 diffractometer and CuK$_\alpha$ radiation.

The hot cracking sensitivity of a weld was determined by a test specially recommended for austenitic stainless steels (Ref. 28), named as FISCO test, performed using FISCO apparatus (Ref. 29). For this study, an in-house fabricated FISCO apparatus (Fig. 3) was used with a slight modification in the design given in Ref. 29, where the sideways screws are not present. This

Table 1 — Chemical Compositions (wt-%), Calculated Cr_{eq}, Ni_{eq}, and Impurity Contents (P + S) for 316L and 904L Filler Metals

Element/Material	316L	317L	904L
C	0.025	0.02	0.01
Mn	1.52	1.61	1.89
Si	0.49	0.39	0.37
P	0.026	0.025	0.013
S	0.010	0.011	0.001
Cr	17.13	18.69	19.95
Ni	11.58	13.57	25.00
Mo	2.610	3.21	4.35
Cu	—	0.75	1.39
N	<0.010	0.031	0.037
Cr_{eq}	21.44	23.67	26.47
Ni_{eq}	12.29	15.24	27.18
Ratio Cr_{eq}/Ni_{eq}	1.69	1.51	0.96
(P+S)	0.036	0.036	0.014

Note: Hammar and Svenson formula used.

Table 2 — Hot Cracking Sensitivity Factor of 317L and 904L Welds with Varying Nitrogen Contents in the Shielding Gas

	Hot cracking sensitivity factor, f_s, at different nitrogen levels				
Substrate/Filler	0 vol-% N_2	0.5 vol-% N_2	1 vol-% N_2	3 vol-% N_2	5 vol-% N_2
316L/317L (wt-% N)	0.6% (0.022)	0.6% (0.055)	0.6% (0.077)	0.6% (0.089)	4.1% (0.11)
316L/904L (wt-% N)	14.6% (0.027)	9.3% (0.058)	10.3% (0.095)	10.6% (0.0119)	11.8% (0.165)

Table 3 — EDAX Results of 904L Welds with 0.027 and 0.058 wt-% N

Elements (wt-%)	Weld with 0.027 wt-% N		Weld with 0.058 wt-% N	
	Dendrite	Interdendrite	Dendrite	Interdendrite
Cr	15.62	19.07	17.70	18.70
Ni	26.37	19.82	23.56	23.96
Si	0.12	1.35	0.60	0.94
Mo	3.14	4.57	4.03	4.45

variation was required because a single 316L plate with central U groove along the length was used in the present study; unlike the two separate plates normally used when two individual plates are butt joint welded. The sideways screws in the design given in Ref. 29, help to change the root opening.

In this study, the 316L plate was placed over the cogged plate in such a way that the U-groove was over the furrow of the FISCO apparatus over which rests the welding wire. In order to get more starts and ends, four beads each of 40-mm length and 5-mm interweld distance were deposited. Welding was carried out using the standardized welding parameters mentioned before. After welding, the welded plate was clamped in a vice and the beads were bent by striking the other side with a hammer. The ends of the beads were examined by the naked eye and a magnifying lens for the presence of any cracks before and after hammering. In order to reveal the microcracks, a dye penetration test (Ref. 30) was carried out on the bent plates. The crack lengths of the bent plates were measured with vernier calipers and the crack sensitivity factor, f_s (Ref. 29), was calculated as follows:

$$f_s = (\text{total crack length/total length of 4 weld beads}) \times 100 \quad (2)$$

If $f_s < 20\%$, the cracks were confined to craters and were categorized as crater cracks. Over this value, if cracks extended beyond the crater, the cracks were classified as solidification cracks (Ref. 29).

The test severity depends on plate thickness (0–40 mm), chamfer shape, and gap between the plates (Ref. 29). These parameters were constant and the only variable was the nitrogen introduced in the welds through the shielding gas. The crater crack ends of the weld beads were later examined using a Cameca SU 30 scanning electron microscope (SEM). For this study, polished samples were etched by methanolic aqua regia (45 mL HCl, 15 mLHNO_3, 20 mL 1N methanol) (Ref. 27). The wave dispersive spectra (WDS) were carried to get an idea of the segregation or distribution of various elements. In some cases, energy dispersive analysis by X-rays (EDAX) was also carried out using LEO 1455 SEM.

