WELDING Journal

May 2004

AWS

Torches & Guns

- **Hand Tools to Fit the Job**
- **The Right Spin on Abrasive Wheels**
- **Titanium Filler Metals**

PUBLISHED BY THE AMERICAN WELDING SOCIETY TO ADVANCE THE SCIENCE, TECHNOLOGY AND APPLICATION OF WELDING

Global Leader in Welding Automation

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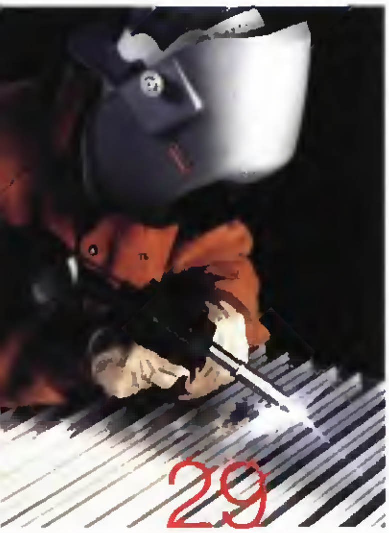

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PRESS TIME NEWS

Airgas to Acquire BOC's U.S. Packaged Gas Business

Airgas, Inc., Radnor, Pa., recently signed a definitive asset purchase agreement to acquire most of the U.S. packaged gas business of The BOC Group, Inc. The transaction is valued at up to $200 million. The Federal Trade Commission has completed its regulatory review, and the transaction is expected to close on or about July 31.

Airgas will acquire about 120 locations in 21 states, including retail stores, warehouses, fill plants, and other operations involved in distributing packaged industrial, specialty, and medical gases, as well as welding equipment and supplies sold through BOC's stores and distributors. The company plans to offer employment to the more than 1000 workers aligned with the operations, which generated about $240 million in revenues in fiscal 2003. Approximately 65% of the revenues were from gas sales and cylinder rent, with the remainder from welding hard goods and supplies.

The transaction will exclude packaged electronic gases, helium, and hydrogen delivered in tube trailer or in liquid form, and bulk gases.

Modular Steel Bridge Speeds Reopening of Southbound I-95 in Connecticut

Crews assembled and erected a modular steel bridge in four days to get traffic moving on a critical section of congested Interstate 95 near Bridgeport, Conn. On Thursday evening, March 25, a fuel truck crashed, spilling home heating oil onto the southbound overpass. The bridge collapsed after the oil exploded and burned.

Acrow Corp., Carlstadt, N.J., built the 80-ft-long, three-lane modular vehicle bridge. The company's crews lifted the bridge without the deck to keep the weight down.

A crane lifts a temporary steel bridge leased from Acrow Corp. onto its abutments for the southbound lanes of Interstate 95. Crews quickly installed the steel deck panels and added an asphalt wearing layer in order to restore traffic. (Photo courtesy of Acrow Corp.)

The steel deck, which consists of orthotropic steel plates, took about two hours to put down, explained Bill Killeen, Acrow's president. Afterward, crews put a standard black asphalt wearing surface on the deck.

The modular bridge is made of high-strength grade 65 steel. "The higher-strength steel lets us use smaller components to keep the bridges lighter," Killeen said. "This version of the bridge will carry live loads of 40-ton vehicles going in one direction. A simple rocker bearing handles expansions and contractions caused by temperature variations."

The state of Connecticut is leasing the modular bridge. When the southbound bridge is rebuilt within the year, crews will disassemble the temporary bridge and return the parts to Acrow.

Acrow is a member of the National Steel Bridge Alliance (NSBA), a nonprofit division of the American Institute of Steel Construction Inc. Members of NSBA consist primarily of steel-producing and fabrication companies.

Barreto Applauds Senate Approval of SBA Lending Bill

U.S. Small Business Administrator Hector V. Barreto called the Senate's passing of legislation that will increase lending authority for the SBA's 7(a) loan program "a great day for small business." The bill, HR 4062, had already passed the House and is expected to be signed into law by President George W. Bush.

The new bill will increase the 7(a) program's lending authority for this year by up to a third, to $12.5 billion. The legislation will also allow the SBA to remove the $750,000 cap on 7(a) loans, returning it to its previous $2 million level. Lenders will have the option to make SBA Express loans of up to $2 million. Piggyback loans will once again be allowed.

In addition, the legislation reauthorizes the 504 loan program and the Small Business Investment Company program through the end of the fiscal year.

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A Year of Accomplishment

This has been a good year for AWS. While the economy has not rebounded as we had hoped, we have adapted well. Our volunteers and staff have worked to continue to provide services while controlling our expenses. The efforts made this year will continue to serve us into the future. Our headquarters staff organization has been realigned to most effectively use the staff's talents to serve our members. A strategic plan, and a business plan to support it, has been produced. We have not had a coordinated set of plans for a few years, so this alone should help improve our direction for the future. Following are just a few of the year's accomplishments.

For the first time, we're offering a program that directly addresses the economics of welding — the Certified Welding Supervisor. This program was developed in response to findings uncovered in the National Shipbuilding Research Program, conducted with the help of Bender Shipbuilding and Repair Co., Mobile, Ala., and Barckhoff and Associates, Minneapolis. A trial program at Bender showed projected costs per welder were reduced by $17,000 annually. Labor hours on successive modular construction sequences decreased 1000 hours per module. (You can download the report from the Research & Studies page at *www.aws.org*.)

Thanks to the diligent efforts of the Education Committee, led by Dennis Klingman of Lincoln Electric, the SENSE (Schools Excelling through National Skills Education) initiative earned the stringent certification of the National Skills Standards Board. This achievement is a significant milestone in our goal to advance nationwide skill standards. Revisions to the SENSE program are planned and will incorporate updated specifications and standards, as well as a modular approach. AWS has increased communication between educators and students by expanding the education Web pages to include a directory of all U.S. welding programs.

We have increased our involvement and leadership in the international standards community. In cooperation with the German Welding Society, which chairs ISO/TC 44/SC 3 on Welding Consumables, AWS has taken on the role as secretariat. This type of cooperative arrangement is a healthy step forward in developing a consensus on issues important to the global welding industry. AWS is now working toward the adoption of a number of ISO standards as American National Standards, particularly in the areas of welding consumables and mechanical testing.

During this past year, AWS has implemented Web-based standards development software to form e-committees, an idea built from our initial work on "virtual" meetings. Our aim is to improve the efficiency of the AWS standards development process. The initial response has been favorable but, as with all new projects, we've experienced a few growing pains. But, we're working through them and we intend to implement online balloting by the end of the year.

Last year, I mentioned the videos that we produced to educate the public on welding professions. Claudia Bottenfield was instrumental in the production of the public service announcement for television broadcast. Her home Section, the York-Central Pennsylvania Section, raised funds and corporate sponsorships to broadcast the welding commercial throughout the area. This is the type of project we can all support. After all, who is a better choice to work at improving the public image of welding careers than our members?

Finally, I would like to thank all of the volunteers who work for the American Welding Society. Last April I called them our Society's greatest asset. I did not exaggerate. During my travels over the last 11 months, I've had the opportunity to meet and speak with hundreds of volunteers in this country and around the world. I can honestly tell you that we have strength in numbers. We will need to rely on that strength, and on your expertise and enthusiasm to forcefully shape the future of our industry. It is our membership working together in pursuit of common goals that has made AWS the center of the welding industry for so many years. I would like to say thank you to the volunteers, and to the companies and families that support you. We couldn't have accomplished so much without you.

Thomas M. Mustaleski
AWS President


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ESAB Plasma Cutting Equipment Speeds Armoring of Army Vehicles in Iraq

An Army welder in Iraq uses an ESAB plasma arc cutting machine to cut doors on vehicles for armor reinforcing.

A U.S. soldier in Iraq sits in one of the vehicles that has had its doors armor reinforced.

Equipment purchased by the U.S. Army from ESAB Welding & Cutting Products, Florence, S.C., has made its way to the front lines of Operation Iraqi Freedom. A PCM-875 Plasmarc™ machine is helping one Army maintenance team cut doors on vehicles for armor reinforcing. By producing faster, more effective cuts, the ESAB plasma arc cutting machine is allowing the welding team to provide safer armored vehicles for U.S. soldiers at three times the rate they previously could.

"I'm writing to tell you how much the PCM-875 has helped us here in Iraq," e-mailed Staff Sergeant Ian Mason. He adds, "We have been armoring our vehicles since the day we got here and have had to use an oxyfuel torch to cut the steel. We recently received our ESAB plasma cutter through the Army supply system, and we're so thankful for it. We have been able to triple the number of armor doors that we can get done in one day."

As head of his battalion's maintenance team, Sgt. Mason claims he's constantly challenged to find better ways to get things done since he can't run out to the nearest welding distributor or equipment store. The new equipment has really helped.

Since safety gear and other equipment is sometimes in short supply for Sgt. Mason and his welders, ESAB put together a "care package" with plasma nozzles, helmets, welding caps and do-rags, shirts, gloves, training materials, and other items. "We're pleased to be able to support our frontline troops in this small way," said ESAB Engineering Manager Shannon Soupiset.

Auto Aluminum Design Challenge Winners Announced

Students from the Art Center College of Design, Pasadena, Calif., presented the winning design for the inaugural Auto Aluminum Design Challenge sponsored by The Aluminum Association. The competition required students to design a sport utility vehicle that incorporated aluminum's attributes to meet criteria that included design quality in form and function; safety for the occupants of the car, passengers of other vehicles, and pedestrians; positive environmental impact through fuel efficiency and lower emissions; and consumer appeal.

Top automotive design students from Detroit's College for Creative Studies and Art Center College of Design competed

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Joseph Choi (left) and Sang Park, students at the Art Center College of Design, Pasadena, Calif., pose with their design for a 2008 Nissan aluminum sport utility vehicle.

against one another. The winners were announced during a recent ceremony at the Detroit Institute of Arts. They were as follows: First place — Joseph Choi and Sang Park, Art Center College of Design; second place — Darren Chilton and Shane Lindsay, Detroit College for Creative Studies; third place — Loren Kulesus and Noah Sussman, Art Center College of Design.

Both schools received $35,000 education donations for participating in the event from The Aluminum Association. Scholarship prize money was awarded from those donations. The students on the first-place team received $5000 scholarships; second-place winners received $2000 each; and third-place winners each received $1000.

"Automotive designers are going to continue to be presented with more options in material use and design — as well as more challenges," said Ken Okuyama, chair of Art Center's Transportation Design Department. "Aluminum holds limitless possibilities as the auto industry deals with balancing performance goals with safety standards and environmental concerns. This design challenge helps our students prepare for this reality."

SBA Announces Record Year for Small Business Contracts

For the first time ever, the federal government awarded more than a quarter of its prime contracting dollars to small businesses in fiscal year 2003, Hector V. Barreto, administrator of the U.S. Small Business Administration, announced recently.

The data indicate that small businesses did $62.7 billion of business with the federal government as prime contractors, representing 25.37% of all government prime contracting dollars, an increase of $9.7 billion over fiscal year 2002. Every category of small business tracked by SBA showed gains in federal contracts during fiscal year 2003.

According to Barreto, the statutory goal for small business contracting is 23%. "We not only exceeded those standards, but we set an all-time record, awarding a higher percentage of federal contracting dollars to America's small businesses than ever before," he said. The $62.7 billion in prime contracts awarded to small businesses in 2003 will create or retain approximately 469,632 jobs.

Northrop Grumman Shipyard Helps Restore Historic Aircraft Carrier

Continental Maritime, a subsidiary of Northrop Grumman Newport News located in San Diego, Calif., recently helped re-

The aircraft carrier USS Midway *is pictured at Navy Pier in downtown San Diego, where it's being converted into a museum and memorial. (Photo by Chas Pfeil.)*

store the historic aircraft carrier USS *Midway* for the San Diego Aircraft Carrier Museum. The *Midway* was built by Newport News and delivered to the U.S. Navy in 1945. The ship was decommissioned in 1992, after serving nearly 50 years, and is now being converted into a museum and memorial.

Last November, the museum asked all shipyards in the area for help with the restoration by repairing and restoring three brow platforms and two brows. Continental Maritime responded to the request and its structural, coating, and rigging departments worked on the project. In January, tugs pulled the *Midway* to Naval Air Station North Island. Restored vintage aircraft were taken on board and the restored brows and brow platforms were transported across the bay on a Continental Maritime barge for the arrival of *Midway* at Navy Pier Downtown.

The ship will open to the public soon. Information is available at *www.midway.org*.

eBay and Machinery Dealers Team to Sell Used Equipment

eBay and the Machinery Dealers National Association (MDNA) recently established a relationship to help MDNA's members expand their sales of used machinery and equipment to the eBay Business Marketplace, where equipment and supplies are offered for a broad range of industries. As part of the agreement, the two organizations will provide education and support to MDNA to help start and grow its sales on the Internet auction site.

The MDNA is a nonprofit international trade association whose members represent the largest group of used machinery dealers in the United States. "Teaming with eBay will give the MDNA and its dealers exposure on one of the hottest and fastest-growing Web sites in existence," said John Stencel III, MDNA president. "It will also provide an additional venue to increase the liquidity of MDNA dealer inventories."

On any given day, eBay Business (*www.ebaybusiness.com*) has more than a million listings for business equipment and supplies across a broad range of categories including metalworking, test equipment, construction equipment, agriculture, restaurant equipment, and computers.

Milwaukee Electric Tool Celebrates 80th Anniversary

Milwaukee Electric Tool Corp., Brookfield, Wis., is celebrating its 80th consecutive year of manufacturing heavy-duty power tools. Milwaukee manufactures its red power tools in both 120 and 230 volts for worldwide use. Its product lines covers more than 500 different tool models ranging from reciprocating saws to drills, circular saws, and rotary hammers.

The company was founded in 1924 in Milwaukee by A. F. Siebert around the Hole Shooter, a lightweight, portable, one-handed ¼-in. capacity drill.

Industry Notes

- Multiquip Inc., Carson, Calif., recently named Multiquip Construction Equipment Pvt. Ltd., Mumbai, India, as its distributor for India, Myanmar, Bangladesh, Sri Lanka, Pakistan, Bhutan, Nepal, and the Maldives. Naridner Jit Singh, a veteran of the construction industry, is operating the new distributorship. Multiquip's expansion into the Indian subcontinent is part of its continuing global growth. The company supplies compaction equipment; welding machines; generators; concrete and masonry cutting, placing, and finishing products; dewatering pumps; and other construction equipment.
- The U.S. Small Business Administration has proposed new rules that will simplify the standards by which the SBA determines the size of a business. Under the proposed rules, number of employees will determine business size in almost all cases and the number of different size categories will be reduced from 37 to 10. The size standards define whether a business qualifies as small and whether it is eligible for government programs and assistance reserved for small businesses. Under the new rule, more small businesses will be eligible to apply for SBA's financing and loan programs, as well as contracting and business development programs.♦

BY DAMIAN J. KOTECKI

Q: We are welding heavy wall 304H stainless steel pipe for a power plant using E308H-16 and ER308H filler metals. Our Welding Procedure Specifications are essentially AWS B2.1-8-212 (GTAW), AWS B2.1-8-213 (SMAW), and AWS B2.1-8-214 (GTAW root and SMAW fill). Each of these specifies 350°F (175°C) maximum interpass temperature, 50°F (10°C) minimum. When we put two welders on a joint, the temperature builds up in the pipe around the joint, so we have to stop welding for a while, and we lose the advantage of putting two welders on the joint. We really don't want to specify a higher interpass temperature, as the welders complain now about the hot pipe. Is there anything wrong with accelerating the cooling using forced air draft, water mist spray, or even direct water cooling to maintain the maximum interpass temperature? The Welding Procedure Specifications say nothing about accelerated cooling.

A: Table 1 lists the compositions for 304H base metal (from ASTM A312), E308H-16 filler metal (from AWS A5.4), and ER308H filler metal (from AWS A5.9). Note that each includes a required minimum carbon content because carbon improves creep resistance at high temperatures.

In many cases, a maximum interpass temperature is specified for welding austenitic stainless steels in order to limit chromium carbide precipitation on grain boundaries, which occurs between about 900° and 1650°F (480° and 900°C) during welding. These chromium carbides often form at the expense of chromium depletion beside the grain boundaries, which is often referred to as "sensitization" because the steel becomes sensitive to intergranular corrosion in aqueous environments. However, in the case of 304H piping for power plant applications, the service temperature is likely to be in that temperature range, so any carbide precipitation that occurs during welding will be insignificant compared to that which occurs as a result of service temperature exposure. The reason for using 304H stainless steel pipe in a power plant is not so much for corrosion resistance as for high-temperature creep resistance.

So, as a bit of an aside, I see no objection, other than welder discomfort, to allowing interpass temperatures to exceed 350°F (175°C) for your particular application. But that is not what you asked.

There is nothing wrong, from a metallurgical point of view, with accelerating the cooling of austenitic stainless steel welds, provided that both base metals and the filler metal are austenitic, which is the case in your situation. In fact, quenching from high temperatures is part of the annealing heat treatment for austenitic stainless steels. This is entirely different from the situation of welding ferritic steels or martensitic stainless steels. In the latter two cases, accelerated cooling promotes undesirable microstructures in the weld metal and the heat-affected zone. Nothing of the sort happens with austenitic stainless steels.

However, there are some practical concerns with applying accelerated cooling while welding austenitic stainless steel. It is essential that whatever means is used

Table 1 — Compositions of 304H, E308H-16, and ER308H

Alloy	C	Mn	P	S	Si	Cr	Ni	Mo	Cu
	Composition (%) (Single values are max. limits)								
TP304H	0.04–0.10	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	—	—
E308H-16	0.04–0.08	0.5–2.5	0.04	0.03	0.90	18.0–21.0	9.0–11.0	0.75	0.75
ER308H	0.04–0.08	1.0–2.5	0.03	0.03	0.30–0.65	19.5–22.0	9.0–11.0	0.50	0.75

for accelerated cooling does not disturb the arc or its shielding. In both GTAW and SMAW, use of forced air cooling or a water mist spray can displace shielding gas from either the GTAW arc or the SMAW arc. Air contains nitrogen, and nitrogen in the arc leads to nitrogen pickup in the weld metal. Water mist spray includes air, and the same concern about nitrogen pickup arises. Nitrogen pickup results in loss of ferrite in the weld metal, which can easily lead to solidification cracking. It is essential to prevent any forced air or water mist spray from reaching the arc.

Water, if it enters the arc, decomposes into hydrogen and oxygen, and the hydrogen leads to porosity in the weld. Welding over any wetness is especially risky in regard to causing porosity. The joint surfaces must be kept dry to avoid this risk. Water contact with any sort of crevice in the joint is especially to be avoided because it is difficult to remove all of the water before welding over it.

Furthermore, covered electrodes can easily pick up moisture from exposure to damp air. Using water mist spray is a great way to humidify the air, and a consequence of moisture pickup in the electrode is again porosity. So it is advisable to protect the electrodes from moisture pickup by treating them as if they were low-hydrogen electrodes. Keep the electrodes in a sealed container, or in a heated oven.

Another concern is nonuniform application of accelerated cooling. In welding pipe, the weld shrinkage is normally symmetrical, so the pipe axis tends to stay relatively straight. However, if one quadrant of the pipe is cooled more effectively than another, for example, by letting water run through the bottom of the pipe after the root pass is completed, the pipe axis is likely to bend toward the cold quadrant as more layers of weld metal are deposited. The cold quadrant achieves full strength more quickly than the hotter quadrants, which causes this. So you may encounter greater distortion.

Finally, any introduction of water into an area where electric arc welding is being done carries with it safety risks. Water generally increases the likelihood of stray electrical currents that can be hazardous to those working in the area. And water on surfaces makes them slippery and can lead to a fall. Any introduction of water into a welding environment should be carefully thought through and policed to avoid hazards to people as well as to weld quality.♦

DAMIAN J. KOTECKI is Technical Director for Stainless and High-Alloy Product Development for The Lincoln Electric Co., Cleveland, Ohio. He is a member of the AWS A5D Subcommittee on Stainless Steel Filler Metals; AWS D1 Committee on Structural Welding, D1K Subcommittee on Stainless Steel Welding; and a member and past chair of the Welding Research Council Subcommittee on Welding Stainless Steels and Nickel-Base Alloys. Questions may be sent to Dr. Kotecki c/o Welding Journal, 550 NW LeJeune Rd., Miami, FL 33126 or via e-mail at Damian_Kotecki@lincolnelectric.com.

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The Debate on International Standards Continues

Below are comments by RAINER ZWÄTZ on the article "Philosophy and Feedback on Welder Qualification Standards" that was published in the August 2003 Welding Journal, *pp. 14–16.*

The United States is a member of the International Organization of Standardization (ISO) and American delegates serve as members in numerous ISO committees. Furthermore, the United States is chairing many of the ISO Secretariats. As a result of this participation, at the end of 2002, 140 Welding Standards and 150 Drafts of International Welding Standards or Projects have been published or treated by ISO/TC 44 "Welding and Allied Processes."

The author of the article "Philosophy and Feedback on Welder Qualification," Walter Sperko, has worked since 1998 as an ISO Observer on the European Committees of Standardization, e.g., in CEN/TC 121/SC, 2 "Qualification of Welding and Allied Processes Personnel," so he was able to follow the European standardization activities directly.

Some of his statements published in the article mentioned above can be fully supported by the welding community, but some of them are hard to accept and cannot be left unaddressed, e.g., the designations of welding positions for welder qualification test PC (a designation 2G according to AWS and ASME codes) are not based on European standards only. This designation is based on the International Standard ISO 6947. CEN (the European Organization of Standardization) fully adheres to the Vienna Agreement — an agreement between CEN and ISO — and ISO standards take over whenever it seems practicable and useful.

Comments on EN ISO standards, which will be developed under the Vienna Agreement, can be submitted by all CEN and ISO member countries. Following the rules, these comments will be considered in the relevant standard if the majority of the committee members agree with them.

The statement of the author that prEN ISO 9606-1, *Qualification Test of Welders — Fusion Welding — Part 1: Steels,* was developed by delegates who are only working in the field of making standards or performing welder education and training is only partly correct. Indeed the delegates in the meetings of CEN/TC 121/SC 2 are mostly members of organizations for standardization, but the real discussion of comments and arguments takes place in the meetings of the national mirror committees. In these meetings, a great many European industry experts and end users are participating. Only for reasons of limited time and money do delegates from European industry not participate in meetings of CEN committees in greater numbers.

I completely agree with the author when he complains about the ISO voting system. It is indeed unsatisfactory that big countries like the United States and China have the same number of votes as smaller countries like Luxembourg. This problem will not be solved by not accepting ISO standards, but it could be by trying to change this ISO voting system and to make it similar to the CEN voting system. In the CEN voting system, the number of votes for a country varies from 1 to 10, depending on the industrial importance and the number of citizens of the respective country.

It is difficult for European and Asian countries to understand why the United States and Canada have accepted the present valid version of ISO 9606-1 and -2 as well as EN ISO 9606-3 (copper), -4 (nickel), and -5 (titanium and zirconium), but do not accept the revision of part 1, which comparatively contains only minor changes. The argument used is that the revision of prEN ISO 9606-1 does not meet "global relevance." What is the definition of global relevance, and when is it given? We don't believe "global relevance" means that only interests of one or two countries have to be take into consideration.

Table 1 shows the present situation of the standard series EN 287, which complies without any changes with the ISO 9606 series.

One strong argument against prEN ISO 9606-1 by the United States is the fact that in this standard the validity of the welder qualification is limited to two years. But the present valid version of EN 287-1/ ISO 9606-1 also contains this regulation. If United States industry believes it is sufficient for the qualification of a welder to have passed one welder qualification test successfully without any requalification tests, this opinion is contrary to the opinion of most other industrial countries. The skill of a welder cannot be guaranteed for life, but has to be regularly trained and retested after a reasonable period of time. But, if the quality of components will be regularly inspected and tested by nondestructive test methods such as RT and UT during production, there is no requirement for repeat qualification tests for the welders involved, not even according to prEN ISO 9606-1 or EN 287-1/ ISO 9606-1.

Furthermore, it has to be stressed that the designations of the welding processes used in prEN ISO 9606-1 are not a specific European invention. EN ISO standards consequently make use of designations published in other relevant ISO standards such as ISO 4063, *Welding and Allied Processes — Nomenclature of Processes and Reference Numbers.*

When United States industry on the

Table 1 — Status of the EN/ISO Standard EN 287/ISO 9606

EN 287/ISO 9606	Qualification test of Welders (Approval testing of welder) Fusion welding	Published as	Date of publication
Part 1	Steels	EN 287-1 ISO 9606-1	EN: 1997 ISO: 1998
Part 2	Aluminum and aluminum alloys	EN 287-2 ISO 9606-2	EN: 1997 ISO: 1998
Part 3	Copper and copper alloys	EN ISO 9606-3	1999
Part 4	Nickel and nickel alloys	EN ISO 9606-4	1999
Part 5	Titanium and titanium alloys, zirconium and zirconium alloys	EN ISO 9606-5	2000

one hand tries to influence ISO standardization to its satisfaction but, on the other hand, often does not accept nor use ISO standards when they are available, it should not wonder (or be surprised) when other countries spending time and money to reach worldwide harmonized standards have no appreciation for such an attitude.

One other example is the designation of the base metal in prEN ISO 9606-1, which is based on the International CEN/ISO Report ISO/TR 15608: 2000-04, *Welding — Guidelines for a Metallic Grouping System*. American experts and delegates have participated in the development of this international report. The European countries have changed their grouping system accordingly to come as close as possible in line with the American system.

In prEN ISO 9606-1, only those qualification tests are included that can be influenced by the skill of a welder. For example, the majority of the delegates of CEN/TC 121/SC 2 were of the opinion that for the use of consumable inserts no special skill of the welder is required, since the use of consumable inserts is comparable with that for welding on backing.

At present, a discussion is going on in ISO committees about the further development and use of ISO standards. Europe and Asia prefer the use of complete ISO standards, which can be referred to and used without additional specifications. The delegates of the United States have made other proposals in ISO/TC 44. According to their opinion, only minimum requirements should be covered by ISO standards. Additional requirements could be given in regional (e.g., European or Japanese) standards and/or in specifications.

Another example concerns the practice of the welding procedure qualification test in EN ISO 15614-1, *Specification and Qualification of Welding Procedures for Metallic Materials — Welding Procedure Test — Part 1: Arc and Gas Welding of Steels and Arc Welding of Nickel and Nickel Alloys*. In the United States, generally no impact tests are requested for the welding procedure qualification test (similar situations for the base metal). This is, for technical reasons, not acceptable in Japan and Europe. A welding procedure qualification test must include an impact test. With regard to this, it is not correct to say that after acceptance of the standard series EN ISO 15607 to 15614 all welding procedure specifications have to be completely renewed by the American manufacturers. Only some additional, not very costly tests, have to be carried out, such as impact tests, in order to be in line with all of these international standards. Only the WPS format has to be revised.

An export-oriented country like the United States (at present the number one export country worldwide) should have for its own benefit a great interest in worldwide unified standards. American manufacturers of welded components, therefore, should be qualified for export to any country just by carrying out one type of welder qualification test or one type of welding procedure qualification test that is internationally accepted.

RAINER ZWÄTZ, Manager of the Quality Assurance Group of the German Welding Institute in Duisburg, GSI; German delegate to ISO/TC 44 and CEN/TC 121; Convener of CEN/TC 121/SC 2, Qualification of Welding and Allied Processes Personnel; Convener of CEN/TC 121/WG 16, Welding of Reinforcing Steels; Convener of ISO/TC 44/SC 10/WG 1 Revision of ISO 5817 and ISO 10042 (Quality Levels); Convener of ISO/TC 44/SC 10/WG 6 Revision of ISO 13918 and ISO 14555 (stud welding).

Response to comments of Rainer Zwätz.

It's hard to believe that my good friend

Mr. Zwätz and I have been working together on CEN/TC 121/SC 2 for over six years. I have thoroughly enjoyed our joint activities, including the work part.

I am glad to read that Mr. Zwätz agrees that the ISO voting procedures leave a lot to be desired. Those of us involved in writing technical standards under ANSI rules where technical experts have final say on what goes into a standard find the whole concept of countries voting on standards inappropriate.

ANSI rules for the membership of committees that write standards is a far cry from either CEN or ISO committee membership rules. In addition to those who produce products (in this case, employers of welders), consumers (i.e., those who pay for the product produced by the welders) are required to participate in writing the standard — otherwise the standard will not be published with ANSI's blessing. That is, in addition to having welding experts on the committee, the end user of the product that will be welded (utility, oil company, etc., who will pay the bill) must be represented on the committees and in approximately equal proportion to the product producers. Not surprisingly, those paying the bill demand to know how a proposed requirement will be cost effective. Although the CEN committee members had input from their respective countries' welding experts, the perspective of the end user of the products (i.e., the one paying the bill) was missing. This perspective makes a difference in the standards that are developed.

As a result, U.S. practices differ significantly from those in Europe. United States practices tend to be more cost effective, and because there is significant feedback from users, the requirements are simpler and easier to follow.

1) ISO 6947 on welding positions, for example, is far more complex than the U.S. system for designating welding positions, and further, is incomplete since welding positions that lie between PA, PB, PC, etc., are undefined. Accordingly, the record will show that the U.S. voted against this and the other ISO welding standards listed by Mr. Zwätz.

2) Under U.S. standards, the only time a welder loses his or her qualifications is if he or she does not use the process for more than six months. As long as he or she uses the process and his or her employer is satisfied with the quality of his or her work, he or she never has to requalify. This practice has been in place for more than 60 years and has been found to be satisfactory. Adding requirements to volumetrically examine welds biennially will add cost without corresponding benefit.

3) The U.S. has no problem with the assignment of numbers to welding processes as in ISO 4063; U.S. industry does have a problem with that system's failure to identify Process 131 when using the short-circuiting transfer mode since it (i.e., GMAW-S) has caused many problems in the industry, and both producers and consumers of welded product in the United States insist on special qualifications and restrictions for those who will use GMAW-S. The writer personally objects to using numbers instead of names since that just adds more jargon to an industry that is already difficult to understand.

4) Groove welds made using consumable inserts are totally different than welds made on backing since there is nothing supporting the weld metal. Consumable inserts are used at least in the U.S. and the U.K. and should be addressed in any international welder qualification standard; the draft of ISO 9606-1 fails to address them.

As for the contention that earlier editions of ISO 9606 are international standards, a quick comparison shows that they are nothing more than EN 287 with an ISO label. They are in no way international standards — even though they may be published by ISO. Further, at least one European delegate indicated that the previous version of ISO 9606-1 was so flawed as to not be useable. Say something about usage?

The only solution that the writer sees to having one international standard for welder qualification is to extract the common elements from all available standards and use them as the basic standard. As Mr. Zwätz stated, regional requirements such as biennial testing could be added to European annexes and GMAW-S and consumable inserts could be added to the U.S. annexes. Requirements in annexes are mandatory only where those annexes are adopted by a region or country. Although this would not be the ideal situation, it is perfectly acceptable under ISO Guide 21. More importantly, it would serve as a transition mechanism to reaching true international consensus on what a welder has to do to be qualified.

WALTER J. SPERKO, P. E., Chair, US TAG to ISO/TC 44 (ISAC), ISO Observer to CEN/TC 121/SC 1 (Welding Procedures), ISO Observer to CEN/TC 121/SC 2 (Welder Qualification); Convener, ISO/TC 44/SC 10 Working Group 5 "Welding Procedure Qualification." Member AWS Technical Activities Committee, Vice chair ASME Subcommittee IX, Welding and Brazing Qualifications, Member, ASME B31 Code for Pressure Piping Standards Committee, Chair, ASME B31.9, Building Services Piping.

Editor's note: The original article is posted at www.sperkoengineering.com.

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CNC Software Maximizes Materials Management

The company's ProMotion Nest Software maximizes shape-cutting efficiency by enabling operators to cut multiple parts in nested plate with a single pierce. The program also provides cost estimating capabilities. The software can import CAD drawings.

ProMotion Controls, Inc. 100
1195 Newell Ln., Medina, OH 44256

Pallet Furnace Heat Treats to 2000°F

The No. 925 pallet furnace uses two modulating natural gas burners with a floor-mounted combustion air blower to

generate 700,000 BTU/h. The unit's workspace measures 30 in. wide × 48 in. deep × 36 in. high.

The Grieve Corp. 101
500 Hart Rd., Round Lake, IL 60073

Low-Cost Welding Machine Handles Light Tasks

The Champion 4500 welding generator provides 4500 W (surge) of AC power and 140 A of welding power for light maintenance, construction, fabrication, and repair projects. The gas-powered unit weighs 190 lb.

Hobart Welders 102
P.O. Box 100, Lithonia, GA 30058

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Loader Offers Variety of Load Configurations

The Omega 4D MultiLoader features all-wheel drive, steering, and braking for maneuverability in constricted work-places. Available with diesel or LP gas power, it comes in capacities of 8000, 10,000, and 12,000 lb.

Baumann Handling Systems 103
1208 Badger St., Yorkville, IL 60560

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Orbital Weld Heads Redesigned for Digital Power Sources

The Redhead line of three orbital weld heads has been redesigned to be used with the digital Tubemaster power source. They handle autogenous and filler welding of pipe from 0.5 in. (12 mm) to 6.625 in. (168 mm), including out-of-round pipe.

Magnatech LP 104
P.O. Box 260, East Granby, CT 06026

Cutting Torch Reduces Flashback

The Silvercut 250 chrome-plated cutting torch has a 9-in. cutting capacity. The torch mixes gases at the tip, reducing flashback and helping extend torch life.

Koike Aronson, Inc. 105
635 W. Main St., Arcade, NY 14009

Dispenser Feeds Wire to Automated Systems

The Tech Pak™ wire dispenser delivers stainless steel or nickel-alloy welding wire in a straight, flip-free line, in diameters from 0.035 to 0.062 in. Alloy is available in 250- and 500-lb dispensers with quick-connect fittings.

Techalloy Co. 106
2310 Chesapeake Ave., Baltimore, MD 21222

Noncontact Instrument Measures Wide Temperature Range

MI-140 Series infrared pyrometers can measure temperatures of up to 5972°F on shiny metals and other materials, with spot sizes as small as 0.01 in. (0.25 mm).

Mikron Infrared, Inc. 107
16 Thornton Rd., Oakland, NJ 07436

Developments in Guns and Torches

BY ROSS HANCOCK AND MARY RUTH JOHNSEN

Easy setup and use, fewer parts, and comfortable, ergonomic designs are among the hallmarks of today's welding guns and torches

Dependable, high-quality welding guns and torches play a vital role in any type of arc welding operation, whether manual, semiautomatic, or automatic. Among the qualities today's fabricators look for are long-lasting consumables, fewer parts to replace, easy setup and use, and ergonomically designed handles.

Following are some of the latest offerings from welding gun and torch manufacturers.

Semiautomatic Gas Metal Arc Welding Guns

Gas-cooled GMAW guns. The Gun Master models 250 and 400 gas-cooled guns offer amperage ratings of 250 and 400 A, respectively, at 100% duty cycle, and handle a wide range of gas metal arc welding applications. The guns fit equipment using Tweco® #4 connectors.

ESAB's Gun Master 250 guns can handle a wide range of GMAW applications.

Features of the Gun Master 250 and 400 guns include the following:

- Lightweight handles that provide increased welder comfort and that are impact resistant for longer life.
- Cables that resist spatter, cuts, oil, and abrasion to extend the cable life and reduce problems for the welder.
- Slide-on standard and heavy-duty copper wall nozzles. *ESAB Welding & Cutting Products, Florence, S.C., (843) 664-4433, www.esab.com.*

Compact spool gun. The MK Sidewider™ spool gun features a low profile that allows it to access tight spaces. It weighs 26 oz, including the wire spool, and accepts small wire sizes from 0.23 to 0.035 in. The wire spool releases with the push of a button, and easily snaps into place without tools. The gun has a built-in gas valve and handles cable lengths of up to 75 ft.

The low profile of the MK Sidewinder spool gun allows its use in tight spaces.

The gun connects to a variety of power sources for welding aluminum, mild steel, stainless steel, and galvanized steel. *MK Products, Inc., Irvine, Calif., (800) 787-9707, www.mkproducts.com.*

ROSS HANCOCK (rhancock@aws.org) is Associate Editor and MARY RUTH JOHNSEN (mjohnsen@aws.org) is Senior Editor of the Welding Journal.

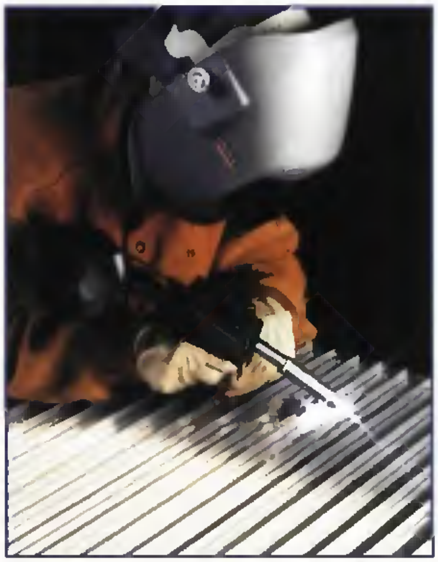
Straight handle for improved ergonomics. The APX line of air-cooled, semiautomatic gas metal arc welding guns includes 300-, 400-, 500-, and 600-A models rated at 100% duty cycle with CO_2.

OXO's line of APX GMAW guns features a patent-pending straight handle for improved ergonomics and 360-deg rotatable necks.

The guns can be ordered with three types of handles: a large curved, a small curved, and a new patent-pending straight handle that offers improved ergonomics. They feature 360-deg rotatable necks so out-of-position welding can be performed without needing to change necks. The necks are available in a variety of lengths and angles; all are interchangeable with any model APX gun.

The guns are fitted with the company's Quik Tip™, which features a conical seat design that provides a large surface contact area for excellent heat transfer and electrical conductivity. The contact tips release quickly with one turn. Benefits include cool operation, long life, and reduced downtime. *OXO Welding Equipment, Beecher, Ill.*, (708) 946-2281, *www.oxoguns.com.*

Spool gun for aluminum welding. Lincoln's Magnum SG spool gun is rated at 250 A at 60% duty cycle. Designed primarily for aluminum welding, it is a low-cost lightweight, hand-held

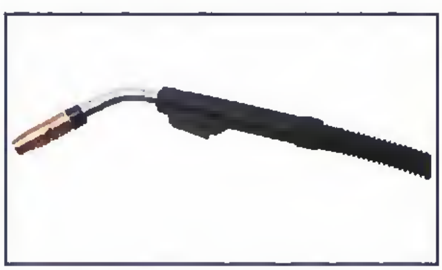


Lincoln's Magnum SG spool gun is a low-cost, lightweight, handheld semiautomatic gun designed primarily for aluminum welding.

semiautomatic spool gun. It can feed from 0.023- to 3/64-in. wire diameters on up to a 4-in.-diameter spool at speeds of up to 650 in./min.

It features see-through spool and body covers that allow the user to see the wire supply and check wire feeding. It comes with a 25-ft cable so the welder can work at a distance from the power source. *The Lincoln Electric Co., Cleveland, Ohio, (888) 355-3213, www.lincolnelectric.com.*

Water-cooled GMAW gun. The 400-A water-cooled Tough Gun features a two-piece ergonomic handle that doubles as the rear housing with a strain relief spring that prevents cable kinking. The light-touch trigger is large enough for single or multi-finger operation.



The 400-A Tough Gun features a two-piece ergonomically designed handle that includes a strain relief spring that prevents cable kinking.

The gun uses extruded, high-conductivity contact tips. *Tregaskiss Ltd., Windsor, Ont., Canada, (800) 618-6966, www.toughgun.com.*

Gooseneck push-pull guns. The CobraMAX is a fixed gooseneck push-pull gun rated at 150 A at 100% duty cycle, making it a good choice for low-end applications. For more demanding applications, five models of Python guns are available. Python options begin with the standard air-cooled gun rated at 200 A at 100% duty cycle. The replaceable gooseneck of the Python can be interchanged with the full water-cooled

The CobraMax fixed gooseneck push-pull gun is rated at 150 A at 100% duty cycle.

barrel and gas cup combination, to achieve a rating of 400 A at 100% duty cycle.

Both the CobraMax and Python guns can handle steel and aluminum wire in diameters from 0.030 to 1/16 in. They also feature a balanced, ergonomically designed handle, convenient trigger location, and three-turn, fingertip wire speed adjustment. The CobraMax features a flip-up drive roll cover and a quick wire release lever for easy, accurate wire feeding. *The Lincoln Electric Co., Cleveland, Ohio, (888) 355-3213, www.lincolnelectric.com.*

Air-cooled GMAW gun. The 400-A Profax® 400HD Heavy Duty Platinum semiautomatic gun is designed to connect

The Profax® 400 HD GMAW gun has been engineered for mixed gas applications and longer duty cycles.

directly to Lincoln, Miller, and Euro wire feeders, with conversion kits for other feeders. Engineered for mixed gas applications and longer duty cycles, the gun is available in 10, 12, 15, 20, and 25-ft. lengths.

The air-cooled gun is recommended for 0.035 to 5/16-in. solid wire and up to 3/64-in. aluminum wire. *Profax, Pearland, Tex., (800) 594-3958, www.profax-lenco.com.*

Strain relief springs keep wire from kinking. The Magnum® 300 and 400 gas-

The Magnum 400 GMAW gun features a fiberglass handle with nonslip grooves for increased comfort and control.

shielded GMAW guns feature new strain relief springs located at both the wire feeder and gun ends of the gun cable. The springs keep the wire from kinking and protect it throughout the entire feeding process.

The Magnum 300 gun is rated at 300 A at 60% duty cycle with CO_2 gas. It can accommodate wire sizes from 0.035 to 5/64 in. and cable lengths in 10, 12, 15, 20, or 25-ft. The 400 model is rated at 400 A at 60% duty cycle with CO_2 and can accommodate the same wire sizes and offers the same cable lengths as the 300 model. The guns feature a fiberglass handle with nonslip grooves that is designed to minimize size and maximize comfort and control, a heavy-duty trigger switch, and a one-piece modular trigger assembly. The outside of the gun tube is armored with an electrically insulated metal jacket to eliminate wear problems. *The Lincoln Electric Co., Cleveland, Ohio, (888) 355-3213, www.lincolnelectric.com.*

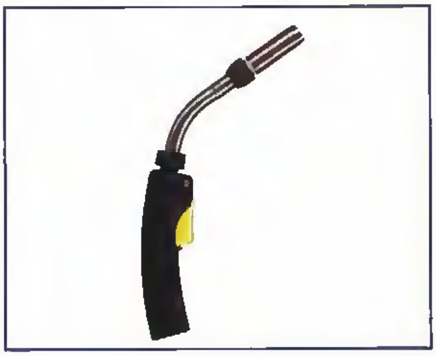
Air-cooled GMAW replacement gun. The Tweco® Fabgun™ 250 features an ergonomic handle and simplified construction with a minimal number of

The Tweco Fabgun 250 offers a simplified construction with a minimal number of parts.

parts. It is designed for use with many manufacturers' welding systems.

The gun is equipped with 12-ft. leads. *Tweco Products Inc., Wichita, Kans., (800) 231-9353, www.tweco.com*

Air-cooled, semiautomatic 150–600 amp guns. Bernard's Q™-Gun line has been restructured with new handles, trigger options, amperage configurations, and simplified consumables. Available amperages at 100% duty cycle with CO_2 are 150, 200, 300, 400, 500, and 600. The guns are available with rotatable or fixed



The Bernard Q-Gun line has been restructured to offer simplified consumables, and new handles, triggers, and amperage configurations.

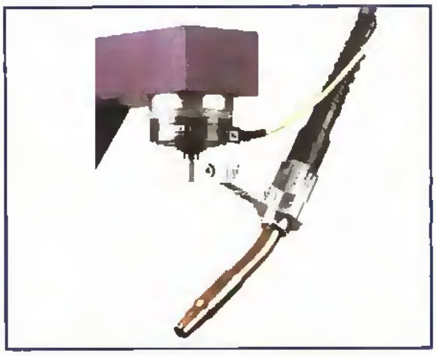
necks in a wide variety of lengths and angles. The 360-deg rotatable necks can be changed quickly without tools. All of the necks will fit any Q-Gun model. The guns are available with curved handles or a new straight handle that offers improved ergonomics. Trigger and switch options include locking trigger, dual pull trigger, dual schedule switch, and trigger extension.

The guns can be ordered with the company's elliptical contact tips or with its Centerfire™ series of GMAW consumables. Benefits of the Centerfire consumables include hand-tightened nozzles that come with built-in spatter shields. The shields protect the diffuser from spatter, and keep the gas flowing more smoothly through the nozzle. The nonthreaded contact tips drop into place and are locked in by tightening the nozzle, making for faster changes following a meltback. The gas diffusers have large-diameter tip bases and tapered seats that help increase electrical conductivity and heat transfer. *Bernard Welding, Beecher, Ill., (708) 946-2281, www.bernard-welding.com.*

Robotic GMAW Guns

Air-cooled robotic GMAW gun. The PAC*MIG Forced Air-cooled Robotic gun uses shop compressed air to eliminate the need for water cooling.

The gun's conductor tubes are available in 18-, 22-, 45-, 60-, 80-, and 180-degree bends. *PAC*MIG, Inc., Wichita, Kans., (316) 269-3040, www.pacmig.com.*



*This PAC*MIG robotic GMAW gun utilizes air cooling.*

Withstands harsh environments. American Torch Tip's new Lightning robotic gas metal arc welding gun has been designed to withstand harsh work

American Torch Tip's Lightning robotic GMAW gun has been designed to withstand harsh environments such as vibration, cable whip, and crashes.

environments such as excessive vibration, cable whip, and unexpected crashes. The gun comes with the Lightning brand of consumables, which include a double-start contact tip, heavy-duty diffuser, and nozzle. The gun is compatible with Tregaskiss products. A robotic mount and insulating disk are available.