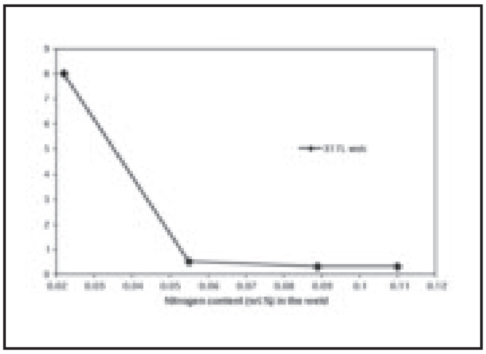


Fig. 7 — Effect of nitrogen additions on the Ferrite Number (FN) of 317L welds.

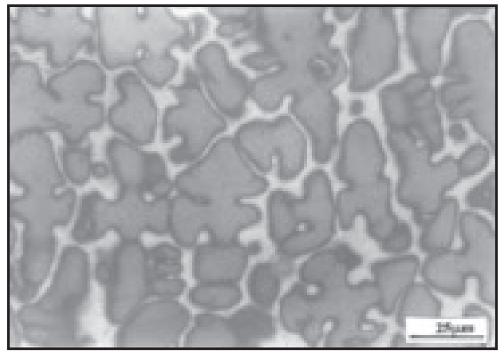


Fig. 8 — Color metallographs of 904L weld in grey scale showing green austenitic dendrites (dark contrast), indicating austenitic mode of solidification. Interdendritic regions are in bright contrast.

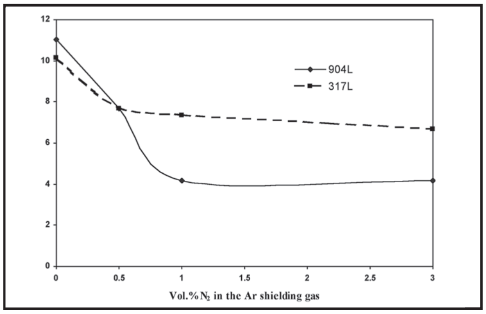


Fig. 9 — Plot of secondary dendrite arm spacing vs. vol-% N_2 in the Ar shielding gas demonstrating effect of nitrogen on the secondary dendrite arm spacing (micrometer). The secondary arm spacing decreases as the wt-% nitrogen in 317L and 904L weld increases.

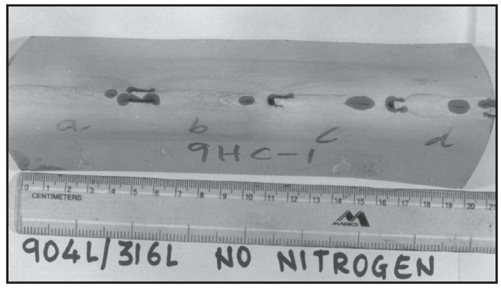


Fig. 10 — Dye penetrant tested (DPT) plate used for measuring crack length for calculating hot cracking sensitivity factor. Red coloration (dark contrast) highlights the crater cracks and the interweld gap in between two beads.

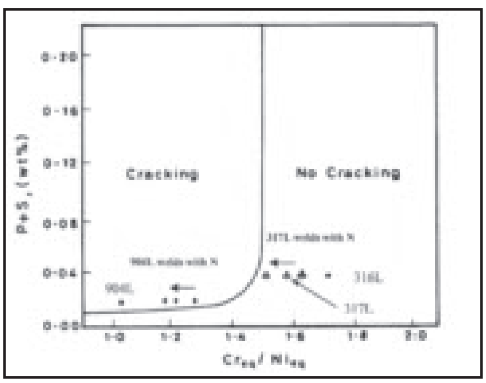


Fig. 11 — (P+S) vs. Cr_{eq}/Ni_{eq}, showing location of 316L, 317L, and 904L consumables and the resultant welds with increasing nitrogen, toward susceptibility for hot cracking. (Legends ♣ and ◆ represent 317L welds and 904L welds, respectively. The addition of N is expected to shift these points toward the left. The legend • represents 904L filler metal and 316L alloys.) (Ref. 2).

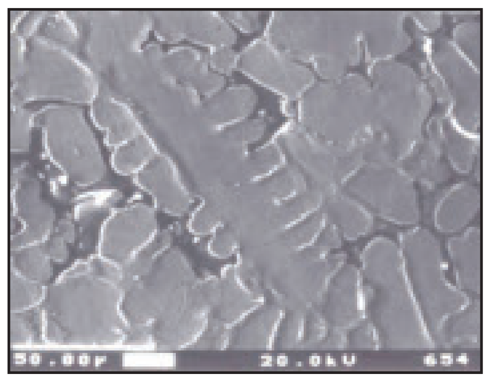


Fig. 12 — Scanning electron micrograph of crater crack formed at the centerline in case of 904L weld. This crack seems to propagate interdendritically.