It includes an Easy-Change gooseneck that allows the neck to be removed without removing the gun. The gooseneck also features a Taper Lock seating system that ensures a tight, secure-locking fit. *American Torch Tip Co., Bradenton, Fla., (941) 753-7557, www.americantorchtip.com.*

Welding Torches

General-purpose, water-cooled GTAW torch. The company's line of Heliarc® general-purpose, water-cooled gas tungsten arc welding torches includes the HW-18 and the HW-18R models. The HW-18 is a 425-A torch made from HFC™ material, a high-

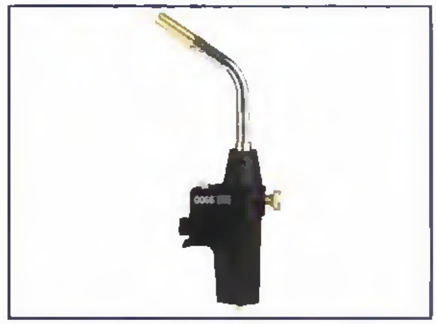
The hard-body HW-18 is made from a high-temperature, fiber-reinforced, composite material that gives it a long service life.

temperature, fiber-reinforced composite. The material's heat and abrasion resistance provides the torch with a very long service life. The torch's light weight (7 oz) helps reduce welder fatigue.

The HW-18R features a silicon rubber body for resistance to breakage. The torch can be used with a gas lens for improved shielding and features a brazed, closed cooling system that makes it watertight.

The HW-18 torches can be used with any welding machine that uses ¼-in. threaded welding power studs. *ESAB Welding & Cutting Products, Florence, S.C., (843) 664-4433, www.esab.com.*

Self-starting hand torch. The Goss GP-300 Trigger Torch features a trigger-

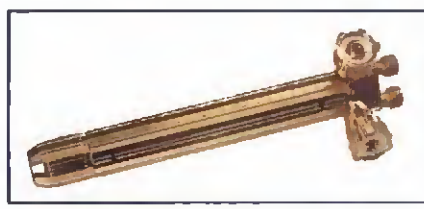


The Goss GP-300 torch can be used with propane or MAPP gas.

activated piezoelectric igniter. Designed for soldering, brazing, or heating, the torch can be used with propane or MAPP® gas. It produces a hot turbine flame with a solder capability of 0.25–2.5 in., and a brazing capability of 0.25–1.25 in.

The torch has a flame adjustment valve and its tip end is replaceable. *Goss Inc., Glenshaw, Pa., (412) 486-6100, www.gossonline.com.*

Oxyfuel gas welding torch. ESAB's OXWELD® W-400 torch can be used for welding (thin gauge to more than 1 in. thick), brazing, and heating (1–200 ft^3/h acetylene). The torch's head hand tightens so it can be changed quickly without the need to use a torch and features swaged copper tips for maximum heat and wear resistance.



The OXWELD W-400 torch features a lifetime warranty and can handle welding, brazing, and heating jobs.

Other significant features of the OXWELD W-400 include a coiled oxygen tube to prevent flashbacks; separate, seamless brass tubes that minimize the possibility of mixed gases inside the handle; the valve packing nut is located under the hand wheel to make it resistant to stem damage. The extruded brass handle is ribbed to provide a secure, comfortable grip and the pressure-forged brass rear body provides excellent strength-to-weight ratio. The torch can be used with any appropriate gas apparatus. *ESAB Welding & Cutting Products, Florence, S.C., (843) 664-4433, www.esab.com.* ◆

What's in Your Toolbox?

Fig. 1 — The Tomcat paint gun has a nice feel to it.

Fig. 2 — The speed square makes layout jobs a lot easier.

Fig. 3 — When you need that special tool, you often can find it in your pocket with the Leatherman Wave.

Welders discuss the small hand and power tools they need on the job, not only their current favorites, but the ones they'd like to own

BY ANDREW CULLISON, MARY RUTH JOHNSEN, AND ROSS HANCOCK

ANDREW CULLISON (cullison@aws.org) *is Publisher/Editor, MARY RUTH JOHNSEN* (mjohnsen@aws.org) *is Senior Editor, and ROSS HANCOCK* (rhancock@aws.org) *is Associate Editor of the* Welding Journal.

There's a certain pleasure in using a good tool — one with a comfortable handle, or just the right amount of heft, or that can handle several types of jobs equally well. And just like the chef who extolls the virtues of a particular saucepan or boning knife, the gardener who favors one brand of pruning shears, or the plumber who always seems to reach for one particular wrench first, welders feel just as passionate about the hand and power tools they use.

Welders from several segments of the fabricating industry let the *Welding Journal* look into their toolboxes, then explained why they especially like using certain tools. Some also noted the tools they'd add if given the chance. Here's your opportunity to see how your toolbox compares.

Tools for a Job Shop

Deep South Welding, Homestead, Fla., is a typical job shop that can handle just about any job that comes through the door. Variety is the name of the game when owner Edward Booth lists some of the jobs his shop has handled. Fabricating basically with carbon steel and aluminum, Booth has worked on antenna towers, aircraft parts, conveyors, boats, steel beams, structural erection, government projects, as well as decorative work for a chain of drug stores.

Since Homestead is an agricultural center, many of his jobs are repairing farm and packing house equipment. In fact, before he had his own shop, he gained a reputation with the local farmers as the man to see for repairs. A machine shop in downtown Miami was going out of business, and he bought $1500 of equipment, including a Hobart portable welding machine. He loaded the machine into the back of his pickup truck and traveled the rural roads of south Florida looking for farmers in need of his services.

He started his present company in 1985, and although he has had up to 30 employees, he likes the more comfortable group of four he has working for him now. Although he admits to a comfortable living, "This isn't going to make you rich," he said. "But really I don't do it just for money. I really enjoy working with my hands, and I like to keep active. When I don't enjoy it anymore, then I'll get out of it."

Below are some of the favorite tools in use at the shop.

Bear Hutcheson has been a welder for 10 years, and he is experienced in all the arc welding processes. For an everyday tool he uses on jobs, he likes his Black &

Decker 4-in. angle grinder. Compared to the 9-in. grinder, it is lighter and easier to get into tight places. The 9-in. grinder might be better if you have a lot of surface to grind, but with the 4-in. grinder, "You don't have to muscle around and fight with it like you do with the bigger grinder," he said.

Although a little out of the realm of hand tools, what Hutcheson really would like to have is a 10-ft hydraulic power shear. They use plasma arc and oxyfuel for cutting now, but he said, "It would just be a quicker and cleaner cut, and there wouldn't need to be as much edge prep for welding."

Fig. 4 — The Needle Scaler beats a chipping hammer for speed and ease.

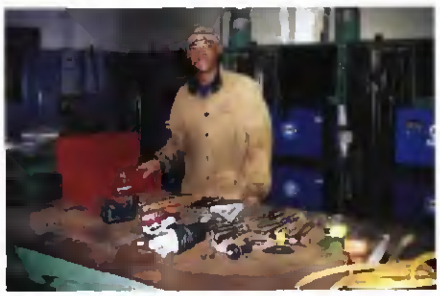


Fig. 5 — McFatter Technical Center student Hilburn Branford shows off the contents of his toolbox, which includes a 4½-in. angle grinder and a variety of measuring and alignment devices.

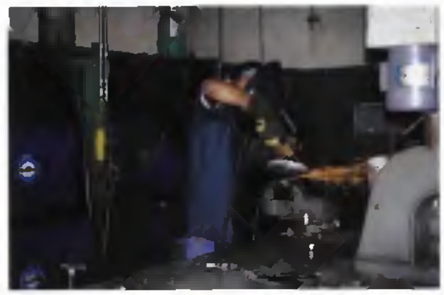


Fig. 6 — Instructor H. G. Riviere favors the larger-sized grinders such as this one Christopher Nelson is using to prepare a weld coupon.

Junior Falcon has been working only a short time at Deep South, but one of his favorite jobs is painting. Maybe that is why one of his favorite tools is a recently purchased paint gun. He's had experience with airbrush painting in automobile customization, but the new Tomcat from C.A.Technologies (Fig. 1) gives him the freedom to cut loose with a nice broad spray pattern. "You still have to take care so the gun doesn't clog," he cautioned.

Ben Ustianowski started welding three years ago right out of high school. A simple tool he finds saves him time in layout is what he calls a speed square — Fig. 2. It's quick and easy to use for setting 90- and 45-deg angles, which are used often in layout work. His wish list also includes a hydraulic shear.

James Messick doesn't go a day without using his Leatherman Wave multitool. A knife, files, pliers, screwdrivers, scissors, and more (Fig. 3) fold into a compact tool that fits easily into a pocket. "When you're doing a job up high or in a tight place you don't have to crawl out or come down just to get another tool. You have it all right in your pocket," he said. Messick has six years' welding experience, having graduated from Robert Morgan Vo Tech.

Owner Edward Booth likes his Needle Scaler (Fig. 3) from Chicago Pneumatic. Hook it up to a compressed air line and you have a great tool for removing rust or scale from steel, deslagging a weld, or "I've found it helps blend in the weld at a stop and makes it easier to restart." It beats a chipping hammer because it's quicker and not as tiring.

The Tools Students Need

When you ask the students in the daytime welding technology class at McFatter Technical Center, Davie, Fla., what their favorite tool is, nearly all give you the same answer: 4- or 4½-in. angle grinders. In fact, student Hilburn Branford calls the small grinders a "universal tool" because they can be used for a variety of weld prep, cleaning, and finishing jobs — Fig. 5.

Instructor H. G. Riviere said most of those same jobs can be performed using the wire brush and chipping hammer the students are required to purchase when they start the program. However, if he were to use a power tool for those tasks, Riviere favors the larger 7- and 9-in. grinders the school buys because he believes they do the same jobs faster and more efficiently — Fig. 6. "The guys like the small ones because they're so lightweight," he said, so many buy the small grinders for themselves.

Branford purchased a 35,000 rpm model Black & Decker 4½-in. angle grinder "because it did what I wanted at a good price." Student Chris Maraj also chose a Black & Decker for the same reason, but Eric Sanders selected a Makita model because it offered higher speeds than some other brands.

The school's campus includes both McFatter Technical Center and the William T. McFatter Technical High School. Riviere teaches both adults and high school students during the day and adults two nights a week. Another instructor handles the rest of the evening classes. Riviere cites a long list of small hand and power tools he considers essential for properly teaching his students to become welders. These include hammers, files, center punches, vises and C clamps, wrenches, levels, strikers, portable power drills, hacksaws, grinders, chipping hammers, wire brushes, fillet gauges, and screwdrivers. The welding lab also includes a Milwaukee Portaband model portable band saw and a small DeWalt chop saw (Fig. 7), among other tools. Another band saw is on Riviere's tool wish list.

When purchasing power tools for the school, Riviere said, he sticks to brands such as Skil, DeWalt, Black & Decker, and Milwaukee because there are a lot of vendors for those products. Also, if they

Fig. 7 — Student Chris Maraj cuts a length of pipe with the school's DeWalt chop saw.

break down, it's easy to find parts and get repairs made to them.

Eric Sanders graduated from the McFatter welding program a week after talking with the *Welding Journal*. During the year and a half he studied at the school, he collected tools to equip a truck for his own mobile welding business. A Native American, Sanders lives and works on the Seminole Reservation in Broward County, Fla. Besides his truck, the tribal council also allows him to use a small shop on the reservation. He mostly does weld repairs on farm equipment or fabricates farm-related items. For instance, he recently built a unit that fits on the back end of a tractor and holds boxes of plants. As the tractor moves down the rows, the planter continuously feeds the boxes down to the farmworkers.

Sanders would like to stock his truck with a gasoline-powered, portable cut-off saw. He used one while working in Oklahoma and liked the way it performed. "It looks something like a chainsaw," Sanders said. "It cuts very nice and is easier to use and makes a cleaner cut than a torch does."

Hilburn Branford has been enrolled in the McFatter welding program approximately six months and hopes to eventually go to The Ohio State University to study for a metallurgical engineering degree. Prior to studying welding, Branford worked as a machinist. In keeping with his machinist training, Branford's toolbox contains items such as a protractor, steel ruler, square, and box wrenches. "These measuring tools keep my work aligned," he said. "I like to keep my work in as close alignment as possible."

Jet Engine Repair Shop

Propulsion Technology Group, Miami, Fla., repairs jet engine and helicopter parts. Its orbital welder, Jose Caldaron, swears by Nicholson files for final weld blending and deburring — Fig. 8. "I've used them for over 35 years, and they seem to last longer than anything else we've tried."

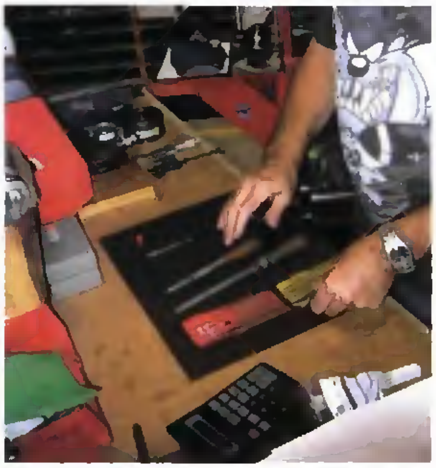


Fig. 8 — Jose Caldaron of Propulson Technology Group likes to use these Nicholson files for final weld blending and deburring.

Fig. 9 — Propulsion Technology Group's Jose Lago finds that this Dotco pneumatic band sander works well for weld finishing.

Another aviation welder at the company, Jose Lago, has a Dotco pneumatic band sander that he likes for finishing welds in magnesium, aluminum, and titanium — Fig. 9.

Theatrical Shop

Phillip Blackwood, technical director of the Jerry Herman Ring Theatre at the University of Miami, relies on a collection of "great" 19.2-V Porter-Cable cordless drills to fasten holding blocks to a table prior to gas metal arc welding structures for theatrical sets — Fig. 10.

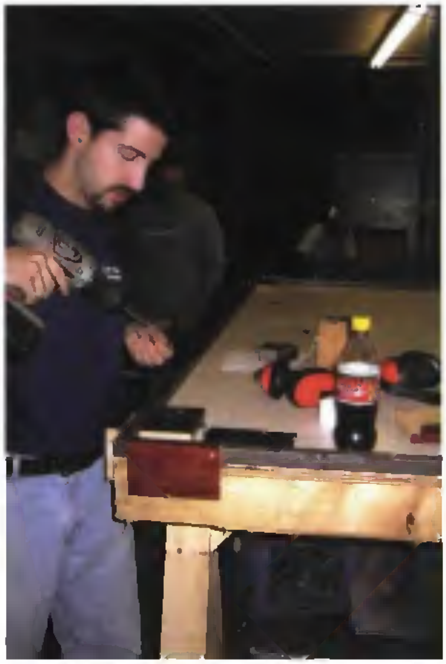


Fig. 10 — Prior to GMA welding of structures for theatrical sets, Phillip Blackwood uses his collection of Porter-Cable cordless drills to fasten holding blocks to this table.

Custom Bike Shop

Robert Pristau, owner of Wicked Custom Cycles, Hialeah, Fla., favors a Milwaukee Orbital Super Saw to cut metal pieces for custom choppers — Fig. 11.

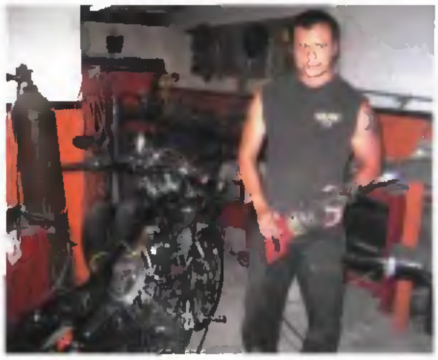


Fig. 11 — Robert Pristau uses a Milwaukee Orbital Super Saw to cut metal pieces for the custom choppers he builds.

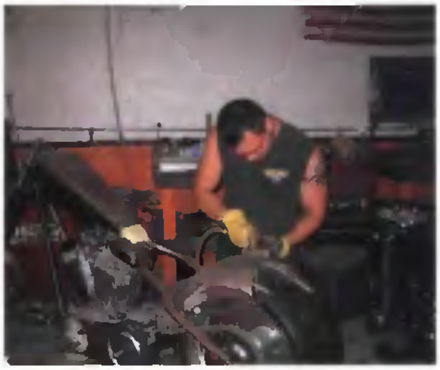
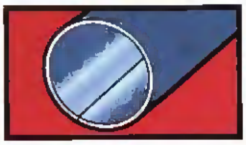


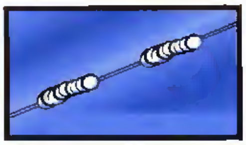
Fig. 12 — Here Pristau uses a ¼-in. pneumatic grinder to shape a chopper fender.

For jobs such as shaping up a chopper fender, Pristau uses a Northern Industrial Tools ¼-in. pneumatic die grinder — Fig. 12.◆

Versatile: You create a very bright weld pool doing high amp welding on stainless. To avoid seeing the brilliant glow when repositioning, you use the new Speedglas ***Delay*** feature to add time before the lens switches from dark to light.



Versatile: You are using a new TIG inverter set at 1 amp with virtually flat frequency. You use the lens' enhanced ***Sensitivity*** setting to sense the arc.



Versatile: You are making a series of tack welds. You want to quickly check each weld before moving on, so you reduce the ***Delay*** to speed up dark-to-light switching.

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Save Time and Money with the Right Abrasive Wheels

A good understanding of the composition of grinding wheels and the types available can lead to greater efficiency and cost savings

BY COLLEEN KARPAC, KURT HONAKER, AND TOM FOGARTY

Seasoned welding professionals will say that their grinder is an extension of their arm. From weld prep to cleanup, the delicate touch of a professional with a grinder makes a big difference — Fig. 1. But no matter which size grinder, without the right abrasive grinding wheel, projects can take more time and have a higher cost in the long run.

When choosing an abrasive grinding wheel, consider each wheel's type (profile), composition, grain size, hardness, designated application, and rpm rating. By understanding how each is called out, the decision process will be easier and the work more efficient.

Wheel Types

An abrasive grinding wheel's type (profile) says a lot about its efficiency over a given area. In fact, each wheel covers varying surface areas differently. The following four types are most commonly used in conjunction with welding or metalworking projects — Fig. 2.

- A Type 27 wheel is the most common type of wheel on the market. With a flat grinding surface, it is used most effectively for weld prep, cleaning, and deburring on flat surfaces such as bar stock and angle iron at 15- to 30-deg angles.

COLLEEN KARPAC is product manager, abrasives, KURT HONAKER is brand manager, accessories, and TOM FOGARTY is communications marketing manager, Bosch Power Tools and Accessories, Robert Bosch Tool Corp., Mt. Prospect, Ill., (224) 232-2000.

- The concave shape of a Type 28 wheel allows it to cover the most area possible on curved or uneven surfaces. Utilized for weld prep, cleaning, and deburring on materials such as bar stock, users should apply it at a 15-deg angle.

- A Type 29 wheel is convex in shape for finishing and blending projects on flat surfaces. This wheel offers the best performance when applied at a 10-deg angle. In addition to Type 29 bonded abrasives, users can also find Type 29 flap discs.

- A Type 1 cut-off wheel is hubless, flat and straight. Available in varying thicknesses and sizes, these wheels are designed to accompany tools ranging from a small angle grinder to circular and cutoff saws.

As differences in profile offer advantages, the composition of each wheel also makes various abrasives better suited for certain applications.

Fig. 1 — Welding professionals use a grinder for jobs ranging from weld prep to cleanup.

Composition

Manufacturers refer to the abrasive material within each wheel as its grain or grit — Fig. 3. From the basic material, alumina, manufacturers derive aluminum oxide, the most prevalent grain for metalworking abrasives. Aluminum oxide is a tough, blocky-shaped grain used for metals and high-tensile-strength materials.

Another higher quality material commonly found within abrasive wheels is zirconium, a very fine, dense, crystalline grain that is often mixed with aluminum oxide to extend the life of a bonded wheel, or used alone for a high-quality, long-life flap disc.

When it comes to wheel composition, manufacturers create their own recipes for acceptable balances between wheel life and removal rate at a competitive price. For example, depending on how long alumina is heated at 2000°C in an electric furnace, when opened and sifted, aluminum oxide emerges in different quantities, qualities, and purities. These can range from a basic brown to special grains tinted pink or white, while anything manufactured of zirconium can be identified by its blue color. Users can also identify which material is used from each wheel's label: A stands for aluminum oxide, Z for zirconium, AZ for alumina zirconium, and AS for aluminum oxide special.

Grain Size

Individually, each grain carries different quality levels and purities that make it more applicable for different wheels, but grain size plays an additional role. The larger or coarser the grain is, the more aggressive the wheel. Manufacturers have developed a broad range of abrasive grain sizes, which can be found on each abrasive wheel's label. Though a broad range exists, the coarse and medium sizes are most prevalent in grinding wheels. In fact, most manufacturers offer wheels ranging from 24 to 180, as follows.

- Very Coarse — 8 to 12

- Coarse — 14 to 24 (main sizes for metal grinding)

- Medium — 30 to 60 (main sizes for metal grinding)

- Fine — 70 to 180

- Dust-fine — 200 to 800

Choosing between the various grits or grains can seem perplexing, but each actually represents varying levels of aggressiveness. Like sandpaper, the larger the grains, the more aggressive the wheel will be; the smaller the grain, the longer the life and less aggressive the wheel.

Wheel thickness also plays a part in wheel aggressiveness and longevity. A good tip to keep in mind is that the life of the wheel is proportional to the thickness. The thicker the wheel, the longer it will last. However, the tradeoff is speed. The thinner the wheel, the faster it cuts or grinds. The key is finding what works best for the project.