Results and Discussion

The nitrogen content variation in the weld is shown in Fig. 4. The figure shows that the wt-% nitrogen in both 317L and 904L welds increased as the nitrogen in the shielding gas was increased. Such a rise in nitrogen content of the weld is in agreement with the earlier work (Refs. 13, 15, 31).

The X-ray diffractograms obtained for both 317L and 904L welds with varying nitrogen contents are shown in Fig. 5A and B, respectively. The patterns in both the cases

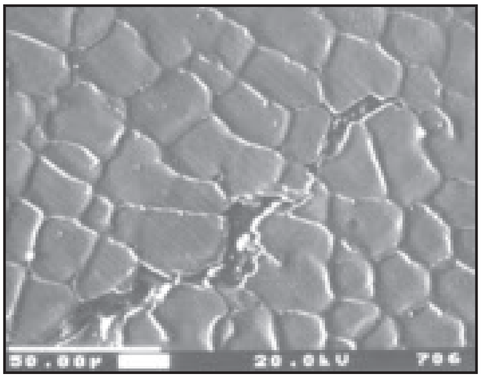


Fig. 13 — Scanning electron micrograph of an end of the crater crack of 317L. The crack seems to propagate across the dendrites at some places.

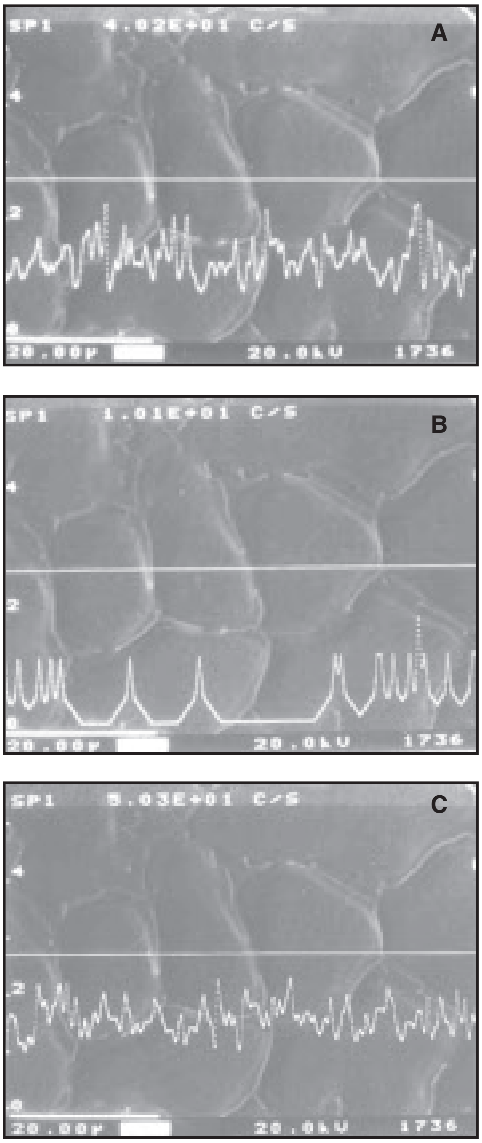


Fig. 14 — WDS patterns of 317L welds prepared without nitrogen in the shielding gas for (A) Cr, (B) S, and (C) Ni. Cr is seen in dendrites as well as in interdendritic regions. Sulfur was not detected at the interdendritic regions and found in dendrites and at triple junctions of grains. Ni is less at interdentritic regions.

can be indexed satisfactorily for an austenite phase. However, a small amount of δ ferrite, as revealed by the presence of (110) peak in the case of the 317L weld obtained without N_2 in the shielding gas. Upon the addition of nitrogen, this peak corresponding to δ ferrite disappeared. Microscopic and ferritoscopic studies further confirmed the X-ray diffraction data. The former showed ferrite in the dendrites with vermicular morphology (Fig. 6A), and the latter measured a Ferrite Number (FN) of 8. With the addition of nitrogen, the ferrite in the dendrites disappeared (Fig. 6B), and the FN dropped to 0.3. This effect of nitrogen on the FN is shown graphically in Fig. 7. A typical micrograph of 904L weld obtained with no N_2 in the shielding gas is shown in Fig. 8 for comparison with 317L weld. According to the literature, Ni-rich phases (mostly austenite) exhibit color contrast varying from blue to green and Cr-rich phases exhibiting color contrast varying from reddish to yellow (Refs. 26, 27). Based on the above criteria, it can be said that 317L welds with nitrogen addition and all the 904L welds, obtained with and without N_2 in the shielding gas, exhibit Ni-rich austenite dendrites (green in color) with dark contrast, and Cr-rich interdendritic (yellow in color) regions with bright/light contrast. Though the Cr-rich phases can be δ-ferrite, the interdendritic regions may not completely belong to this phase, as XRD and Feritscope® data too did not show the corresponding amount of delta-ferrite.