Hardness

Once you understand grain size and composition, abrasive wheels are next gauged by their longevity. Manufacturers call this hardness, the resistance of the grain from breaking out of the wheel's bonding. Categorized alphabetically from A to Z (softest to hardest), 99% of the resin-bonded market falls within the following categories and is listed on the wheel's label as such:

- Q = soft wheel

- R = medium hard wheel

- S = medium hard to hard wheel

- T = hard wheel

Overall, hard abrasive wheels last

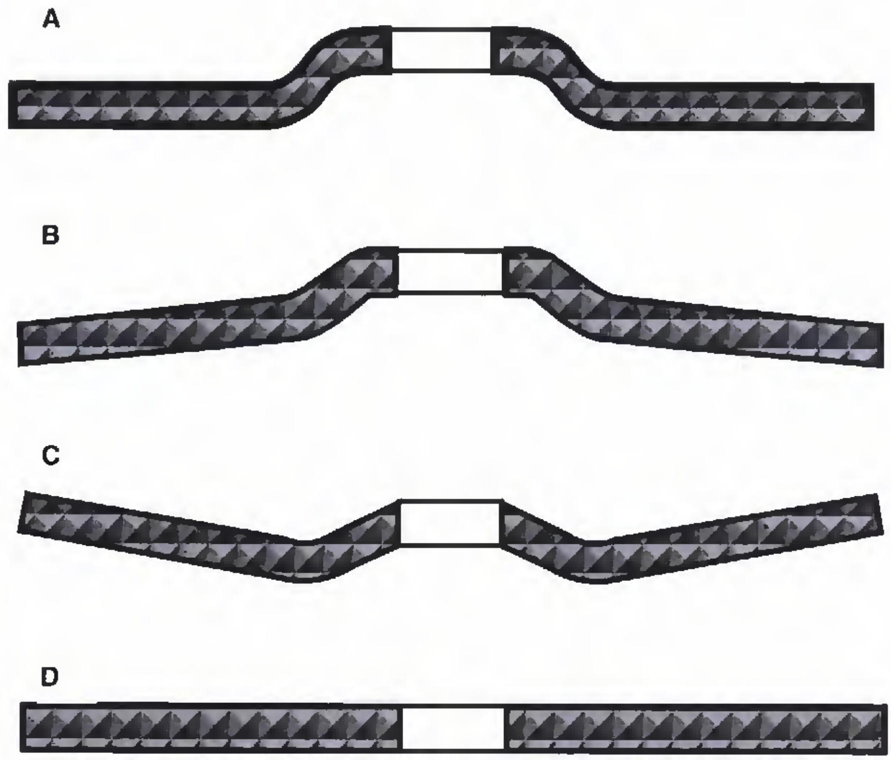

Fig. 2 — The four types of grinding wheels most commonly used with welding or metalworking. A — Type 27; B — Type 28; C — Type 29; D — Type 1.

longer but remove less material per wheel with fewer new grains revealed. Soft abrasives remove material quicker, but wear out faster. As a standard rule, professionals should use soft wheels on hard materials and hard wheels on soft materials. It all comes back to manufacturers looking for the right recipe to balance cut rate and wheel longevity. By choosing the right level of hardness, time can be saved.

Bonding and Reinforcement

The various manufacturers of bonded abrasives use the relatively same bonding agents, gluelike substances that hold the grains together. In addition to a bonding agent, most abrasives also utilize woven fiberglass reinforcement to strengthen the wheel's structure for better performance and safety.

From one manufacturer to another, thickness, size of the weave, whether the fiberglass extends from the arbor to the outer edge, and the number of layers in place can vary. Most metalworking abrasives have a minimum of two layers, while some wheels include a third or fourth sandwiched internally, but there are always exceptions.

Flap discs are not a bonded abrasive with reinforcement, rather they are a unique alternative. The dual-purpose benefit of a flap disc makes it one of the greatest advances in abrasive grinding wheels over the past ten years. A Type 29 flap disc combines the benefits of a layered, heavy-duty coated abrasive, similar to sandpaper, in a unique bonded abrasive grinding wheel design. Because of their dual application, flap discs make it unnecessary to change wheels between beveling and finishing work. Additionally, most flap discs offer more than 20 times more life, stay cooler, and reduce glazing and loading with self-sharpening flaps. Investing in such benefits can save time and money.

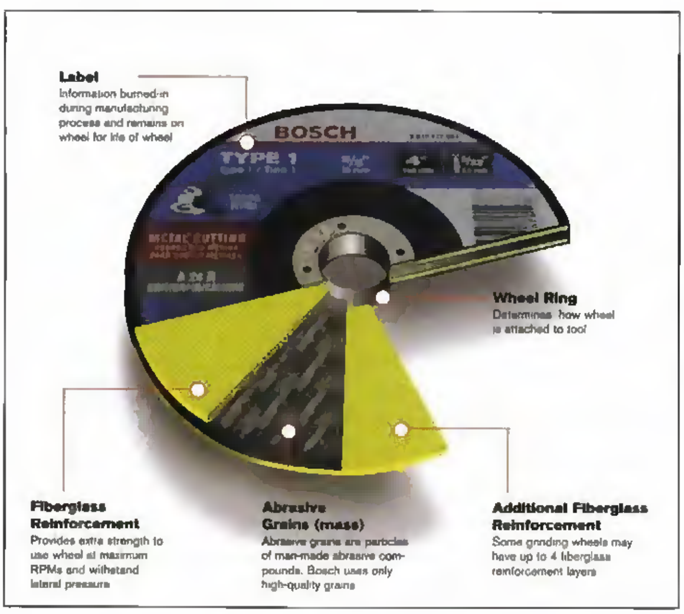

Fig. 3 — The layers that comprise the makeup of an abrasive grinding wheel.

Fig. 4 — To make wheel selection easier, manufacturers burn a wide variety of information into the label, including a color-coded application description.

Application

In an effort to make wheel selection easier (Fig. 4), manufacturers like Bosch Power Tools and Accessories have enhanced and extended the industry's color-coding system to go beyond simple blue for steel and green for masonry. The following represents this easy recognition system:

- Metal — Red
- Stainless (INOX) — Blue
- Aluminum — Grey
- Concrete/Masonry — Green
- Asphalt — Black
- Metal and Masonry — Red and Green

This system allows users to quickly identify wheel applications by color, from general purpose to specialty wheels for aluminum or stainless steel. Furthermore, to protect the integrity of the stainless steel, professionals know they can't use the same wheel to grind other materials, so having a specific identifiable stainless wheel makes the selection process even easier. It also helps distinguish metalworking wheels from concrete application abrasives.

Manufacturers also include special tool icons that identify which tool a wheel is meant to accompany: small angle grinders, large angle grinders, cutoff saws, etc.

Furthermore, in addition to following a color system, manufacturers utilize the same ANSI marking system by including abrasive grain, grain size, hardness, and bond in an universal format. One example includes the following all-purpose wheel: A 30 T – BF stands for aluminum oxide, size 30 grain, hard, reinforced bonded wheel.

Overall, the key to finding the best abrasive wheel for a particular application is to test out new wheels. Often companies won't try new options or only use all-purpose wheels because of price discounts or past relationships. Test out new wheels as frequently as possible and compare each to find the best solutions.

Safety First

Abrasive wheels can seem harmless, but anyone who has experienced one disintegrate into shrapnel at more than 10,000 rpm because of improper use will tell you it is not something they would like to encounter again. To use abrasive wheels safely, keep the following tips in mind.

- First and foremost, always select an abrasive wheel with a rpm rating higher than the grinder it could be mounted to. If a wheel with a lower rpm is mounted to a grinder, it will spin so fast that it could disintegrate right on the tool and possibly cause injury to the user or those close by. Manufacturers specifically call out rpm specifications on abrasive labels and grinder packaging to help avoid these common errors and protect users.
- Use the correct diameter wheel with the appropriate grinder such as a 4½-in. wheel with a 4½-in. grinder. This will help decrease the chances of using the wrong rpm wheel, as well.
- Treat abrasive wheels with care. Store them dry, straight, and frost-free. Drastic changes in temperature or dampness will affect the strength of the bonds and overall structure of the wheel.
- Do not use wheels with any visible cracks or chips, especially in or around the center ring. Avoid hitting or striking the wheel; these kinds of actions can cause the wheel to break apart.
- Always mount a wheel with its ring toward the grinder and use only undamaged original flanges.
- Use a guard that covers one-half the abrasive wheel. Never remove it; a toolless lock mechanism can help avoid any replacement issues as well as make adjustments easier.
- To ensure the wheel is secured correctly, run the grinder with its wheel mounted for at least a minute at full speed before engaging material.
- Never grind with flammable materials within or near the flow of the sparks.
- Concentrate on the task at hand. The only way to prevent an issue is to be aware of what you are doing and what can happen.
- Finally, always wear proper safety goggles and clothing — Fig. 5. Anyone who ever received an injury has wished in hindsight that he or she took the few seconds necessary to don the proper protection.

Fig. 5 — Proper eye protection and clothing should always be used whenever grinders are being used.

Manufacturers worldwide constantly improve their abrasive wheels to make the selection process easier and professional users more successful. Try new abrasive wheels, understand the various solutions available, remember to apply safety rules, and efficiency and cost-savings are sure to follow. ◆

Update: Titanium Specification Revised

Titanium welding in open air depends on careful cleaning and the use of oversize torch gas cups equippped with a gas lens. Trailing shields are normally needed where higher heat input or thinner material result in a longer zone of cooling metal. Photo courtesy of Titanium Fabrication Corp., Fairfield, N.J.

Filler metal standard includes new alloys and reflects current industry practice

BY JAMES A. McMASTER AND RICHARD C. SUTHERLIN

American Welding Society Specification A5.16/A5.16M: 2004, *Specification for Titanium and Titanium Alloy Bare Welding Electrodes and Rods*[1], has been revised to bring it in line with current industry practice. The following are the most important changes since the 1990 revision (Ref. 1):

- Titanium alloy filler metals corresponding to most grades included in the ASTM Product Specifications have been added.
- A range of oxygen has been added to chemistry specifications to better control the strength of the weld deposit, particularly in unalloyed titanium weldments.
- Interstitial element and iron chemistry have been brought in line with industry production, making the specifications more realistic in indicating the true chemistry.
- Matching filler metal grades designed to produce as-deposited weld-metal oxygen to match the base metal is now recommended.
- Metric dimensioning standards have been added.

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1. This revised standard is available through Global Engineering Documents, (800) 854-7179, www.global.ihs.com.

Table 1
Chemical Composition Requirements for Titanium and Titanium Alloy Electrodes and Rods

AWS Classification		UNS	Weight Percent[a,b,c,d]											
2004	1990	Number[e]	Carbon	Oxygen	Nitrogen	Hydrogen	Iron	Aluminum	Vanadium	Palladium	Ruthenium	Nickel	Other Elements	Amount
ERTi-1	ERTi-1	R50100	0.03	0.03–0.10	0.012	0.005	0.08	—	—	—	—	—		
ERTi-2	ERTi-2	R50120	0.03	0.08–0.16	0.015	0.008	0.12	—	—	—	—	—		
ERTi-3	ERTi-3	R50125	0.03	0.13–0.20	0.02	0.008	0.16	—	—	—	—	—		
ERTi-4	ERTi-4	R50130	0.03	0.18–0.32	0.025	0.008	0.25	—	—	—	—	—		
ERTi-5	ERTi-5	R56400	0.05	0.12–0.20	0.030	0.015	0.22	5.5–6.7	3.5–4.5	—	—	—		
ERTi-7	ERTi-7	R52401	0.03	0.08–0.16	0.015	0.008	0.12	—	—	0.12–0.25		—		
ERTi-9	ERTi-9	R56320	0.03	0.08–0.16	0.020	0.008	0.25	2.5–3.5	2.0–3.0			—		
ERTi-9ELI	ERTi-9ELI	R56321	0.03	0.06–0.12	0.012	0.005	0.20	2.5–3.5	2.0–3.0			—		
ERTi-11	n/a	R52251	0.03	0.03–0.10	0.012	0.005	0.08	—	—	0.12–0.25		—		
ERTi-12	ERTi-12	R53401	0.03	0.08–0.16	0.015	0.008	0.15	—	—			0.6–0.9	Molybdenum	0.2–0.4
ERTi-13	n/a	R53423	0.03	0.03–0.10	0.012	0.005	0.08				0.04–0.06	0.4–0.6		
ERTi-14	n/a	R53424	0.03	0.08–0.16	0.015	0.008	0.12				0.04–0.06	0.4–0.6		
ERTi-15A	n/a	R53416	0.03	0.13–0.20	0.02	0.008	0.16	—	—		0.04–0.06	0.4–0.6		
ERTi-16	n/a	R52403	0.03	0.08–0.16	0.015	0.008	0.12	—	—	0.04–0.08		—		
ERTi-17	n/a	R52253	0.03	0.03–0.10	0.012	0.005	0.08	—	—	0.04–0.08		—		
ERTi-18	n/a	R56326	0.03	0.06–0.12	0.012	0.005	0.20	2.5–3.5	2.0–3.0	0.04–0.08				
ERTi-23	ERTi-5ELI	R56408	0.03	0.03–0.11	0.012	0.005	0.20	5.5–6.5	3.5–4.5			—		
ERTi-24	n/a	R56415	0.05	0.12–0.20	0.030	0.015	0.22	5.5–6.7	3.5–4.5	0.04–0.08		—		
ERTi-25	n/a	R56413	0.05	0.12–0.20	0.030	0.015	0.22	5.5–6.7	3.5–4.5	0.04–0.08		0.3–0.8		
ERTi-26	n/a	R52405	0.03	0.08–0.16	0.015	0.008	0.12	—	—		0.08–0.14	—		
ERTi-27	n/a	R52255	0.03	0.03–0.10	0.012	0.005	0.08	—	—		0.08–0.14	—		
ERTi-28	n/a	R56324	0.03	0.06–0.12	0.012	0.005	0.20	2.5–3.5	2.0–3.0		0.08–0.14	—		
ERTi-29	n/a	R56414	0.03	0.03–0.11	0.012	0.005	0.20	5.5–6.5	3.5–4.5		0.08–0.14	—		
ERTi-30	n/a	R53531	0.03	0.08–0.16	0.015	0.008	0.12	—	—	0.04–0.08		—	Cobalt	0.20–0.80
ERTi-31	n/a	R53533	0.03	0.13–0.20	0.02	0.008	0.16	—	—	0.04–0.08		—	Cobalt	0.20–0.80
ERTi-32	n/a	R55112	0.03	0.05–0.10	0.012	0.008	0.20	4.5–5.5	0.6–1.4				Molybdenum Silicon Zirconium Tin	0.6–1.2 0.06–0.14 0.6–1.4 0.6–1.4
ERTi-33	n/a	R53443	0.03	0.08–0.16	0.015	0.008	0.12	—	—	0.01–0.02	0.02–0.04	0.35–0.55	Chromium	0.1–0.2
ERTi-34	n/a	R53444	0.03	0.13–0.20	0.02	0.008	0.16	—	—	0.01–0.02	0.02–0.04	0.35–0.55	Chromium	0.1–0.2

Notes:

a. Titanium constitutes the remainder of the composition.

b. Single values are maximum.

c. Analysis of Fe and the interstitial elements C, O, H, and N shall be conducted on samples of filler metal taken after the filler metal has been reduced to its final diameter and all processing operations have been completed. Analysis of the other elements may be conducted on these same samples or it may have been conducted on samples taken from the ingot or the rod stock from which the filler metal is made. In case of dispute, samples from the finished filler metal shall be the referee method.

d. Residual elements, total, shall not exceed 0.20 percent, with no single such element exceeding 0.05 percent, except for yttrium, which shall not exceed 0.005 percent (see A6.5). Residual elements need not be reported unless a report is specifically required by the purchaser. Residual elements are those elements other than titanium that are not listed in Table 1 for the particular classification, but which are inherent in the raw material or the manufacturing practice. Residual elements can be present only in trace amounts and they cannot be elements that have been intentionally added to the product. If an impurity is intentionally added, it must be tested for.

e. SAE/ASTM Unified Numbering System for Metals and Alloys.

Additional Grades Match New Grades in ASTM Material Specifications

The first and most visible change since the 1990 revision of AWS A5.16 is the addition of many new grades corresponding to the ASTM *Titanium Mill Product Specifications* (Ref. 2). Table 1 lists the grades and the filler metal chemistry included in the revised specification, except that they are organized with the "standard" base grade or alloy (generally in order of increasing strength) grouped together with the corresponding palladium and ruthenium corrosion-enhanced grades. Note that the strengthening alloying elements and interstitial and iron levels within each group are essentially the same. Earlier AWS grade designations, UNS numbers, open Code Cases, and current and proposed ASME *Boiler and Pressure Vessel Code* Section IX filler metal F-numbers are also listed in Table 1.

Oxygen Range and Interstitial and Iron Chemistry Limits

Oxygen ranges and more representative upper limits for iron, nitrogen, and carbon have been added to the requirements for all filler metal grades.

Oxygen, nitrogen, and carbon are termed interstitial elements because they occupy sites between titanium atoms in the regular metal matrix. Iron is a substitutional element because it occupies a site in place of a titanium atom. Increasing levels of these elements strengthen unalloyed titanium and are the principal difference among grades of unalloyed titanium. Nitrogen and carbon are controlled to the lowest possible levels in titanium production. Iron levels are generally kept low in filler metal for reasons of strength control and corrosion resistance. Oxygen is left as the key element to determine strength. These strengthening effects are minor compared to the effects of alloying elements like aluminum and vanadium, but even in the alloys there is an effect, as seen, for example, in comparing mechanical properties of Grade 5 (Ti-6Al-4V) and Grade 23 (Ti-6Al-4V ELI [extra-low interstitial]).

Under the 1990 specification, ERTi-1 and ERTi-2 had the same singular maximum 0.10 wt-% oxygen level, while unalloyed grades ERTi-3 and ERTi-4 had specified oxygen ranges. The ERTi-1 and -2 filler metal chemistries were almost indistinguishable; both were often produced to the oxygen levels as low as 0.02 wt-%, and ERTi-2 often had lower interstitial and iron levels than ERTi-1. The practice of dual-certifying the two grades was common. The "Limits in Data" are based on data from a study of 200 heats of filler metals and show that levels well below the 1990 limits were routinely being achieved (Ref. 3).

Table 2 — Important Changes in Unalloyed Titanium Chemistry

Grade	Revision	Carbon	Oxygen	Nitrogen	Hydrogen	Iron
ERTi-1	2004	0.03	**0.03–0.10**	0.012	0.005	0.08
	1990		0.00–0.10	0.015		0.10
	Limits in Data	0.006–0.030	0.02–0.10	0.004–0.012		0.002–0.06
ERTi-2	2004	0.03	**0.08–0.16**	0.015	0.008	0.12
	1990	0.03	0.00–0.10	0.20	0.008	0.20
	Limits in Data	0.003–0.130	0.02–0.16	0.001–0.020		0.02–0.12
ERTi-3	2004	0.03	**0.13–0.20**	0.02	0.008	0.16
	1990	0.03	0.10–0.15	0.20	0.008	0.20
	Limits in Data	0.009–0.030	0.13–0.23	0.006–0.020		0.04–0.16
ERTi-4	2004	0.03	**0.18–0.32**	0.025	0.008	0.25
	1990	0.03	0.15–0.25	0.200	0.008	0.30
	No data in study					

Table 3 — Theoretical Filler Metal Oxygen Limits in Weld Deposit Compared to Typical Base Metal Levels

	Filler Metal[a]					Base Metal		
Grade	Specified Minimum	Specified Maximum	Added in Welding	Lower Limit	Upper Limit	Minimum	Average	Maximum
ERTi-1	0.030	0.100	0.030	0.06	0.13	0.040	0.062	0.080
ERTi-2	0.080	0.160	0.030	0.11	0.19	0.095	0.142	0.195
ERTi-3	0.130	0.200	0.030	0.16	0.23	0.170	0.226	0.250

(a) Oxygen maximum and minimum levels as in AWS A5.16/2004.

One problem that could result was that some ERTi-2 filler metal was so low in interstitial and iron content that it is questionable whether properties might be made in a weld deposit where effects of base-metal dilution of the filler metal were minimized, such as near the surface of a heavy-section weldment. Because welding procedures are often qualified using full-section tensile tests, it would be easy to miss this low-strength region of the weldment. Of course, welds qualified with a relatively high-oxygen ERTi-2 filler metal might not have the same properties as one of the same grade with very low oxygen.

Fabricators may wish to review chemistry of stock filler metal applied to heavy-section structural weldments where low strength might be a problem in service.

Table 2 illustrates the changes in unalloyed filler metal grades.

Classification of filler metals to multiple grades is discouraged in the revised specification, except in the cases where the narrow range of filler metal chemistry actually does overlap.

Oxygen Levels in the Specification

The oxygen ranges in the new specification were selected assuming a 300 ppm increase in oxygen, typical with normal industrial cleaning and shielding practice (Ref. 4), in the weld deposit from dilution, absorption from shielding gas, surface oxides on base and filler metal, and other sources.

Table 3 lists the specification limits in unalloyed titanium filler metals and calculates theoretical lower and upper limits of oxygen based on a 300 ppm increase in welding, then compares this result to typical oxygen ranges in titanium base metal (Refs. 5, 6). Similar ranges were used for alloys.

Unalloyed Titanium Filler Metal Grades

Unalloyed titanium filler metal Grades 1, 2, 3, and 4 cover the full range of strength and ductility suitable for many engineering applications. The low-strength Grade 1 is used for applications where ductility is of paramount importance. Grade 2, the most widely available and generally lowest-cost grade, is the industry standard structural grade and is typically applied to process equipment where its combination of strength and fabricability is suitable. Grade 3 is applied when the benefit of higher strength outweighs the lower availability, typically for larger projects where a mill production run of plate or pipe is justified. Grade 4 has little application in process equipment, except in some plating equipment where low-cost secondary material may be applied.

The addition of the oxygen range will have the most important effect in the unalloyed filler metal grades.

While special circumstances may dictate selection of a different grade, the intent of A5.16:2004 is that ERTi-1 will be used for Grade 1, ERTi-2 for Grade 2, etc. The overlap of oxygen ranges does provide some room for dual certification, but it is assumed that filler metal input wire bar will be selected to produce the distinct filler metal chemistries.

Intermediate Strength Standard Alloy Filler Metals

Grade 12 (Ti-0.8Ni-0.3Mo) was originally developed to expand the range of corrosion resistance of the unalloyed grades in elevated temperature neutral brines as a lower-cost alternate to Grade 7 (Ti-0.15Pd), but it has found use in pressure equipment because of higher elevated-temperature strength compared to unalloyed grades.

Grade 9 (Ti-3Al-2.5V) is the highest-strength grade accepted for ASME Boiler Code construction. Its use in the future is expected to increase as users gain confidence in its corrosion performance (comparable to Grade 2 in most applications) and titanium applications become more demanding. While the cost of this grade is nominally higher than Grade 2 or 12, it becomes more advantageous on a cost/performance basis, for example, by allowing users to take advantage of reduced shell/tube thickness for lower welding cost and reduced equipment weight.

Note that there is an ERTi-9 (Ti-3Al-2.5V) and an ER-Ti-9ELI. The corrosion-enhanced grades ERTi-18 and ERTi-28 correspond (except for the Pd and Ru) to the ERTi-9ELI formulation. This suggests that ERTi-9ELI may be a better choice for Grade 9.

High-Strength Standard Alloy Filler Metals

Two "standard" high-strength alloys, Grades 5 (Ti-6Al-4V [120 ksi UTS]) and 23 (Ti-6Al-4V ELI [110 ksi UTS]) meet the requirements for most industrial applications. Oxygen ranges and more realistic upper limits on iron have been added to each of these grades. Aluminum and vanadium strength alloying element limits are unchanged from the 1990 specification.

Grade 5 (Ti-6Al-4V) is used extensively in aerospace applications and is the most widely produced high-strength titanium grade. The resulting low cost and high availability have made Grade 5 the high-strength workhorse for the industrial corrosion market. ERTi-5 filler metal should normally produce a weld deposit of comparable tensile properties.

Grade 23 is a lower-interstitial, slightly higher-toughness version of Grade 5. Its cost and availability are only slightly less attractive than Grade 5. Grade 23 should be selected in most high-strength corrosion applications unless the added 10 ksi of strength of Grade 5 is absolutely needed. It is easier to fabricate and more tolerant of physical damage in service. ERTi-23 filler metal should normally produce a weld deposit of comparable tensile properties.

Grade 32 (Ti-5Al-0.9Mo-1.0Zr-1.0Sn [110 ksi UTS]) is an ultrahigh-toughness alloy that evolved from U.S. Navy efforts to find a high-toughness alloy for combat submarine applications that didn't suffer stress corrosion cracking. It may find use in offshore and deep well applications where the toughness of specially heat-treated Grade 23 or 9 is insufficient. ERTi-32 filler metal should normally produce a weld deposit of comparable tensile properties and high toughness.

Palladium and Ruthenium Corrosion-Enhanced Grades

Palladium or ruthenium corrosion-enhanced filler-metal grades corresponding to the unalloyed and the higher strength alloys are also included in the new specification.

Palladium and ruthenium enhance titanium corrosion resistance under mildly reducing acidic conditions and when crevice corrosion in hot halide media (e.g., hot seawater, brines, chlorinated solutions, and wet chlorine) is a concern. These grades have mechanical properties comparable to their standard counterparts.

Sometimes "standard grade" welds may be more susceptible to general corrosion attack, pitting, or crevice corrosion than base metal (Ref. 8). In these cases, use of palladium or ruthenium corrosion-enhanced filler metal of the same strength as the normally used standard filler-metal grade should be considered. Often the same procedure qualifications will apply, but varying weld chemistry and its corrosion resistance in the specific environment should be verified, possibly using bead sequences that maximize the palladium or ruthenium on the exposed surface.

Select Filler Metal to Consider Both Strength and Corrosion

A third significant change is that the new specification recommends matching the filler-metal grade to the base metal to better assure that desired strength and corrosion resistance is achieved.

The revised composition levels in A5.16/A5.16M:2004 are intended to eliminate the need for deliberate undermatching of filler-metal chemistry to the base metal.

Welds for base-metal alloys enhanced with palladium or ruthenium for improved corrosion resistance should normally be made with the corresponding enhanced filler metal to provide optimum mechanical and corrosion properties in the weld deposit. However, because of availability or a desire for somewhat higher corrosion resistance in the weld, ERTi-7 may sometimes be selected for welds in Grade 16 or 26, or ERTi-11 for welds in Grade 17 or 27. Users with aggressive corrosion conditions but not wanting to pay for ERTi-7 may want to consider specifying or selecting filler metal with palladium or ruthenium somewhat above the lower limit of the specification, say 0.06 wt-% for palladium and 0.10 wt-% for ruthenium-enhanced binary grades.

Filler Metal Selection for Welding of Dissimilar Titanium Base Metal Grades

Generally, selecting a filler metal matching the higher strength of the two base metals should be appropriate. For example, where a Grade 2 lug is welded to a Grade 9 pressure component, ERTi-9ELI filler metal provides weld-metal strength at the weld interface with the pressure component more closely matching the strength of the pressure part. Of course, the lug itself may be subject to stresses higher than typically considered because the lug will carry a portion of the load from the shell itself and it may sometimes be appropriate to consider the use of Grade 9 lugs on Grade 9 equipment.

In some cases where Grade 5 (Ti-6Al-4V), an alpha-beta alloy, was welded to an unalloyed all-alpha grade, delayed hydrogen effects have been observed. After a period of time, excessive hydrogen, which has high solubility in beta phase, may migrate to the lower solubility all-alpha-phase material where the hydrides may precipitate and lead to embrittlement or even cracking (Ref. 9). While it has not been documented, this may also occur where alpha-beta Grade 9 is welded to an unalloyed all-alpha grade.

Where a palladium- or ruthenium-enhanced grade base metal is to be welded to a corresponding standard grade base metal (which would usually be assumed to be in nonwetted service), either grade filler metal could be selected.

ASME Status

Grades 1, 11, 17, and 27, 2, 7, 16, and 26, Grade 3, and Grade 9 are all accepted under the current ASME *Boiler Code* for Section VIII. Grade 28 has been accepted under Code Case 2425 (Ref. 7).

ASME is expected to adopt the new AWS specification as ASME SFA 5.16 sometime this year.

Grouping of filler metals for welding procedure and performance qualifications is generally based on comparable weldability. Table 1 lists F-number classifications that have been proposed for inclusion under the ASME Code Section IX, with current numbers indicated in bold typeface.

Metric Dimensional Standards

The revised specification makes use of both U.S. Customary Units (A5.16) and the International System of Units (SI) (A5.16M), and allows filler-metal size to be listed both ways on documentation where appropriate. However, because the conversions are not exact, it is intended that the A5.16 or A5.16M specification be used independently — one or the other.

Filler Metal Marking

The increased number of grades increases the issue of maintaining filler metal traceability from wire production to deposited weld metal. There is no difference in appearance of the different grades, and while it may be possible to distinguish ERTi-5 from ERTi-1 by bending the wire, there is no simple method available for most grades. While the new specification does not cover marking of cut lengths, this topic is under discussion within AWS. Paint color marking systems on wire ends (in use in Japan), paper tags, laser marking, anodized marking, and flattening and coining of wire ends are all possibilities for consideration. ◆

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5. McMaster, J. A. 2003. *Rationalization of Unalloyed Titanium Material Specifications to Current Production Capabilities Offers Opportunities for the Titanium Industry*. Paper No. 03416, presented at Corrosion 2003 (San Diego, Calif., Mar. 17).

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9. Williams, D. L., Krohl, B. G., and Miller, R. A. 1970. Hydrogen segregation in Ti 6Al-4V weldments made with unalloyed titanium filler metal. *Welding Journal* 49(5): 207-s to 212-s.

Joint Considerations in Welding Cast Iron

The design of the weld groove in an iron casting can greatly influence the properties of the weld and ultimately its performance in service. Welds in thin cast iron may be made with single-V or single-U grooves.

With nickel-based filler metals the groove angle should be increased to allow for the manipulation of a sluggish weld pool. Also, the root face must be reduced because nickel-based electrodes achieve less root penetration than standard steel electrodes.

For thicknesses greater than ½ in. (12.7 mm), double-welded joints help to evenly distribute the stresses induced during welding. For thicknesses up to ¾ in. (19 mm), a double-V groove (Fig. 1) or a double-bevel groove (Fig. 2) should be used. For thicknesses greater than ¾ in., a double-U groove (Fig. 3) or double-J groove (Fig. 4) should be considered. When only one side is accessible, a U-groove might be used or a modification that reduces weld metal mass — Fig. 5.

Ways to improve joint design in castings are shown in Fig. 6. In part A of the figure, the crevice created by incomplete penetration can act as an initiation site for the propagation of a crack through the weld. Section B shows how to locate welds away from changes in metal thickness where bending stresses concentrate. In part C, a fillet weld is added to decrease flexing between the top and bottom joint members. These designs should improve the service life of the weldments.

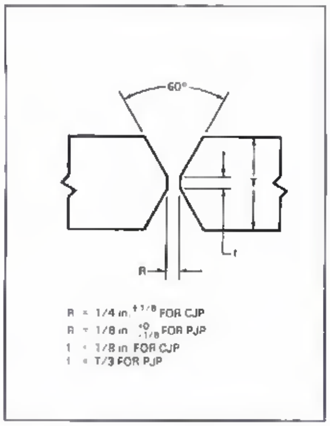

Fig. 1 — Double-V groove.

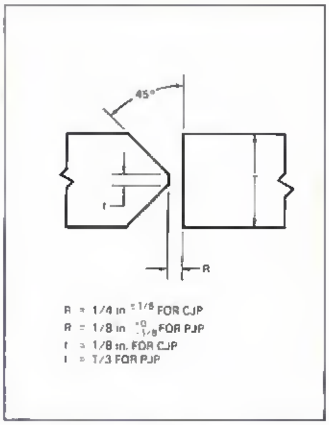

Fig. 2— Double-bevel groove.

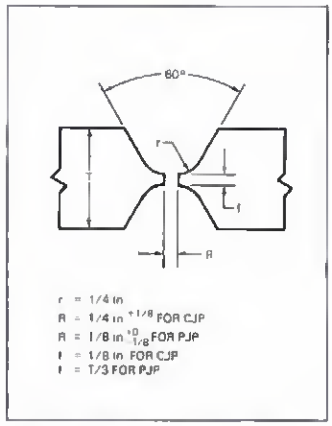

Fig. 3 — Double-U groove.

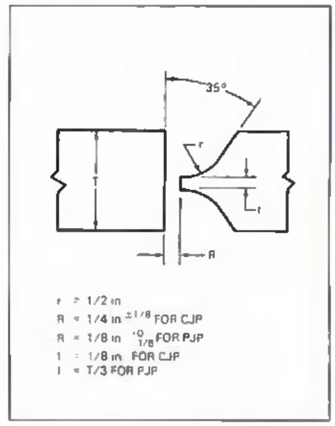

Fig. 4 — Double-J groove.

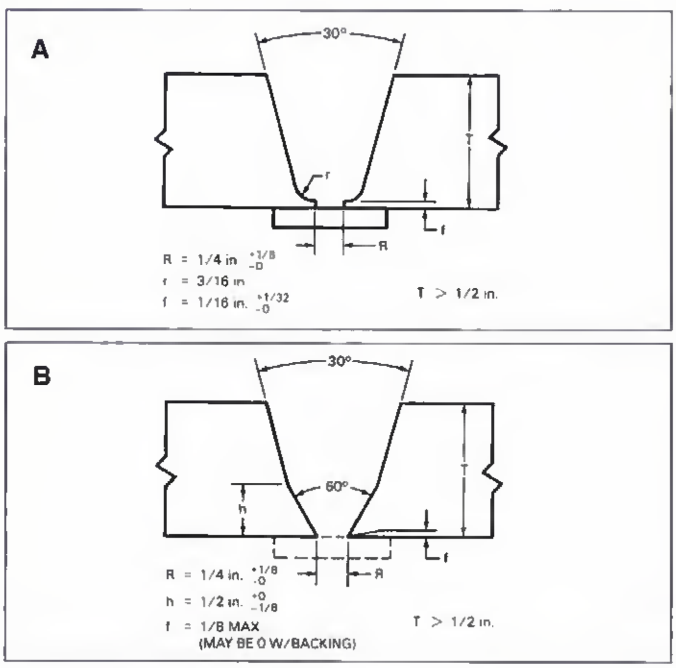

Fig. 5 — U-groove (A) and its modification (B).

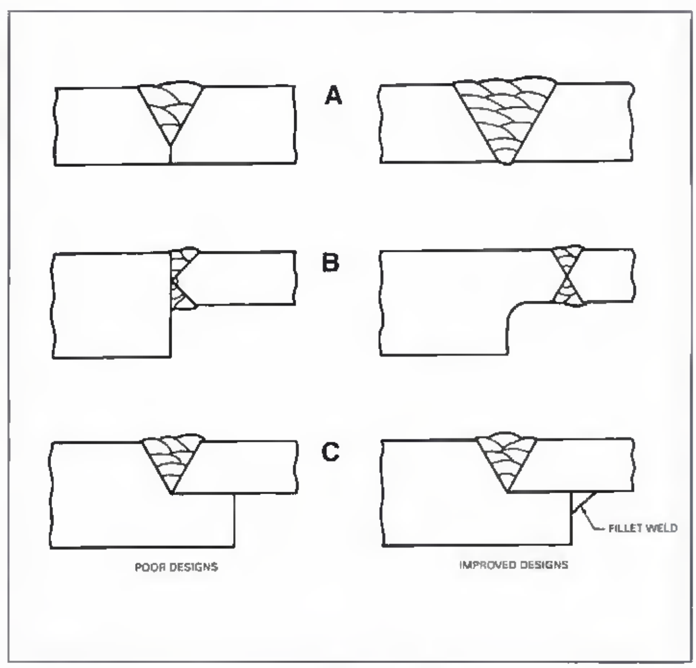

Fig. 6 — Suggested joint design improvements.

Excerpted from ANSI/AWS D11.2, *Guide for Welding Iron Castings.*

NJC Developing Welding for Multi-Role Surface Combatant

The Navy Joining Center is participating with shipbuilders and other Navy MANTECH Centers of Excellence (COE) in several technology development projects for the U.S. Navy's next-generation multi-role surface combatant named DD(X).

One such project addresses a design concept that includes a number of large structures fabricated from thick-section, high-strength steel. Navy Joining Center, the National Center for Excellence in Metalworking Technology (NCEMT), and Naval Surface Warfare Center-Carderock are working with several Navy shipbuilders to develop high-productivity welding technology to replace the manual welding procedures presently used.

Construction of the DD(X) will include high-strength steel structures with fabrication designs requiring welds of the highest integrity. Fabrication of these structures to meet present design requirements has limited the welding procedure options to only manual practices. Welders are required to deposit many layers of weld metal while working in tight spaces as the base material is preheated to minimize risks of hydrogen-induced cracking. Use of manual welding procedures for these structures will require thousands of production worker-hours per ship and result in long production cycles.

Material applications requiring increased strength in greater thicknesses require a different manufacturing approach than currently employed. To be cost-effective it is necessary to

- optimize the deposition rate
- increase the allowable heat input limits
- decrease the joint volume
- mechanize or automate the process
- utilize filler material systems with reduced cracking sensitivity.

This project is developing high-productivity welding technology for large thick-section, high-strength steel structures for enhanced survivability in next-generation surface combatants. This will be accomplished by developing major technologies including selection of welding processes and consumables, development of robust welding procedures with the preferred processes, and the employment of automation to maximize first-time quality in both factory and erection areas. These advancements will not only reduce welding worker-hours, but also will control distortion, assure first-time quality and reduced production schedules, and reduce DD(X) acquisition costs.

The successful completion of this project will improve productivity and quality on large marine structures made from high-strength steel. Automation solutions will be maximized to reduce the demands on welding personnel. It is estimated that a mechanized automated welding system will reduce weld labor costs by 50%.

The developed automated welding technology will be transitioned to the participating shipyards in 2005, where it will be used in production to maximize the productivity and quality of large marine structures. The shipyards will incorporate the technology into the DD(X) manufacturing processes where feasible and cost-effective.

For more information contact Larry Brown at *larry_brown@ewi.org*; (614) 688-5080; or Dennis Harwig at *dennis_harwig@ewi.org*; (614) 688-5132.

The Navy Joining Center is developing a high-productivity welding technology for large thick-section, high-strength steel structures for enhanced survivability in the next-generation of surface combatants like the DD(X) shown here.

What's Happening at NJC?

Dates: August 17–18, 2004
Workshop: University Welding Research Conference for Defense Applications
Host: Edison Welding Institute and Navy Joining Center, Columbus, Ohio
Organizer: The Navy Joining Center
Objective: To promote awareness of current materials-joining research activities to industry and Department of Defense and provide a forum for discussion of future research issues and needs.

For more information, contact Larry Brown, Edison Welding Institute, at (614) 688-5080; *larry_brown@ewi.org*.

NJC Operated by EWI

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e-mail: *NJC@ewi.org*
www: *http://www.ewi.org*
Contact: Larry Brown

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

♦ **Sheet Metal Welding Conference.** May 11–14, Sterling Heights, Mich. Sponsored by the AWS Detroit Section. Contact: (810) 231-2502 or visit *www.sheetmetalwelding.org*.

♦ **2004 International Conference on Aluminum Structural Design (INALCO 2004).** June 2–4, The Lincoln Electric Co., Cleveland, Ohio. Cosponsored by The Lincoln Electric Co., the American Welding Society, the Aluminum Association, ASCE Structural Engineering Institute, the Japanese Light Metal Welding and Construction Association, and Univ. Prof. Dr.-Ing. H. D. Kosteas, Light Metal Structures and Fatigue, Technical University of Munich. Contact *randy.kissell@tgbpartnership.com*.

26th Annual Industrial Ventilation Conferences. June 7–10, Las Vegas, Nev.; October 20–23, Birmingham, Ala. Sponsored by the University of Alabama at Birmingham, and University of Nevada at Las Vegas. For complete information, contact (205) 934-8994; *www.eng.uab.edu/epd*.

Metalform Mexico Exposition. November 10–12, Santa Fe Exposition Center, Mexico City. Sponsored by the Precision Metalforming Association. Targeted at the metal stamping, fabricating, and assembly industries in Mexico. Contact Precision Metalforming Assn., 6363 Oak Tree Blvd., Independence, OH 44131; (216) 901-8800; *www.metalforming.com*.

Robots 2004 Conference. June 9, 10. Ypsilanti Marriott at Eagle Crest Resort, Ypsilanti, Mich. Will examine how robotics can strengthen domestic manufacturing. Sponsored by the Robotics Industries Assoc. For details, visit *www.roboticsonline.com*.

Educational Opportunities

Modern Furnace Brazing Course. May 5–7, Madison Heights, Mich. For design, metallurgical, and production engineers. Presenters include Robert Peaslee, Dr. S. Rangaswamy, and David Bielec. Contact: Marianne Huesing, Wall Colmonoy Corp., 30261 Stephenson Hwy., Madison Heights, MI 48071. (248) 585-6400, ext. 248.

Hobart Institute of Welding Technology. Welding for the Non-Welder, May 24, August 16, or October 11. Fundamentals of Visual Inspection, July 7 or September 8. Classes are held at the Hobart Institute of Welding Technology, Troy, Ohio. For further information and 2004 schedules, call (800) 332-9448 or e-mail *hiwt@welding.org*; *www.welding.org*.

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

Welding Introduction for Robot Operators and Programmers. This one-week course is offered at the Troy, Ohio, facility, or

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presented at a corporate location tailored to specific needs. Contact Hobart Institute of Welding Technology, 400 Trade Square East, Troy, Ohio; (800) 332-9448, ext. 5603; *www.welding.org*.

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

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

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

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

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

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

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

How to Buy Gases 2004 Road Show Seminars. For buyers of specialty gases. Forty seminars are scheduled for 27 states nationwide through August. For schedule of dates, cities, and sign-up information, contact your local Airgas distributor or visit *www.airgas.com*.

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

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

Shielded Metal Arc Welding of 2-In. Pipe in the 6G Position —

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

2004 Motor Sports Welding School. Classes are scheduled at Lincoln Electric headquarters in Cleveland, Ohio. For more information and a complete schedule, contact: Lincoln Electric Motor Sports Welding School, 22801 St. Clair Ave., Cleveland, OH 44117, (216) 383-2461, FAX: (216) 383-8088, e-mail: *lori_bollas@lincolnelectric.com; www.lincolnelectric.com.*

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

Welding Skills Training Courses. Courses include weldability of ferrous and nonferrous metals, arc welding inspection and quality control, preparation for recertification of CWIs, and others. For a complete 2004 schedule, contact: Hobart Institute of Welding Technology, 400 Trade Square East, Troy, OH 45373, (800) 332-9448 or, outside the U.S., (937) 332-5000, FAX: (937) 332-5200; *www.welding.org.* ♦

Educational Opportunities

AWS 2004 Schedule
CWI/CWE Prep Courses and Exams

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

City	Exam Prep Course	CWI/CWE Exam
Alhuquerque, N.Mex.	Aug. 1–6 (API 1104 Clinic also offered)	Aug. 7
Anchorage, Alaska	Sept. 12–17 (API 1104 Clinic also offered)	Sept. 18
Atlanta, Ga.	Oct. 24–29 (API 1104 Clinic also offered)	Oct. 30
Baltimore, Md.	Oct. 31–Nov. 5 (API 1104 Clinic also offered)	Nov. 6
Beaumont, Tex.	June 6–11 (API 1104 Clinic also offered)	June 12
Beaumont, Tex.	Nov. 7–12 (API 1104 Clinic also offered)	Nov. 13
Charlotte, N.C.	Aug. 22–27 (API 1104 Clinic also offered)	Aug. 28
Columbus, Ohio	Aug. 2–6 (API 1104 Clinic also offered)	Aug. 7
Columbus, Ohio	Nov. 1–5 (API 1104 Clinic also offered)	Nov. 6
Corpus Christi, Tex.	EXAM ONLY	Sept. 18
Dallas, Tex.	Sept. 26–Oct. 1 (API 1104 Clinic also offered)	Oct. 2
Denver, Colo.	Oct. 3–8 (API 1104 Clinic also offered)	Oct. 9
Detroit, Mich.	Sept. 26–Oct. 1 (API 1104 Clinic also offered)	Oct. 2
Houston, Tex.	Aug. 2–7 9-YEAR RECERTIFICATION COURSE	
Houston, Tex.	Aug. 15–20 (API 1104 Clinic also offered)	Aug. 21
Indianapolis, Ind.	Aug. 15–20 (API 1104 Clinic also offered)	Aug. 21
Long Beach, Calif.	Nov. 7–12 (API 1104 Clinic also offered)	Nov. 13
Los Angeles, Calif	July 19–24 9-YEAR RECERTIFICATION COURSE	
Memphis, Tenn.	Aug. 8–13 (API 1104 Clinic also offered)	Aug. 14
Miami, Fla.	EXAM ONLY	Aug. 19
Miami, Fla.	EXAM ONLY	Sept. 16
Miami, Fla.	EXAM ONLY	Oct. 14
Milwaukee, Wis.	Sept. 26–Oct. 1 (API 1104 Clinic also offered)	Oct. 2
Minneapolis, Minn.	Sept. 19–24 (API 1104 Clinic also offered)	Sept. 25
New Orleans, La.	Sept. 12–17 (API 1104 Clinic also offered)	Sept. 18
New Orleans, La.	Sept. 13–18 9-YEAR RECERTIFICATION COURSE	No Test
Philadelphia, Pa.	Aug. 9–14 9-YEAR RECERTIFICATION COURSE	
Phoenix, Ariz.	Oct. 3–8 (API 1104 Clinic also offered)	Oct. 9
Pittsburgh, Pa.	Oct. 17–22 (API 1104 Clinic also offered)	Oct. 23
Portland, Oreg.	Nov. 7–12 (API 1104 Clinic also offered)	Nov. 13
Reno, Nev.	Oct. 31–Nov. 5 (API 1104 Clinic also offered)	Nov. 6
Rochester, N.Y.	EXAM ONLY	Aug. 21
Sacramento, Calif.	Aug. 8–13 (API 1104 Clinic also offered)	Aug. 14
Sacramento, Calif.	Oct. 4–9 9-YEAR RECERTIFICATION COURSE	
San Antonio, Tex.	Oct. 17–22 (API 1104 Clinic also offered)	Oct. 23
San Diego, Calif.	Sept. 19–24 (API 1104 Clinic also offered)	Sept. 25
Seattle, Wash.	Sept. 19–24 (API 1104 Clinic also offered)	Sept. 25
Tulsa, Okla.	Oct. 17–22 (API 1104 Clinic also offered)	Oct. 23

AWS International Schedule

MEXICO

CWI Training: June 21–25, November 8–12
Examinations: June 26, November 13
Location: DALUS, S.A., Monterrey, N.L.
Contact: Lorena Garza
Telephone: 52 (81) 8386 1717
FAX: 52 (81) 8386 4780
E-mail: *info@dalus.com*

VENEZUELA

CWI Training: June 9–13
Examination: June 14
Location: Centro Internacional de Educación y Desarrollo
Contact: Carlos Quintini
Telephone: 582 906 4694
FAX: 582 906 4690
E-mail: *quintinic@pdvsa.com*

INDIA

CWI Training: June 14–18
Examination: June 19
Location: Industrial Quality Concepts
Contact: V. Raghavendran
Telephone: 44 2 499 3826
Fax: 44 2499 3826
E-mail: *iqc.in.org@vsnl.com*

BY HOWARD M. WOODWARD

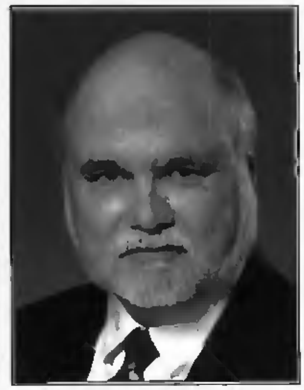
VOLUME 83 • NUMBER 5 • MAY 2004

AWS Elects Its New Slate of National and District Officers

James E. Greer
president

Damian J. Kotecki
vice president

Gerald D. Uttrachi
vice president



Gene E. Lawson
vice president

The American Welding Society elected a new slate of national officers on April 5 at the AWS Annual Meeting held in Chicago, Ill. The new officers will take office on June 1.