The variation in secondary dendrite arm spacing of the 317L and 904L welds without and with nitrogen in the Ar shielding gas was also measured using a calibrated scale of the eyepiece. As the nitrogen content increased, the secondary dendrite arm spacing was found to decrease — Fig. 9. The secondary dendrite arm spacing is reported to be a function of cooling rate and the mobility factor (Ref. 32). As the heat input of all the welds was almost same, the variation in cooling rate is assumed to remain constant, it being less significant (Ref. 33). The mobility factor has been related to surface tension of the melt and partition coefficient of the elements. These two factors in turn depend on the composition of the weld. The present welds are obtained with various N levels. Hence, the decrease in the secondary dendrite arm spacing can be attributed to the N. A detailed calculation of the change in the mobility factor upon nitrogen addition to austenitic stainless steel welds has been communicated by the authors (Ref. 34).

A photograph of a typical plate subjected to dye penetration test is shown in Fig. 10 and the data of hot crack sensitivity factors of 317L and 904L welds as a function of volume percentage nitrogen in the shielding gas and wt-% is summarized in Table 2. As the hot crack sensitivity factor in all these cases is lower than 20%, the welds can be considered to be resistant toward hot cracking. Visual examination of these welds showed the absence of solidification cracks, but craters were noticed in all cases irrespective of whether or not the N was added to the welds. The 317L welds showed negligible intensity of crater cracks even up to 5 vol-% N_2 addition to the shielding gas. This can be attributed to possible presence of δ-ferrite at high temperature along with the effect of nitrogen in decreasing secondary dendrite arm spacing. The 904L welds were found to exhibit higher cracking tendency than 317L welds though these cracks were within the critical limit to call them solidification cracks. Notably, the hot cracking sensitivity of 904L was minimal with 0.5 vol-% N_2 in the shielding gas.

Hot cracking in a weld depends on various factors like thermomechanical stresses, welding process, welding parameters, and chemistry of the weld (Refs. 35–38). It was reported by Lundin et al. that cold fed GTA-welded beads are less susceptible to hot cracking as was used in the present study (Ref. 15). The hot cracking propensity can be reduced by the presence of high-temperature delta ferrite (Cr-rich) (Refs. 2, 3, 6). The higher Cr content in the interdendritic regions can be seen in the following manner. It is possible that at high temperatures, these regions existed as delta ferrite, although the Cr content of these regions is not sufficient enough to retain its BCC structure at room temperature. It can transform to austenite by solid-state transformation. Therefore, under these conditions, Cr in interdendritic regions can dissolve more sulfur. Moreover, ferrite is ductile enough to resist the growth of cracks (Ref. 3). Sulfur is soluble in Cr-rich delta ferrite or it can form compounds (inclusions) with Cr, apart from Mn in Fe-Cr-Ni system (Ref. 14). Wilken and Kliestner and Astrom et al. have reported that the presence of eutectic ferrite (Ref. 28) and inclusions (Ref. 13) both are desirable as they pin the crack growth or complicate the crack path. The crack morphology changes to brittle from ductile as the Cr content in interdendritic regions keeps on decreasing (Ref. 17). Other elements that have detrimental effects on hot cracking resistance include Si (up to 2 wt-%) (Ref. 11), Fe and Ni in the presence of trace impurities like S and P. The mechanism for exacerbating hot cracking in many instances is formation of low melting point films (sulfides, phosphides, and silicates) in the interdendritic regions (Ref. 14). This brittle film ruptures due to stresses giving hot cracks (Refs. 18, 37).