James E. Greer was elected president of the Society. He is a professor and coordinator of the welding program at Moraine Valley Community College, Palos Hills, Ill., and president of Techno-Weld Welding Consultants. Greer received his A.S. degree from Moraine Valley Community College, his B.S. from Northern Illinois University, and his M.S. from Chicago State University.

Damian J. Kntecki was elected to his third term as vice president of the Society. He is technical director for stainless and high-alloy product development at The Lincoln Electric Co., Cleveland, Ohio. Dr. Kotecki received his undergraduate and Ph.D. degrees in mechanical engineering from the University of Wisconsin-Madison.

Gerald D. Uttrachi was elected to his second term as vice president. He is president of WA Technology, LLC. Uttrachi holds bachelor's and master's degrees in mechanical engineering and a master of science degree in management from New Jersey Institute of Technology.

Gene E. Lawson was elected to his first term as vice president. Lawson is senior territory sales manager for ESAB Welding and Cutting Products, representing the company's southern California, Arizona, and Hawaii territory.

Incoming President Greer and Vice Presidents Kotecki, Uttrachi, and Lawson will serve on the Society's board of directors. The following elected national and district directors will also serve on the Society's board of directors.

Bruce Albrecht was elected a director-at-large. He is vice president of technology for Miller Electric Mfg. Co., where he has held various technical and general management positions since 1985. Albrecht holds several welding patents and received his bachelor's and master's degrees from the University of Wisconsin Platteville and the University of Wisconsin at Oshkosh.

Nancy C. Cole was reelected a director-at-large. Cole, a Fellow of the American Welding Society, has been a Society member for more than 30 years. She was chair for the AWS Technical Activities Committee (1997–2001), having first joined the committee as chair of the C3 Brazing and Soldering Committee.

— continued on next page

Bruce Albrecht
director-at-large

Nancy C. Cole
director-at-large

— *continued from previous page*

Kenneth R. Stockton was elected District 2 director. Stockton is a test engineer with the NDE Group of PSE&G, Maplewood Testing Service in Maplewood, N.J.

Leonard P. Connor was elected District 5 director. Before his recent retirement, Connor served as managing director, Technical Services Division, at AWS headquarters in Miami, Fla.

Wallace E. Honey was reelected District 8 director. Honey is a sales representative for Anchor Research Corporation in Russellville, Ala.

Eftihios Siradakis was reelected District 11 director. Siradakis has served as a sales representative, branch manager, and strategic account manager for Airgas Great Lakes in Bay City, Mich.

Tully C. Parker was reelected District 14 director. Parker is a district manager for Miller Electric Mfg. Co. in Saint Louis, Mo.

Oren P. Reich was reelected District 17 director. Reich is senior welding instructor at Texas State Technical College at Waco.

Nancy M.Carlson was elected District 20 director. Carlson is an advisory scientist at Idaho National Engineering and Environmental Laboratory. ♦

Leonard P. Connor
District 5 director

Wallace E. Honey
District 8 director

Eftihios Siradokis
District 11 director

Tully C. Parker
District 14 director

Oren P. Reich
District 17 director

Nancy M. Carlson
District 20 director

AWS Taps New Fellows and Counselors

The American Welding Society has honored the outstanding accomplishments and welding-industry contributions of 12 AWS members by conferring the titles of Fellow and Counselor. The new Class of Fellows and new Class of Counselors inductees were officially recognized at the AWS Annual Meeting held April 5 during the AWS Expo at McCormick Place, Chicago, Ill.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

For more information on the AWS Awards program, contact Wendy Sue Reeve at (800) 443-9353, ext. 215; *wreeve@aws.org*. ♦

Dayton's Careers Event Scores Big with Students

The AWS Dayton Section held its annual Careers in Welding program March 1, 2004, hosted by Hobart Institute of Welding Technology in Troy, Ohio. The event was attended by more than 200 students, welding instructors, parents, and AWS members.

Dayton Section Chair **Chris Anderson** of Motoman, Inc., served as emcee. He described the student membership and scholarship programs available through the American Welding Society, and its national drive to improve the image of welding. Anderson also discussed an AWS study that predicts a shortage of skilled welders in the near future and its economic impact.

Andre Odermatt, president of the Hobart Institute, welcomed the attendees to Hobart, and introduced **Steve Houston**, director of training materials development. He presented an overview of the institute, followed by **Marty Baker**, manager of Internet and library services and editor of *The World of Welding*. Baker interested the students in entering an upcoming welded art competition open to high school students, cosponsored by Hobart and the AWS Dayton Section.

Dayton Education Chair **Sam Hart** of Norcold, Inc., who is a welding student at Edison Community College, provided details on its welding program and encouraged students to look beyond basic skills training to further their opportunities in welding. The Edison program, he said, is designed to produce welding technicians and technologists. An agreement between Edison and Hobart Institute permits Edison students to transfer credit for their welder training toward an associate's degree.

Shown at the Hobart Institute of Welding Technology dining room in Troy, Ohio, the 200-plus attendees were nourished in body and mind during the AWS Dayton Section's Careers in Welding program held March 1.

Hart described his career for the students. Starting as a factory worker, he took on-the-job training to become a gas tungsten arc welder at Norcold. Wanting to further his opportunities, he sought and was awarded a scholarship from the Dayton Section to pay for his night classes at Edison.

Steve Barhorst of Hobart Brothers Co. spoke about his experiences in the welding profession. He majored in welding engineering at The Ohio State University. Barhorst encouraged the students to consider further education in welding, even for those students who currently may be struggling with their academic classes in high school.

Zane Michael of Motoman, Inc., said his welding career began as a student at the Hobart Institute; he later joined the staff as an instructor. He eventually became interested in the field of welding robotics. He pursued higher education and is now director of product development at Motoman, Inc. Michael encouraged the students to work hard and stay in school. He emphasized the importance of a positive attitude to achieve success at work. "If you are serious and persistent about your work, employers will notice and will provide you with the opportunities," said Michael, "even if you are not making straight As in high school."

The door prizes for the evening were distributed just prior to the group leaving for a tour of the Hobart facility. The major prizes in the student raffle included a Hobart Handler power source, a Miller autodarkening welding helmet, a Lincoln SP135 power source, and a credit for Motoman Robot Training class.

The AWS Dayton Section members and Hobart professionals have served as role models to stimulate the career interests of the local young men and women about to enter the labor force.

The Dayton Section's annual Careers in Welding programs bring the students into one-on-one contact with the industry leaders who can help them get the scholarships and the education they need for rewarding careers in the metals-joining industry. ♦

A New Award for AWS Student Members

The AWS Board of Directors has esablished a new recognition category named the Student Chapter Member Award.

Its purpose is to recognize AWS Student Members whose Student Chapter activities have producted outstanding achievements in the school, community, or industry.

This award provides an excellent opportunity for Student Chapter advisors, Section officers, and District directors to recognize outstanding students affiliated with AWS Student Chapters, as well as to enhance the image of welding within their community.

The first winner of this award is:

Wesley Marshall
Columbiana County Career and Tech Center Student Chapter in Lisbon, Ohio

To qualify for this award certificate, the individual must be an AWS Student Member affiliated with an AWS Student Chapter. Criteria and nomination forms are posted on the Web page: *http://www.aws.org/sections/awards/student_chapter.pdf*. Or contact theAWS membership Dept. at (800) 443-9353, ext. 260, for further information. ♦

District 13 Achievers

The District Director Award provides a means to recognize individuals who have made outstanding contributions to their local Section's and/or District's activities.

Jesse L. Hunter, District 13 director, has nominated the following Members for this award for 2003–2004.

John Willard
Zach Award
Mike Spangler
Art Suprenant
Doug Rowley
Eldon LaFevre
Ken Kobus
Deborah Woodruff.

Member-Get-A-Member Campaign

Listed below are the people participating in the 2003–2004 AWS Member-Get-A-Member Campaign. For campaign rules and a prize list, see page 67 of this *Welding Journal*. Call the AWS Membership Department at (800) 443-9353, ext. 480, for more information.

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

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

*Denotes the number of times an Individual Member achieves Winner's Circle status. Status will be awarded at the close of each membership campaign year.

President's Guild
(AWS Members sponsoring 20 or more new Individual Members between June 1, 2003, and May 31, 2004.)

President's Roundtable
(AWS Members sponsoring 11–19 new Individual Members between June 1, 2003, and May 31, 2004.)
R. Purvis, *Sacramento* — 14
P. Evans, *Chicago* — 12
T. Hart, *Mobile* — 12

President's Club
(AWS Members sponsoring 6–10 new Individual Members between June 1, 2003, and May 31, 2004.)
K. Baucher, *Fresno* — 10
G. Taylor, *Pascagoula* — 10
C. Daily, *Puget Sound* — 9
J. Powell, *Triangle* — 9
W. Drake, Jr., *Ozark* — 8
P. Walker, *Ozark* — 7
J. Compton, *San Fernando Valley* — 6

President's Honor Roll
(AWS Members sponsoring 1–5 new Individual Members between June 1, 2003, and May 31, 2004. Only those sponsoring 2 or more AWS Individual Members are listed.)
R. Fontenot, *Oklahoma City* — 5
D. St.-Laurent, *Northern Alberta* — 5
B. Suckow, *Northern Plains* — 5
C. Wesley, *Northwestern Pa.* — 5
S. Abarca, *Illinois Valley* — 4
C. Dynes, *Kern* — 4
J. Smith, *Columbus* — 4
D. Wright, *Kansas City* — 4
C. Boulden, *North Texas* — 3
K. Campbell, *LA/Inland Empire* — 3
J. Cantlin, *Southern Colorado* — 3
C. Chilton, *Ozark* — 3
R. Culbert, *Inland Empire* — 3
B. Franklin, *Mobile* — 3
J. Greer, *Chicago* — 3
S. Jamaluddin, *Long Island* — 3
T. Nichols, *West Tennessee* — 3
G. Ullman, *Lakeshore* — 3
C. Casey, *Arizona* — 2
S. Colton, *Arizona* — 2
A. DeMarco, *New Orleans* — 2
E. Duplantis, *San Antonio* — 2
S. Henson, *Spokane* — 2
R. Holman, *Florida Space Coast* — 2
R. Johnson, *Detroit* — 2
P. Krishnasamy, *India* — 2
T. Lettich, *Sacramento*– 2
S. Luis, Jr., *Calif. Central Coast* — 2
G. Mulee, *Rochester* — 2
J. O'Neal, *Ozark* — 2
R. Painter, *Holston Valley* — 2
S. Schrecengost, *Pittsburgh* — 2
T. Shirk, *Tidewater* — 2
H. Shore, *Tulsa* — 2
R. Stobaugh, Jr., *Carolina* — 2
R. Warner, *Utah* — 2
M. Wilkes, *Mahoning Valley* — 2
R. Wright, *Southern Colorado* — 2

Student Sponsors
(AWS Members sponsoring 3 or more new AWS Student Members between June 1, 2003, and May 31, 2004.)
D. Scott, *Peoria* — 66
G. Euliano, *Northwestern Pa.* — 42
R. Olson, Siouxland — 36
W. Kielhorn, *East Texas* — 34
M. Pointer, *Sierra Nevada* — 27
C. Donnell, *Northwest Ohio* — 26
F. Mong, *Pittsburgh* — 26
J. Sullivan, *Mobile* — 26
T. Buchanan, *Mid-Ohio Valley* — 25
S. Sivinski, *Maine* — 24
M. Arand, *Louisville* — 23
C. Overfelt, *Southwest Virginia* — 23
M. Wilkes, *Mahoning* — 23
D. Combs, *Santa Clara Valley* — 22
D. Hatfield, *Tulsa* — 21
D. Ketler, *Williamette Valley* — 21
F. Juckem, *Madison-Beloit* — 20
S. Robeson, *Cumberland Valley* — 20
L. Davis, *New Orleans* — 19
F. Wernet, *Lehigh Valley* — 19
J. Carey, *Boston* — 18
B. Chesney, *Green & White Mountains* — 17
T. Baldwin, *Arrowhead* — 16
J. Daugherty, *Louisville* — 16
R. Durham, *Cincinnati* — 16
A. Reis, *Pittsburgh* — 16
J. Hepburn, *Johnston-Altoona* — 15
R. Norris, *Maine* — 15
D. Roskiewich, *Philadelphia* — 15
M. Anderson, *Indiana* — 14
W. Harris, *Pascagoula* — 13
K. Ellis, *Central Pennsylvania* — 12
A. Badeaux, *Washington D.C.* — 12
J. Miller, *San Diego* — 12
J. Smith, Jr., *Mobile* — 12
T. Strickland, *Arizona* — 12
P. Walker, *Ozark* — 12
J. Boyer, *Lancaster* — 11
R. Tupta, Jr., *Milwaukee* — 11
D. Weeks, *Southwest Virginia* — 11
R. Williams, *Ozark* — 11
M. Koehler, *Milwaukee* — 10
J. Pelster, *Southeast Nebraska* — 10
A. Vidick, *Wyoming* — 10
G. Gammill, *Northeast Mississippi* — 9
W. Johnson, *Portland* — 9
D. Vranich, *North Florida* — 9
J. Mendoza, *San Antonio* — 8
J. Swoyer, *Lehigh Valley* — 8
J. Compton, *San Fernando Valley* — 7
A. Dommer, *Kern* — 7
R. Gallagher, Jr., *Lehigh Valley* — 7
W. Galvery, Jr., *Long Beach/Orange County* — 7
C. Kipp, *Lehigh Valley* — 7
M. Tryon, *Utah* — 6
D. Zabel, *Southeast Nebraska* — 6
J. Carney, *Western Michigan* — 5
T. Kienbaum, *Colorado* — 5
J. Livesay, *Nashville* — 5
A. Mattox, *Lexington* — 5
W. Miller, *New Jersey* — 5
R. Richwine, *Indiana* — 5
S. Williams, *Central Arkansas* — 5
R. Douglas-Wells, *Atlanta* — 4
F. Henry, *L.A./Inland Empire* — 4
W. Menegus, *Lehigh Valley* — 4
J. Morash, *Boston* — 4
J. Olivarez, Jr., *Puget Sound* — 4
D. Smith, *Niagara Frontier* — 4
W. Wilson, *New Orleans* — 4
C. Bridwell, *Ozark* — 3
T. Bur, *Northern Michigan* — 3
R. Chase, *LA/Inland Empire* — 3
J. Ciaramitaro, *N. Central Florida* — 3
J. Crosby, *Atlanta* — 3
R. Grays, *Kern* — 3
S. Hoff, *Sangamon Valley* — 3
R. Huston, *Olympic* — 3
C. Jones, *Houston* — 3
R. Ledford, Jr., *Birmingham* — 3
H. McRae, *New York* — 3
A. Ochoa, *San Francisco* — 3
H. Riviere, *South Florida* — 3
T. Shirk, *Tidewater* — 3

Technical Committee Meetings

All AWS technical committee meetings are open to the public. Persons wishing to attend a meeting should contact the staff secretary of the committee as listed below at AWS, 550 NW LeJeune Rd., Miami, FL 33126; telephone (800) 443-9353; (305) 443-9353.

May 19–21, 2004, A2 Committee on Definitions and Symbols. Providence, R.I. Standards preparation and general meeting. Staff contact: C. Jenney, ext. 304.

May 19–21, 2004, A2B Subcommittee on Definitions. Providence, R.I. Standards preparation and general meeting. Staff contact: C. Jenney, ext. 304.

May 19–21, 2004, A2C Subcommittee on Symbols. Providence, R.I. Standards preparation and general meeting. Staff contact: C. Jenney, ext. 304.

Revised Standard Approved by ANSI:

A5.8/A5.8M:2004, *Specification for Filler Metals for Brazing and Braze Welding*. Approval date: 2/11/04.

ISO Draft Standards for Public Review

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

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

ISO/DIS 3834-1, Quality requirements for fusion welding of metallic materials — Part 1: Guidelines for selection and use.

ISO/DIS 3834-2, Quality requirements for fusion welding of metallic materials — Part 2: Comprehensive quality requirements.

ISO/DIS 3834-3, Quality requirements for fusion welding of metallic materials — Part 3: Standard quality requirements.

ISO/DIS 3834-4, Quality requirements for fusion welding of metallic materials — Part 4: Elementary quality requirements.

ISO/DIS 3834-5, Quality requirements for fusion welding of metallic materials — Part 5: Normative references to fulfill the requirements of ISO 3834-2, ISO 3834-3, and ISO 3834-4.

Rail Welding Standard Updated

AWS D15.2:2003, *Recommended Practices for the Welding of Rails and Related Rail Components for Use by Rail Vehicles*, is the first revision since 1994.

The 48-page standard covers repair, joining, maintenance, and inspection procedures for rails and austenitic manganese-steel components. It includes three tables and 13 figures.

The document is intended for personnel concerned with welding quality on railroad, crane, guard, electrical-contact, girder, and retarder rails, and related rail components including rail crossings and turnouts, switch points, stock rails, switch point guards, spacer blocks, connecting rods, switch rods, plates, frogs, and frog components.

Purchase the standard from Global Engineering Documents at (800) 854-7179; or online at *www.global.ihs.com*.♦

Nominations for AWS District Directors

The term of office for District directors in the following Districts will terminate on May 31, 2005. As District Nominating Committees will be appointed this spring, it is time to be thinking of position nominations. For further information, use your current District director's contact information given below.

District 3
Alan J. Badeaux, Jr., Instructor
Charles County Career & Tech Center
7775 Marshall Corner Rd.
Pomfret, MD 20675
Telephone: (301) 934-9061
FAX: (301) 934-0165
e-mail: *abadeaux@ccboe.com*

District 6
Neal A. Chapman, Welding Engineer
Entergy Nuclear Northeast
15491 McIntyre Rd.
Sterling, NY 13156
Telephone: (315) 349-6960
FAX: (315) 349-6625
e-mail: *chapman@redcreek.net*

District 9
John C. Bruskotter
Dynamic Industries, Inc.
2804 Peters Rd. (70058)
P.O. Box 44
Harvey, LA 70059
Telephone: (504) 363-5900
FAX: (504) 363-5920
e-mail: *jbruskotter@dynamicind.com*

District 12
* **Michael D. Kersey**, Technical Sales Representative
The Lincoln Electric Company
W223 N798 Saratoga Drive #H
Waukesha, WI 53186
Telephone: (262) 650-9364
FAX: (262) 650-9370
e-mail: *michael_d_kersey@lincolnelectric.com*

District 15
* **Jack D. Heikkinen**, President
Spartan Sauna Heaters, Inc.
7484 Malta Rd.
Eveleth, MN 55734
Telephone: (218) 741-8433
e-mail: *spartans@cpinternet.com*

District 18
John Mendoza
City Public Service
3319 Kashmuir
San Antonio, TX 78223-1612
Telephone: (210) 532-9098
e-mail: *mendoza727@aol.com*

District 21
Les J. Bennett
Associate Professor
Allan Hancock College
1020 Fairway Vista Dr.
Santa Maria, CA 93455
Telephone: (805) 348-1838
e-mail: *lesweld@aol.com*

** Denotes current District Director is not eligible for reelection to another three-year term.*

AWS Supporters

Supporting Companies

Ace Welding Co., Inc.
715A Daniel Webster Hwy.
Merrimack, NH 03954

All Metals Fabricators, Inc.
6 Hadco Rd.
Elsmere, DE 19804

MME
1039 Industrial Ct.
Suwanee, GA 30040

Reinke Mfg. Co., Inc.
101 Reinke Rd.
Deshler, NE 68340

Educational Institutions

Cattaraugus-Allegany BOCES
5550 Rte. 242
Ellicottville, NY 14731

Ivy Tech State College
590 Ivy Tech Dr.
Madison, IN 47250

Silver Lake Regional H.S.
260 Pembroke St.
Kingston, MA 02364

KY Tech Carroll County Area
Technology Center
1704 Highland Ave.
Carrollton, KY 41008

Shawsheen Valley Technical H.S.
100 Cook St.
Billerica, MA 01821

Distributor Members

aMAESing Tools Mfg. Inc.
10802 Hawkins Ave.
Conifer, CO 80433

Affiliate Companies

Doc's Welding & Repair, Inc.
6057 San Casa Dr.
Englewood, FL 34224

Fackler Welding
1265 Durkee Rd.
Highgate Center, VT 05459

HMB Steel Corp.
4080 Pines Industrial Ave.
Rockledge, FL 32955

Jigsaw Custom Fabricated, Inc.
33 Maple Ave., Ste. #1
Riverside, RI 02915

Macon Metal Products Co.
803 W Colvert Dr.
Taylorville, IL 62568

Metal S.A.
7801 NW 37th St.
Section 2438/GUA
Miami, FL 33166

New Sustaining Member

Aquasol Corporation
1576 Sweet Home Rd.
Amherst, NY 14228
1-800-564-WELD
Fax: (716) 564-8889
Representative: Mike Hacikyan

Aquasol™ water-soluble papers and tapes are efficient and economical for damming argon or helium gases during gas tungsten arc welding of steel or aluminum pipes.

Easy to use, just cut the product to the diameter of the pipe, then fold and apply. The tape holds the purge dam in place. After welding is completed, flush the weld with water or steam and the purge dams dissolve away instantly. The products are available in a wide range of standard grades, sizes, and formats. ♦

Welding Teacher and W.E.L.D. Recognized by U.S. House

Richard E. Hart, a welding teacher at Max S. Hayes Vocational High School, Cleveland, Ohio, was recognized by the U.S. House of Representatives for his outstanding achievements. The text of the entry published in the *Congressional Record* of the 108th Congress, Second Session, February 2004, Volume 149, follows:

"Dennis J. Kucinich of Ohio, in the House of Representatives.

"In Honor and Recognition of Mr. Richard Hart and Project W.E.L.D.

"Mr. Speaker, I rise today in honor and recognition of Mr. Richard Hart — teacher, mentor, guide, and source of strength and inspiration for countless young men and women at Max S. Hayes Vocational High School.

"Mr. Hart, a Certified Welding Educator, created Project W.E.L.D. several years ago, intent on energizing the school's welding program. The acronym stands for Worthy Employment, Leadership Development, which is exactly what students take away from the program. Mr. Hart was so deeply committed to this project that he initiated this program on his own personal time, using his own personal funds.

"Project W.E.L.D. provides students with a real insight and understanding into the profession of welding by bringing industry employees and employers into the classroom. Additionally, students are exposed to the latest in welding technology through funds and equipment donated from local welding companies. Beyond his scholastic and professional contributions, awards and accolades, Mr. Hart's most powerful accomplishment continues to be the impression he makes on his students, through his method of teaching by example that offers each student the promise of a bright future.

"Mr. Speaker and Colleagues, please join me in honor and recognition of Mr. Richard Hart, whose leadership, commitment, and belief in the students at Max S. Hayes Vocational High School continues to uplift the lives of countless students and strengthens our entire community." ♦

AWS Membership

Member Grades	As of 4/1/04
Sustaining Companies	405
Supporting Companies*	207
Educational Institutions	322
Affiliate Companies	223
Welding Distributor Companies	49
Total Corporate Members	**1,206**

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

Individual Members	43,252
Student & Transitional Members	4,502
Total Members	**47,754**

SECTION NEWS

Speaker Joe Zawodny (left) is shown with Rick Moody, Boston Section trustee, at the March meeting.

Motorcycle guru Indian Larry fascinated the Morris County School of Technology Student Chapter members and the school's automotive students with his stories, facts, and figures.

DISTRICT 1

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

District 1 Conference
May 21, 22, Holiday Inn
New London/Mystic, Conn.

BOSTON

MARCH 1
Speaker: **Jue Zawodny**, welding engineer, CWI
Affiliation: Linde Gas LLC
Topic: Shielding gases for GMA welding of carbon and stainless steels
Activity: The program was held at Hilltop Steak House in Saugus, Mass.

GREEN & WHITE MOUNTAINS

FEBRUARY 12
Speaker: **Jason Doody**
Affiliation: The Lincoln Electric Co.
Topic: Gas metal arc welding
Activity: The talk included a hands-on demonstration of the GMAW process. The members discussed the upcoming SkillsUSA welding contest. The program was held at the Advanced Welding Institute in Rutland, Vt.

MAINE

FEBRUARY 25
Speaker: **Jeff Fields**, Section chair
Affiliation: Bath Iron Works
Topic: Upcoming SkillsUSA event
Activity: The attendees discussed the testing criteria and equipment to be used for the welding students in Maine. The contestants will use Miller XMTs with 60-series wire feeders for the FCAW tests; Lincoln Idealarcs and Miller Syncrowaves for the SMA and GTA welding projects. The PAC work will be performed using Hypertherm Powermax 600s.

DISTRICT 2

Director: Alfred F. Fleury
Phone: (732) 868-0768

District 2 Conference
May 17, Tempil Mfg. Co.,
South Plainfield, N.J.

MORRIS COUNTY TECH Student Chapter

Activity: During January, the welding students in the Morris County School of Technology Student Chapter plus students from the school's automotive programs met with **Indian Larry (Larry Desmedt)**, a famous designer and builder of custom motorcycles. Larry thrilled the students with his stories and his tricks of the motorcycle-building trade. The prize exhibit was Larry's favorite bike he has nicknamed "Way Out Daddy-O from Weirdsville." Chapter Advisor **Herbert Browne**, a welding instructor at the school, arranged the event.

NEW JERSEY

MARCH 16
Speaker: **John Luck**, product manager

Speaker John Luck (left) is shown with Gus Manz, Section historian, at the March meeting of the New Jersey Section.

Affiliation: Miller Electric, Industrial Engine Products division
Topic: The changing pipeline industry
Activity: The meeting was held at L'Affaire Restaurant in Mountainside, N.J., for 25 attendees.

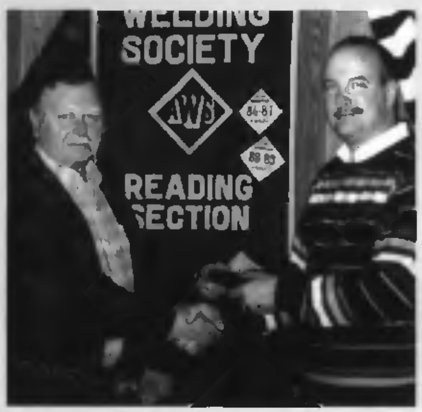
PHILADELPHIA

FEBRUARY 21
Activity: The Section held its Student Welding Competition at Camden County Technical School in Sicklerville, N.J. Eight schools competed for honors. The top-scoring students were **John Otto**, **Nick Gottschling**, **Chris Winkels**, **Tom Ridge**, and **Mike Pedrick**. Overseeing the contests were welding in-

Shown at the awards presentation following the Philadelphia Section's student welding contest are (from left) Nick Gottschling, Chris Winkels, welding instructor Dan Roskiewich, and John Otto.

AWS President Tom Mustaleski (center) accepts his speaker gift from student director Travis Ort and York Central Pennsylvania Section Chair George Bottenfield.

Philadelphia Section Chair Mike Desai (left) is shown with speaker Ron Belle at the March meeting.



Reading Section Chair John Miller presents a speaker gift to Scott Frassl at the January 15 program.

structors **Rich Bender**, Bucks County; **Mel McCollum**, Salem County; and **Dan Roskiewich**, Gloucester County.

MARCH 10
Speaker: **Ron Belle**
Affiliation: Perry Johnson Registrars
Topic: ISO 9000:2000
Activity: This Philadelphia Section program was held at the Ramada Inn in Essington, Pa.

Dennis Martin (left) accepts his Silver Award from Chair George Bottenfield at the York Central Pennsylvania program.

DISTRICT 3

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

District 3 Conference
June 4, Four Seasons
Sheraton, York, Pa.

READING

JANUARY 15
Speaker: **Scott Frassl**
Affiliation: Cor Met
Topic: Flood welding repair of forging dies
Activity: The program was held at the Crystal Springs Family Restaurant in Reading, Pa.

YORK CENTRAL PENNSYLVANIA

MARCH 4
Speaker: **Thomas M. Mustaleski**, AWS National President
Affiliation: BWXT Y-12 LLC, Oak Ridge, Tenn.
Topic: Electron beam welding
Activity: **Dennis Martin** received his Silver Award for 25 years of active membership in the Society. **Samuel Yinger** and his student **Samuel Weller** from Cumberland Perry Area Vo-Tec School were cited for their activities in the school and local Rotary Club.

DISTRICT 4

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

District 4 Conferenca
May 21, Quality Inn & Suites
Greensboro, N.C.

RICHMOND

MARCH 2
Activity: The Section relocated its welding library to the Richmond Technical Center Library, 2020 Westwood Ave., Richmond, Va. The library may be accessed during all regular school hours.

SOUTHWEST VIRGINIA

MARCH 10
Speaker: **Mike Flagg**, senior applications engineer
Affiliation: The Lincoln Electric Co.
Topic: The latest innovations in welding waveform technology
Activity: **Rivers Claytor**, executive vice president, John W. Hancock, Jr., Inc., accepted the Section's Industry Support Certificate of Appreciation Award. The meeting was held at Dynasty Chinese Buffet in Salem, Va.

TIDEWATER

FEBRUARY 12
Speaker: **Jim Matyiko**, owner
Affiliation: Expert House Movers, Inc.
Topic: Moving the Cape Hatteras lighthouse
Activity: The Section hosted its annual Ladies' Night program at Bill's Seafood House in Newport News, Va.

DISTRICT 5

Director: Wayne J. Engeron
Phone: (404) 501-9185

District 5 Conference
June 11, 12, Hollywood Beach
Golf & Country Club
Hollywood, Fla.

DISTRICT 6

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

District 6 Conference
May 14, Barbagallo's
Restaurant, Syracuse, N.Y.

NORTHERN NEW YORK

FEBRUARY 3
Activity: **Mike Mason**, owner, conducted 34 Section members on a tour of the Maximum Security Products plant in Waterford, N.Y.

MARCH 2
Speaker: **Kenneth Phy**, senior project manager
Affiliation: Entergy Nuclear Northeast, Inc.
Topic: Welding containers for spent nuclear fuel waste
Activity: This Northern New York Section program was held at Mill Road Restaurant and Tavern in Latham, N.Y.

DISTRICT 7

Director: Robert J. Tabernik
Phone: (614) 488-7913

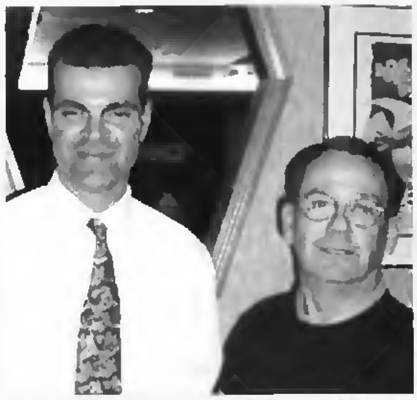
District 7 Conference
Juna 11, EWI, Columbus, Ohio

COLUMBUS

MARCH 11
Speaker: **Karl Graff**
Affiliation: Edison Welding Institute
Topic: The application of ultrasonic metal welding in the automotive and aerospace industries
Activity: The program was held at Edison Welding Institute in Columbus, Ohio.

DAYTON

MARCH 1
Activity: The Section held its annual Students' Night Careers in Welding Program hosted by the Hobart Institute of Welding Technology in Troy, Ohio. More than 200 participated. The full story about this event appears on page 65 of this issue of *Welding Journal.*



Speaker Mike Flagg (left) is shown with Bill Rhodes, Southwest Virginia Section chair, at the March 10 meeting.

Karl Graff (right) accepts the Columbus Section's speaker's gift from Chairman John Lawmon at the March meeting.

PITTSBURGH

MARCH 9
Activity: The Section toured the Maglev, Inc., facility in McKeesport, Pa., to study its high-tech measuring devices, finite element analysis, and coherent laser radar scanning technology. Presenters included **Brad Shaw**, senior welding engineer, and **Steve Hand**, senior metrologist.

DISTRICT 8

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

District 8 Conference
June 11, Holiday Inn
Jackson, Tenn.

The West Tennessee Section will host the District 8 Conference, June 11, 8:00 a.m. to 3:30 p.m., at Holiday Inn, I-40, exit 80-A, in Jackson, Tenn.

CHATTANOOGA

JANUARY 20
Activity: The Section hosted its annual Ladies' Night at Chattanooga Choo Choo Station House Restaurant.

Rivers Claytor (left) accepts the Industry Support Certificate from Bill Rhodes, Southwest Virginia Section chair.

Shown during the Pittsburgh Section's tour of Maglev, Inc., are (from left) Brad Shaw, publicity chair Ron Campbell, and Steve Hand.

GREATER HUNTSVILLE

FEBRUARY 26
Speaker: **Wallace E. Honey**, District 8 Director
Topic: District 8 conference
Activity: **Ed Monroe** and **Joe Smith** presented plans for a student welding contest to be held in April.

HOLSTON VALLEY

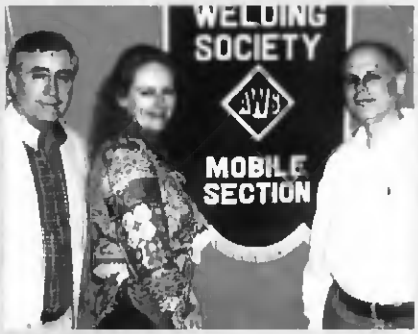
MARCH 2
Activity: Following a barbecue dinner provided by **Jerry Sullivan** and students, the Section hosted a welding contest for its Students' Night program. Nominations were accepted for officers. The event was held at Tennessee Tech in Surgoinsville, Tenn.

NASHVILLE

MARCH 18
Activity: The Section toured World Testing, Inc., in Mt. Juliet, Tenn.

NORTHEAST MISSISSIPPI

FEURUARY 19
Activity: Following dinner at Barnhill's Buffet, the Section toured Flexsteel Industries, Inc., in Starkville, Miss., to study its CNC cutting operations.



Shown at the Mobile Section program March 11 (from left) are speakers Vice Chair Lavon Mills and Treasurer Teresa Hart with Chairman Greg Pierce.

Shown at the February New Orleans meeting are (from left) AWS President Tom Mustaleski, meeting hosts Ted and Marlene Stone, Chair David Foster, and John Bruskotter, District 9 director.

Pratik Patel (left) accepts the Sustaining Company Member plaque from Dick Corbin at the Mobile Section program in March.

Tesa Lujano, Haywilk Galvanizing Co., is formally introduced as a new member of the New Orleans Section by Vice Chair Shelton Ritter.

Greg Koprowitz (left) accepts the Mobile Section's Past Chairman's Appreciation Award from AWS President Tom Mustaleski at the Northeast Tennessee Section meeting in October.

AWS President Tom Mustaleski (right) accepts a speaker gift from John Bruskotter, District 9 director (left), and David Foster, New Orleans Section chair.

NORTHEAST TENNESSEE

OCTOBER 21

Activity: As a surprise event, **Greg Koprowitz**, Mobile Section's past chair (2002–2003) received the Mobile Section's Past Chairman's Appreciation Award from AWS President **Thomas M. Mustaleski.** Koprowitz is currently a member of the Northeast Tennessee Section.

WESTERN NORTH CAROLINA

FEBRUARY 19

Activity: The Section held a reorganization meeting. The Executive Committee will meet the third Thursday of each month; letters will be sent to all Section members; and a tour of the BMW plant is scheduled for May. The new slate of officers is **Bob Fellers**, chair and treasurer; **Todd Thompson** and **Bernhard Eich**, vice chairs; **Bob Humphrey**, secretary; **Curtis Plummer**, program chair; **Paul Phelps** and **Ron Souther**, membership and education chairs, respectively. The program was held at the BMW plant in Spartanburg, S.C. Contact Bob Fellers, (864) 224-8411; *bfellers@fellerswelding.com*.

DISTRICT 9

Director: John Bruskotter
Phone: (504) 363-5900

District 9 Conference
May 22, Southeastern Louisiana University
Hammond, La.

MOBILE

MARCH 11

Speakers: **Lavon Mills**, vice chair; and **Teresa Hart**, treasurer

Topic: Careers in welding

Activity: **Pratik Patel**, quality engineer for Bredero Shaw LLC, accepted the Section's Sustaining Company Member plaque. The program was held at Cock of the Walk Restaurant in Mobile, Ala. Past Chair **Greg Kuprowitz** received the Mobile Section's Appreciation Award from AWS President **Tom Mustaleski** at a Northeast Tennessee Section program.

NEW ORLEANS

FEBRUARY 17

Speaker: **Thomas M. Mustaleski**, AWS National President

Affiliation: BWXT Y-12 LLC, Oak Ridge, Tenn.

Topic: AWS plans for the new century

Activity: Appreciation awards were presented to **Byron Landry, Joe Golemi, Travis Moore, Tony DeMarco, Bruce Hallila, Bobby Duhon, John Pajak,** and **Shelton Ritter.** The program was hosted by **Ted** and **Marlene Stone,** owners of Inspection Specialists, in Marrero, La.

DISTRICT 10

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

District 10 Conference
May 14, Tri-State Welding Lab
Erie, Pa.

CLEVELAND

February 23
Speaker: **Garth Stapon**, productivity manager
Affiliation: Praxair Distribution
Topic: How to match shielding gas blends to the welding application
Activity: The program was attended by 45 members.

DISTRICT 11

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

District 11 Conferance
June 7, Sheraton
Lansing Hotel, Lansing, Mich.

DETROIT

March 11
Speaker: **Eric Young**, arc welding group manager
Affiliation: RoMan Engineering Services, Inc.
Topic: Design and implementation of robotic GMAW systems
Activity: The Section presented 25 awards to members this evening in recognition of their many years of service. **Bernie Bastian** received the Gold Membership Award presented for 50 years of active membership. This meeting was hosted by the Schoolcraft College in its new VisTaTech Center. The Section toured the new education and business centers, as well as the state-of-the-art welding-fabrication technology training facility. **Rodney Johnson** conducted the tour and discussed the welding curriculum.

Rodney Johnson (wearing the checkered cap) conducted the Detroit Section on a tour of the Schoolcraft College VisTaTech Center, March 11.

NORTHWEST OHIO

February 26
Activity: **John Wise**, manufacturing engineer, conducted the Section on a tour of Tower Automotive in Bellevue, Ohio. The facility manufactures body frames for Ford Econoline vehicles using the gas metal arc welding process in both manual and robotic configurations.

SAGINAW VALLEY

March 3
Activity: The Section members participated in judging the welders at the Regional SkillsUSA-VICA competition held at Delta College in University Center, Mich. The top ranked welders from Bay Arenac ISD Career Center were **Zach Casey, Andrew Casey, John Giffel, Zach Willard, David Julian, Mike Kennedy, Matt Urban, David Born, Tom Hodder, Kim Hall, Scott Bokhart**, and **Kyle Wesolowski. Mark Wright** got high scores for Midland High School as did **Don Hart** for Alma High School.

The Saginaw Valley Section members judged at the Regional SkillsUSA-VICA welding competitions. Shown above are the contestants from Bay Arenac ISD Career Center.

Bob Gardner (left), Cleveland Section chair, is shown with speaker Garth Stapon at the February program.

WESTERN MICHIGAN

February 23
Speaker: **Dave Schnider**
Affiliation: The Lincoln Electric Co.
Topic: Welding technology
Activity: The members discussed the upcoming AWS Welding Show, and promotion for the Section's annual golf outing in June. The meeting was held at O'Malley's Grill and Pub in Grand Rapids, Mich.

Speaker Eric Young (left) receives a speaker's gift from Detroit Section Chair Don DeCorte at the March meeing.

Bernie Bastian received the Gold Membership Award for fifty years of active service to the Society at the Detroit Section meeting.

Speaker Todd Holverson (right) is shown with Fox Valley Section Vice Chair Al Sherrill at the January meeting.

Bob Branan discussed operation of gas tungsten arc welding machines at the Peoria Section program in February.

Mike Anderson (left), Indiana Section chair, presents a speaker gift to Joe Daumeyer at the February 23 meeting.

DISTRICT 12

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

District 12 Conference
May 21, Lincoln District Office, Milwaukee, Wis.

Dale Sabo demonstrated cutting operations for the students attending the Saint Louis Section's vendors' night event in November.

FOX VALLEY

JANUARY 13
Speaker: **Todd Hulverson**
Affiliation: Miller Electric Mfg. Co.
Topic: Features of Miller's new Axcess line of power supplies
Activity: The meeting was held in Appleton, Wis.

MILWAUKEE

JANUARY 19
Activity: About fifty Section members toured the laser lab at Waukesha County Technical College in Pewaukee, Wis. **Roger Bratberg**, instructor, demonstrated setup and fitup for various laser beam cutting operations. The dinner was provided by the students majoring in culinary arts at the college.

DISTRICT 13

Director: J. L. Hunter
Phone: (309) 888-8956

District 13 Conference
June 4, Starved Rock Lodge Utica, Ill.

CHICAGO

JANUARY 28
Speaker: **Stu Klevin**, quality engineer
Affiliation: Alloyweld Inspection
Topic: NDE of a Civil War submarine
Activity: The evening's topic concerned the restoration of the CSS *Hunley*, which disappeared mysteriously in 1864 and was not found until 1995. Section Appreciation Awards were presented to Section long-time members **Hank Sima**, **Jeff Stanczak**, **Craig Tichelar**, and **Bob Zimny**.

PEORIA

FEBRUARY 18
Speaker: **Bob Branan**, instructor, Great Lakes Area Boilermakers Apprenticeship Program
Affiliation: Boilermakers Local #60
Topic: Details of the Magnatech orbital GTAW machine operation
Activity: The program was held at the Lariat Club in Peoria, Ill.

DISTRICT 14

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

District 14 Conference
June 12, Louisville, Ky.

INDIANA

FEBRUARY 23
Speaker: **Joe Daumeyer**
Affiliation: Wesco
Topic: Resistance welding
Activity: Chairman **Mike Anderson** discussed the local welding competitions and AWS's involvement in the judging. The program was held at Jonathan Byrd's Restaurant in Indianapolis.

LEXINGTON

FEBRUARY 26
Activity: Thirty-five Section members toured the Link Belt Corp. plant to study the welding operations used in the manufacture of cranes.

SAINT LOUIS

NOVEMBER 13
Activity: The Section hosted a Students' and Vendors' Night program at Cee-Kay Supply for 132 attendees. **Dale Sabo**, Scan Lab, spoke on metal cutting and demonstrated the process. The vendors included Lincoln, Miller, Quality Testing, Lenco, MK Cobramatic, Victor, Eutectic, Pandjiris, and Scan Lab.

DECEMBER 12
Activity: The Saint Louis Section held its annual Christmas celebration with the awarding of prizes, fine dining, and dancing. The event was held at St. Louis Sheet Metal Workers Local No. 36. The emcees for the evening were **Gay Cornell** and **Jerry Simpson**.

SANGAMON VALLEY

FEBRUARY 23
Activity: The Section leaders held a meeting at Cheddar's Restaurant in Decatur, Ill., to finalize plans for the Section's bus trip to the AWS Expo.

DISTRICT 15

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

District 15 Conference
April 30, May 1, Fortune Bay Casino, Tower, Minn.

ARROWHEAD

JANUARY 15
Speaker: **Doug Mroz**, welding instructor, CWI, CWE
Affiliation: Mesabi Range Community and Technical College
Topic: OSHA19-26 construction safety
Activity: The program was held at LeGrand Supper Club, Pike Lake, Minn.

FEBRUARY 19
Activity: The Arrowhead Section sponsored a Vendors' Night welding show/program at Mesabi Range Community and Technical College in Eveleth, Minn. Factory reps demonstrated the latest wares from Lincoln, Miller, and ESAB.

NORTHWEST

JANUARY 22
Activity: The Section hosted its New Products Night program at PRI Robotics in Plymouth, Minn. Twelve local vendors demonstrated their latest wares.

FEBRUARY 19
Activity: The Northwest Section hosted its Behind the Mask welding contest at Ridgewater Technical College, Willmar Campus. The contest winners were **Jake Miller**, **Ryan Lippert**, **Anthony McReynolds**, **Dan Wilson**, **Reid Roepke**, **Cody Sarsland**, **Lowell Hjelle**, and **Nick Wuertz**.