The effect of nitrogen addition on the solidification cracking tendency of fully austenitic steel welds (like 904L in the present study) can be understood in the following manner:

According to the pseudo-binary phase diagram (Ref. 38), N addition shifts the composition of the alloy, which will lie away from the eutectic (Ref. 39). This also leads to a reduction in the solidification range. For this reason, S segregation becomes higher in these welds (Ref. 17). This also leads to a reasonable segregation of the major alloying elements. Thus, for primary austenitic solidifying welds, S along with Cr will remain in eutectic regions, but the addition of nitrogen has two distinct effects in this study: 1) a decrease in secondary dendrite arm spacing, and 2) a reduction in partition coefficient.

The decrease in secondary dendrite arm spacing leads to more interfacial area (Refs. 6, 8). As reported by Lippold and Savage, the distribution of the trace impurities over a wider area results in lowering the intensity and continuity of localized impurities. This results in reduction in hot cracking (Ref. 6). At higher levels of nitrogen, the accumulation of sulfur in the interdendritic regions overrides the effect of nitrogen decreasing the arm spacing, which makes welds susceptible toward hot cracking.

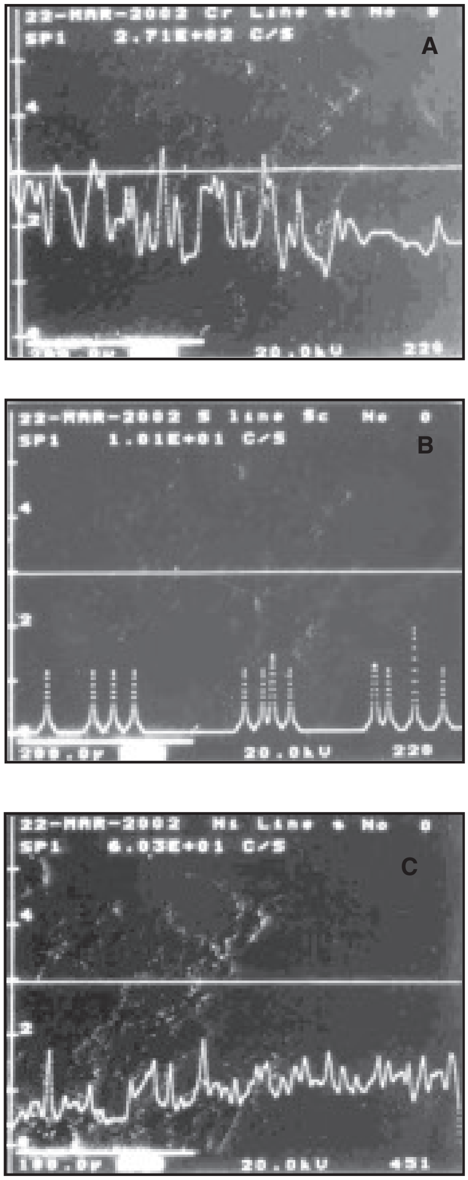


Fig. 15 — The WDS taken for 317L welds prepared with no nitrogen in the shielding gas. A — Cr; B — S; C — Ni at the craters of 317L welds.

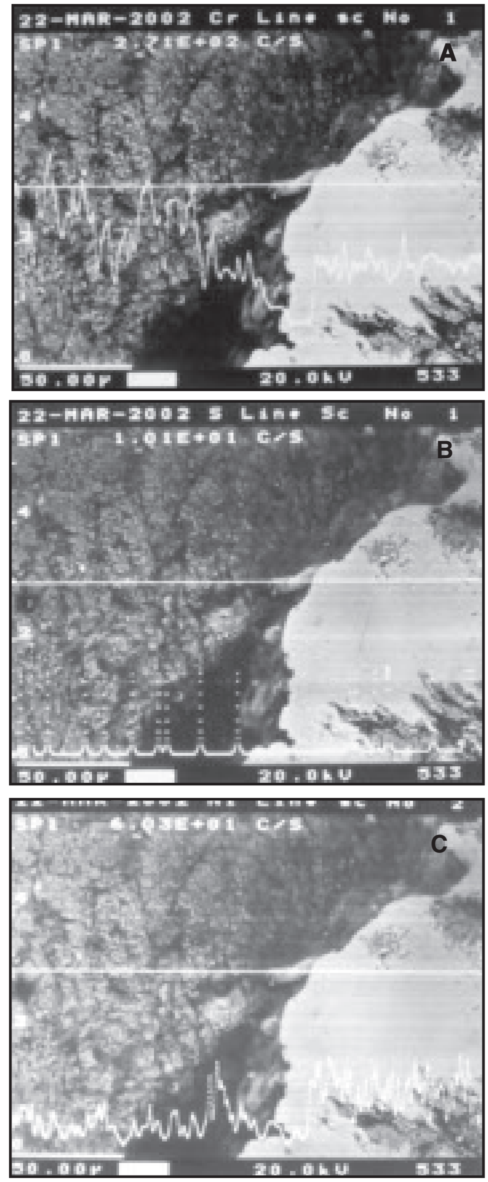


Fig. 16 — The WDS taken for 317L welds prepared with 0.5 vol-% nitrogen in the shielding gas. A — Cr; B — S; C — Ni at the craters of 317L welds.

The hot cracking tendency of austenitic stainless steel welds can be avoided by 1) ensuring the primary delta ferrite mode of solidification of the weld, and 2) lowering S and P levels of the welding wires. The former depends on (Cr_{eq}/Ni_{eq}) and the (P+S) limit depends on dilution value as brought out by Fig. 11 (Ref. 38). In the same diagram, positions of the current welds are also marked to get an idea of the hot cracking tendency of the welds.

The (Cr_{eq}/Ni_{eq}) and the (P+S) values were obtained based on the dilution measurements. The amounts of dilution obtained for 317L welds were 47, 43, and 41%, while that of 904L welds were 63, 61, and 59%, corresponding to 0, 0.5, and 1 vol-% N_2 in the shielding gas, respectively. The 316L base metal and 317L filler metal are primary ferritic solidifying alloys. Hence, the resultant weld is prevented from hot cracking, but the addition of nitrogen to 317L welds shifts the mode of solidification to primary austenite (Refs. 1–5). This makes the welds susceptible to solidification cracking, but the present study results (Table 2) indicated all these welds to be resistant to hot cracking.

In the case of the 904L/316L system, the weld obtained with no dilution lies close to the borderline separating cracking and noncracking zones. However, in the current weldments, the change in Cr_{eq}/Ni_{eq} values and (P+S) impurity levels, both due to dilution, shifts the weld fusion zone into the cracking regime as shown in Fig. 11. The addition of nitrogen shifts both welds further into the hot cracking susceptibility regimes. To understand this cracking process in detail, the crater cracks formed at the end of the weld bead were examined using SEM. Microscopy examination of the craters showed cracks to propagate at the centerline of the weld interdendritically — Fig. 12. In the case of 904L welds, cracks extend over a larger area leading to higher crack sensitivity as compared to that of 317L welds. Whereas, cracking is mostly limited to equiaxed dendrites in the case of 317L welds. Figure 13 shows the end of a crater crack, which propagated across the dendrites (ductile) at some places (Ref. 17).

WDS of 317L welds prepared without nitrogen in the shielding gas showed variations of Cr even within the dendrites as

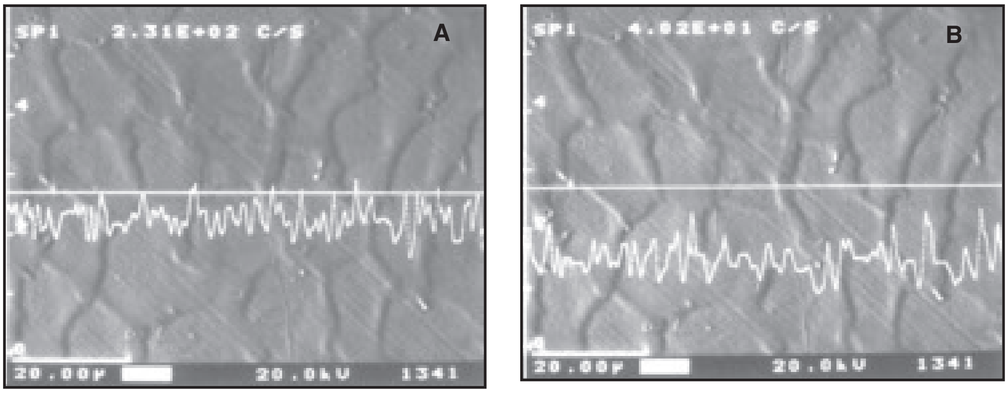
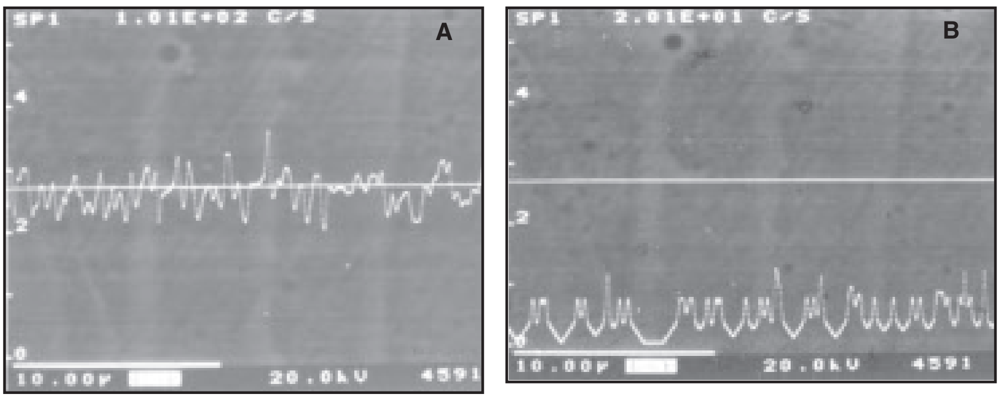


Fig. 17 — WDS patterns of 317L welds prepared with 5 vol-% nitrogen in the shielding gas. A — Cr; B — Ni. The WDS pattern shows the presence of Cr at the interdendritic regions and Ni at the interdendritic regions was leaner.



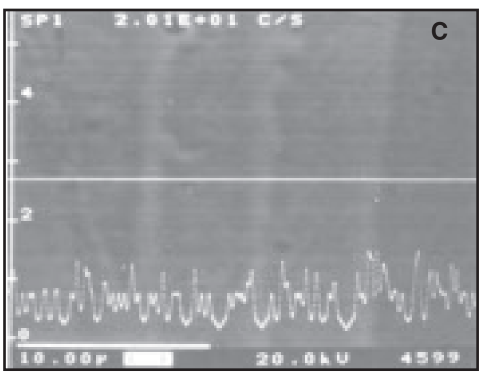


Fig. 18 — Various WDS patterns of 904L welds prepared with no nitrogen in the shielding gas. A — Cr; B — S; C — Si. Cr and Si are higher in interdendritic regions. S distribution is uniform.

well as interdendrites — Fig. 14A. This variation could be possibly due to the presence of vermicular δ ferrite in the dendrite of the predominantly austenite phase and eutectic mixture of austenite and delta ferrite in interdendritic regions. This is comparable to XRD, Feritscope® data, and optical micrograph shown in Fig. 6A having vermicular ferrite in dendrites. However, it is interesting that sulfur was not detected at the interdendritic regions and found within the dendrites and at some triple junctions of dendrites/grains — Fig. 14B. Nickel scans show a reverse of Cr, indicating the interdendritic regions have lower Ni content than the dendritic regions — Fig. 14C. This combination is responsible for no cracking in this weld.

WDS of Cr, S, and Ni obtained at the craters of 317L welds without and with 0.5 vol-% N_2 in the shielding gas show some trends — Figs. 15A–C and 16A–C. With nitrogen additions, Cr and S content in the crack increases (Fig. 16A, B), whereas, the Ni content decreases (Fig. 16C) in the crack. Though this weld showed no ferrite from ferritoscopic studies, it did solidify through a path having ferrite, which is responsible for solidification cracking resistance.

With further addition up to 5 vol-% nitrogen, the weld solidified by the fully austenitic mode, which is in agreement with the optical microscopic studies and Feritscope® data. The WDS patterns of Cr and Ni too showed the presence of higher Cr (Fig. 17A) and lower Ni in the interdendritic regions (Fig. 17B). This weld can be comparable to 904L in terms of solidification and cracking behavior.

The 904L welds prepared without nitrogen in the shielding gas had a higher Cr content in the interdendritic regions (by 3.45 wt-%) and lower Ni content (by 6.54 wt-%) than the dendrites. The trace impurities (S, P, and Si) accumulated at the interdendritic regions that could form compounds preferentially with Cr than with Fe and Ni, thus avoiding hot cracking. A few WDS results support this trend showing higher Cr (Fig. 18A), S (Fig. 18B), and Si (Fig. 18C) in interdendritic regions. All these elements do not show an increment in the same location, possibly due to differences in local solidification rates in a weld.

At 0.5 vol-%N_2 in the shielding gas, a significant reduction in Si was found from 1.23 to 0.34 wt-% (difference between dendrite and interdendritic region) in welds with 0.027 wt-% N and 0.058 wt-% N, respectively (Table 3). The drop in Si content possibly could contribute toward enhancing the hot cracking resistance of the weld (Ref. 11), although a marginal decrease in Cr and a rise in Ni content had a very minor countereffect. Other beneficial effects are a reduction in Fe content in this region — Fig. 19A. Sulfur showed marked localization at some locations and was not present preferentially at interdendritic regions — Fig. 19B. This favorable distribution of these elements resulted in the lowest hot cracking sensitivity in the 904L/316L system.

At 1 vol-% N_2 in the shielding gas, the Ni content in the interdendritic regions had gone up (by 1.03 wt-%) at the expense of Cr (by 0.76 wt-%). This presence of higher Ni is suspected to enhance the cracking tendency.

Conclusions

The effect of N on the crater crack formation was investigated using hot cracking sensitivity factor. In the case of 317L welds, no appreciable rise in cracking sensitivity was noticed until 3 vol-% N_2 was added to the shielding gas. In the case of 904L weld, crack sensitivity initially decreased with an addition of 0.5 vol-% N_2 and then increased gradually with further N_2 additions. The explanations for the behaviors of each are as follows:

The 317L solidifies through a path where high-temperature delta ferrite may exist, even though less or no delta ferrite is retained at ambient temperature. In addition, nitrogen reduces the secondary dendrite arm spacing. The reduction in the secondary dendrite arm spacing re-

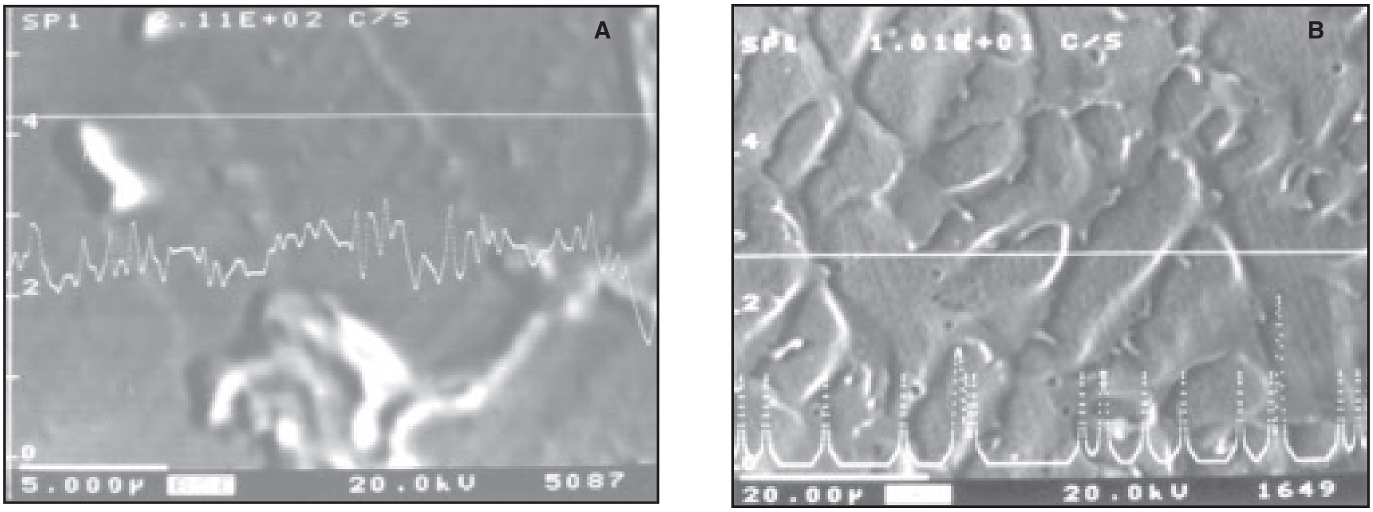


Fig. 19 — Various WDS patterns of 904L welds prepared with 0.5 vol-% nitrogen in the shielding gas. A — Fe; B — S. Fe remains on the lower side for primary austenitic solidifying welds. S seems to get locked; might be as inclusions and shows peaks at certain regions.

tained to reduce the accumulation of sulfides in the interdendritic regions.

In the case of 904L welds, the resistance to solidification cracking arises due to a reduction in the secondary dendrite arm spacing as well as a decrease in Si in the interdendritic region. Notably at higher N levels, Ni tends to partition more at interdendritic regions in preference to Cr, contributing toward the solidification cracking tendency of the welds.

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