DISTRICT 16

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

District 16 Conference
June 12, Grand Island, Neb.

KANSAS CITY

FEBRUARY 12
Activity: Thirty-five Section members toured the Zephyr Products plant in Leavenworth, Kans., led by **Dennis Wright** and his associates.

DISTRICT 17

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

Shown at the January Arrowhead Section meeting are (front row, from left) Ron Leonzal, LaVonne Heikkinen, and Marvin Anderson; (back row, from left) Lois Knutson, Jack Heikkinen, Ervin Stock, Tom Baldwin, and speaker Doug Mroz.

The winners in the Northwest Section's welding contest were (from left) Jake Miller, Ryan Lippert, Anthony McReynolds, Dan Wilson, Reid Roepke, Cody Sarsland, Lowell Hjelle, and Nick Wuertz.

Gay Cornell and Jerry Simpson awarded the door prizes at the Saint Louis Section's Christmas party held December 12.

Welding students (from left) Doug Mattson, Darren Akkanen, and Shane Kotnik are shown at the Arrowhead Section's welding show in February.

College representatives who participated in the East Texas program in February are (from left) Ron Hancock, Johnny Johnson, Mike Player, Robert Warke, and David Waites.

Speaker Jonathan Bear (left) is shown with Robert Warke, East Texas Section chairman, at the February program.

Speaker Brian Williams (left) is shown with Larry Smith, Houston Section chair, at the March meeting.

Tac Edwards (left), Lake Charles Section chair, presents a speaker gift to Allan Gibbs at the February meeting

Lake Charles Chair Tac Edwards (left) is shown with speaker Chuck Meadows at the March meeting.

Shown at the Sabine Section program are (from left) speaker Sonny Keeton, his son Jason, and James Amy, chairman.

District 17 Conference
June 10, 11, Dallas, Tex.

EAST TEXAS

FEBRUARY 19
Speaker: **Jonathan Bear,** welding lab instructor, Student Chapter chair
Affiliation: LeTourneau University
Topic: Welding engineering
Activity: The Section hosted students from local high schools who wanted to learn about welding educational opportunities in the area. Representatives from five local colleges offered literature promoting their welding programs. On hand to answer questions were **Ron Hancock**, Tyler Junior College; **Johnny Johnson**, Panola College; **Mike Player**, Kilgore College; **Robert Warke**, LeTourneau University; and **David Waites**, Texas State Technical College.

DISTRICT 18

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

District 18 Conference
April 30, May 1, Holiday Inn
Port Arthur, Tex.

HOUSTON

MARCH 17
Speaker: **Brian Williams**, chief engineer
Affiliation: independent consultant
Topic: Heat treatment of pressure vessels

LAKE CHARLES

FEBRUARY 18
Speaker: **Allan Gibbs**
Affiliation: Niton LLC
Topic: PMI — Positive material identification technology
Activity: The meeting was held at Logan's Road House in Lake Charles, La.

Shown at the Puget Sound Section program are (from left) ASME Chair Mary M. Davis, speaker Raj Talwar, and Sid Capouilliez, chairman.

MARCH 4
Speaker: **Chuck Meadows**
Affiliation: AvesaPolarit Welding, Inc.
Topic: Pickling stainless steels
Activity: This Lake Charles Section program was held at the Logan's Roadhouse Restaurant in Lake Charles, La.

SABINE

FEBRUARY 17
Speaker: **Sonny Keeton**, owner
Affiliation: Custom Motorcycles
Topic: Custom metalworking

DISTRICT 19

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

District 19 Conference
May 22, Columbia Basin
College, Pasco, Wash.

PUGET SOUND

FEBRUARY 12
Speaker: **Raj Talwar**, engineer
Affiliation: Boeing Aircraft Co.
Topic: Advances in friction stir welding
Activity: This was a joint meeting with members of the local chapter of ASME headed by Chair **Mary M. Davis.**

MARCH 4
Speaker: **Scott Roswold**
Affiliation: Thermadyne Corp.
Topic: Exothermic cutting
Activity: Roswold offered a hands-on opportunity for members to try their skills with exothermic cutting torches.

DISTRICT 20

Director: Jesse A. Grantham
Phone: (303) 451-6759

District 20 Conference
May 14, 15, Park City, Utah

DISTRICT 21

Director: Les Bennett
Phone: (805) 348-1830

District 21 Conference
May 15, Marriott Rancha Las Palmas, Palm Springs, Calif.

L.A./INLAND EMPIRE

FEBRUARY 19
Speaker: **Harold Sumpter**, president, CEO
Affiliation: H&H Industries
Topic: LAIE engineering school
Activity: Twenty-five members attended this program held at Royal Cut in Los Angeles, Calif.

SAN DIEGO

FEBRUARY 18
Speaker: **Dale Harrington**, materials joining engineer
Affiliation: Hi-Tech Welding Services
Topic: Welding titanium using the GMAW process
Activity: Following the presentation, the Section members toured the Hi-Tech Welding facility in El Cajon, Calif., to see demonstrations of the process.

DISTRICT 22

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

District 22 Conference
May 7, 8, Maritime Academy Vallejo, Calif.

SACRAMENTO VALLEY

MARCH 17
Speaker: **John Madri**, manager
Affiliation: Madri Weld Sales and Training
Topic: Welding cast iron
Activity: This program was held at Rancho Cordova Restaurant in Sacramento, Calif.

Welding Technology Workshop

Ball State University, Muncie, Ind., will host an all-day welding technology workshop for pros and amateurs alike on July 1. Cosponsored by The Ohio State University. The $25 fee and SASE should be mailed to **Ed Wyatt**, 9551 S. CR 200, East Muncie, IN 47302. For more information contact Ed Wyatt, (317) 576-6420, ext. 303; (765) 289-0459; e-mail *wyatt.w@worldnet.att.net*.

District 19 Director Phil Zammit (left) and Charles Daily are shown at the March meeting of the Puget Sound Section. The plaque is Gary Diseth's AWS Distinguished Member Award to be presented to him later at a special ceremony.

Dan Nelson (right) receives the District Educator Award from Phil Zammit, District 19 director, at the Puget Sound Section program in March.

Speaker Scott Roswold (left) is shown with Sid Capouilliez, Puget Sound Section chair, at the March program.

Speaker Harold Sumpter (right) is shown with Henry Jackson, Los Angeles/Inland Empire Section chairman, at the February program.

Dale Harrington explained the gas metal arc process for welding titanium for the San Diego Section members in February.

Speaker John Madri (left) is shown with Kerry Shatell, Sacramento Valley Section vice chair, in March.

Sacramento Valley Section members are shown at the March 17 program.

Guide to AWS Services

550 NW LeJeune Rd., Miami, FL 33126
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Internet: www.aws.org
Phone extensions appear in parentheses.

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

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

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

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

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

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

INTERNATIONAL INSTITUTE OF WELDING
Information.. *gricelda@aws.org* ....(294)

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

GOVERNMENT LIAISON SERVICES
Hugh K. Webster
Webster, Chamberlain & Bean
Washington, D.C.
(202) 466-2976; FAX (202) 835-0243
hwebster@wc-b.com

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

WELDING EQUIPMENT MANUFACTURERS COMMITTEE
Mary Ellan Mills.. *memills@aws.org* ......(444)

WELDING INDUSTRY NETWORK (WIN)
Mary Ellen Mills.. *memills@aws.org* ......(444)

CONVENTION & EXPOSITIONS
Exhibiting Information .... (242, 295)

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

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

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

PUBLICATION SERVICES
Department Information ....(275)

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

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

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

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

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

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

Plans and coordinates marketing of AWS products and services.

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

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

Marketing Reaearch & Development
Corporate Director
Debrah C. Weir.. *dweir@aws.org* ....(482)

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

MEMBER SERVICES
Department Information ....(480)

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

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

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

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

Information on education products, projects, and programs. Responsible for the S.E.N.S.E. program for welding education, and dissemination of training and education information on the Web.

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

Responsible for conferences, exhibitions, and seminars on topics ranging from the basics to the leading edge of technology. Organizes CWI, SCWI, and other seminars for preparation for certification.

CERTIFICATION OPERATIONS
Managing Director
Wendy S. Reeve.. *wreeve@aws.org* ....(215)

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

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

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

AWS AWARDS, FELLOWS, and COUNSELORS
Managing Director
Wendy S. Reeve.. *wreeve@aws.org* ....(215)

Coordinates AWS awards and AWS Fellow and Counselor nominees.

TECHNICAL SERVICES
Department Information ....(340)

Managing Director
Andrew R. Davis.. *adavis@aws.org*........(466)
International standards activities, computerization of welding information.

Director, National Standards Activities
Peter Howe.. *phowe@aws.org* ....(309)
Machinery and equipment welding, robotic arc welding.

Manager, Safety and Health
Stephen P. Hedrick.. *steveh@aws.org* ......(305)
Metric practice, personnel and facilities qualification, friction welding, safety and health.

Engineers

Harold P. Ellison.. *ellison@aws.org* ....(299)
Welding in sanitary applications, joining metals and alloys, automotive welding, resistance and high-energy beam welding.

John L. Gayler.. *gayler@aws.org* ....(472)
Structural welding.

Rakesh Gupta.. *gupta@aws.org* ....(301)
Filler metals and allied materials, international filler metals, instrumentation for welding, sheet metal welding.

Cynthia Jenney .. *cynthiaj@aws.org* ......(304)
Definitions & symbols, brazing, soldering, brazing filler metals, braze welding, technical editing

Richard McGinnis.. *richard@aws.org* ....(471)
Procedure and performance qualification, railroad welding, mechanical testing of welds.

Brian McGrath . *bmgrath@aws.org* ......(471)
Thermal spray, arc welding and cutting, welding in marine construction, welding of piping and tubing, joining of plastics andcomposites.

Regarding technical inquiries, 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.

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

AWS publishes numerous documents, including standards used throughout the industry.

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

Nominees for National Office

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

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

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

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

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

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

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

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

This material should be sent to Ernest D. Levert, Chairman, National Nominating Committee, American Welding Society, 550 NW LeJeune Rd., Miami, FL 33126.

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

Honorary-Meritorious Awards

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

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

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

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

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

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.♦

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AWS Mission Statement

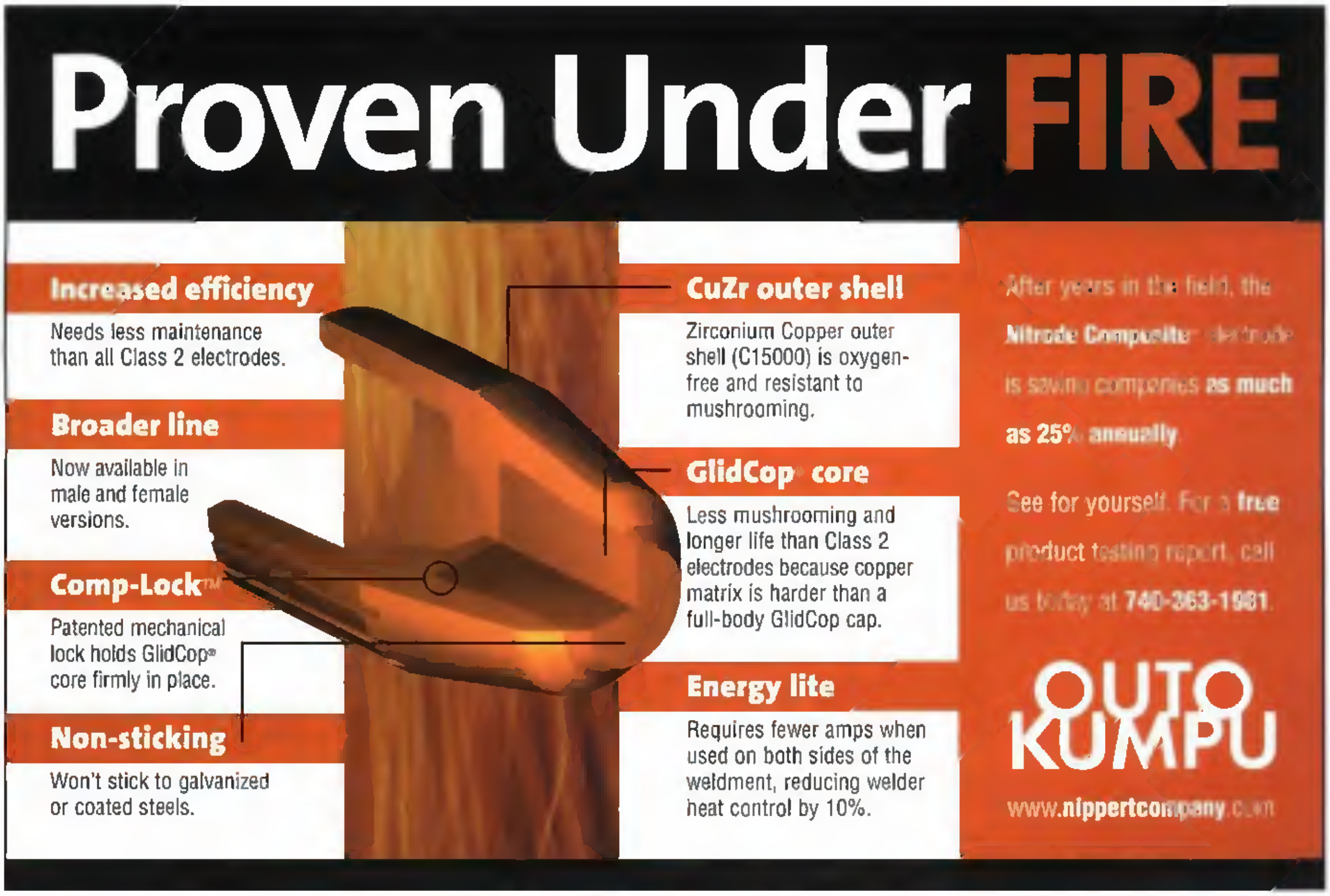
The mission of the American Welding Society is to provide quality products and services to its members and the industry that will advance the science, technology, and application of materials joining throughout the world.

It is the intent of the American Welding Society to build AWS to the highest quality standards possible. The Society welcomes your suggestions. Please contact any of the staff listed on the previous page or AWS President Thomas M. Mustaleski, BWXT Y-12 LLC, P.O. Box 2009, Oak Ridge, TN 37831-8096.

AWS Foundation, Inc.

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

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



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Welding in the Defense Industry Conference
July 13–14, Orlando, Florida
Grosvenor Resort in the Walt Disney World Resort

The companies involved these days in the fabrication and manufacture of fighter aircraft, tanks, and destroyers have never had it better. To bring the engineers in these companies up to date in the advanced technologies being used to make these defense-related products, this timely two-day conference will examine such processes as electron beam welding, laser beam welding, flux-assisted GTA welding, friction stir welding, and hybrid welding, and how these processes are used on steels, stainless steels, aluminum alloys, and titanium alloys. Eighteen presentations will be made: six each from the Army, Navy, and Air Force. A speaker from the Picatinny Arsenal will discuss the application of GMAW-P titanium welding in Army armament systems. An engineer from the Boeing-Phantom Works will examine friction stir welding as a means of joining vital aircraft structures, and last but not least, a team from the Naval Surface Warfare Center and Lehigh University will look at the welding of stainless steel advanced double-hull structures.

Friction Stir Welding Conference
August 10–11, Orlando, Florida
Grosvenor Resort in the Walt Disney World Resort

Possibly the hottest subject in the welding industry these days is friction stir welding. Engineers in hosts of industries are wondering whether this relatively new process is for them. One way to find out is to attend this two-day conference in Orlando. The first AWS conference on this subject, it will elicit speakers from the firing line — from the universities and from the research laboratories. One talk will describe how the process is being used, exclusively, on the Eclipse 500 aircraft. Another speaker will discuss its application on both current and future designs of automotive vehicles. Other presentations will indicate how the U.S. Army is using friction stir welding on both aluminum and titanium structures.

Overcoming the Problems of Dissimilar Metal Welding
September 14–15, New Orleans, Louisiana
The Monteleone

One of the most difficult problems a welding engineer faces is how to weld dissimilar metals together. There don't seem to be any textbooks on this topic, nor do the codes cover it, so the welding engineer is left to sink or swim. The forthcoming conference in New Orleans is aimed at helping the engineer make some educated decisions on the matter. Certain processes like laser beam welding, friction stir welding, magnetic pulse welding, and inertia welding can be used effectively to solve many dissimilar metal welding problems. There are also several transition joints that can be used to effect the bridge from such difficult-to-join combina-

tions as aluminum to steel. Diffusion bonding and adhesive bonding are other workable alternatives. All of these topics, plus others, will be covered in this two-day conference.

The Fifth Weld Cracking Conference
February 15–16, 2005, Orlando, Florida
Grosvenor Resort in the Walt Disney World Resort

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

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

AWS D1.1 Code Week
May 17–21, Chicago, Ill.
September 20–24, San Francisco, Calif.
October 11–15, Philadelphia, Pa.
November 8–12, Atlanta, Ga.

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

◆ Day 1 — D1.1 Road Map

◆ Day 2 — Design of Welded Connections

◆ Day 3 — Qualifications

◆ Day 4 — Fabrication

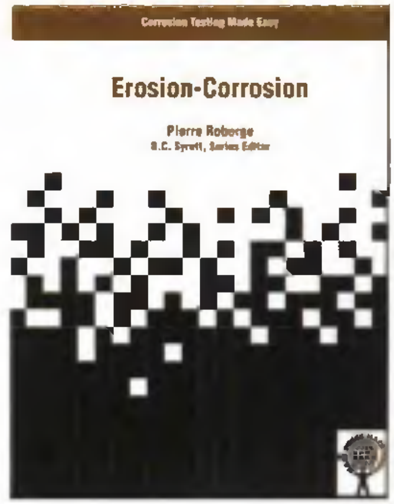
◆ Day 5 — Inspection

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

FOR MORE INFORMATION, CIRCLE NUMBER ON READER INFORMATION CARD.

Final Volume of Corrosion Testing Series Published

Corrosion Testing Made Easy: Erosion-Corrosion, by Pierre Roberge, is the eighth and final installment of the *Corrosion Testing Made Easy* series. The book introduces concepts of electrochemistry and fluid dynamics in the context of erosion-corrosion and flow-assisted corrosion, and reviews test methods to qualify materials for usage in flow-intense situations. Specific test methods are arranged into rotating systems (disk, cylinder, and cage) and flow systems (flow loop, nozzle or orifice, and impinging jet). Published by NACE Press, it can be ordered at *www.nace.org* or (281) 228-6223. Cost is $84.



Guide Includes Deburring Tips

A free booklet includes technical information on burr classification, brush se-

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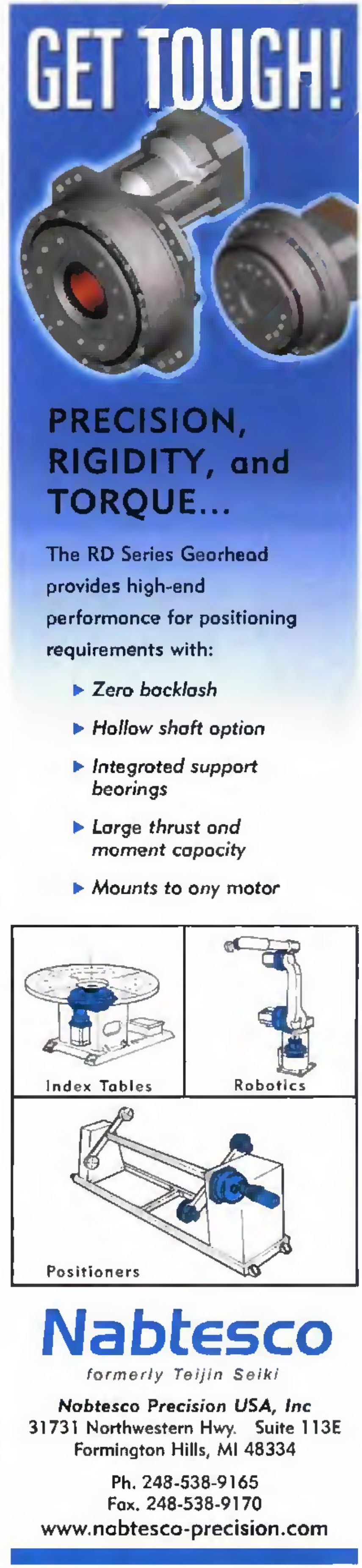

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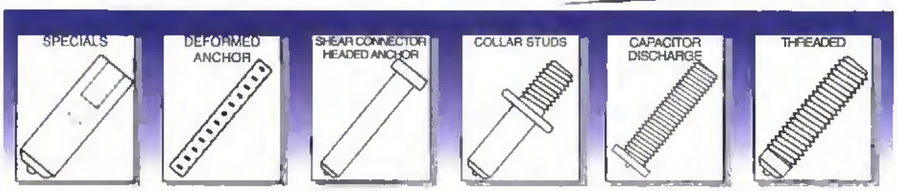


— continued from page 86

lection, and optimization tips for using tube-end deburring machines.

Weiler Corp. 108
One Wildwood Dr., Cresco, PA 18326-0149

CD-ROM Features Orbital Welding Products

The free "OrbiCD" includes digital literature on tube and pipe welding products and technical papers ranging from the basics of the process up to applications of equipment. Links to Web sites are also included.

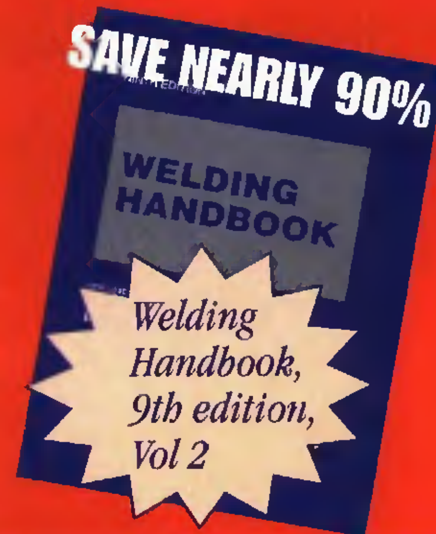
Orbimatic GmbH 109
P.O. Box 416, Welbeck Way, Peterborough, PE7 3FT, U.K.

Specifications Sheet Describes Work Positioner

A two-sided, color spec sheet provides details of the company's LTN1 Electro-Hydraulic Work Positioner, which lifts and tilts part bins for easy access by an operator. The device is available in 2500-, 4000-, and 6000-lb capacities.

Pentalift Equipment Corp. 110
P.O. Box 1510, Buffalo, NY 14240-1510

ATTENTION AWS INDIVIDUAL MEMBERS



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Five VP Appointments Made at Northrop Grumman

Northrop Grumman, Newport News, Va., has announced three appointments to vice president positions. **Becky Stewart**, currently vice president, surface ship and submarine fleet maintenance program, has been chosen to head the submarine program. **Irwin F. Edenzon**, currently vice president, business and technology development, has been named vice president, technology development and fleet support. **John J. Mazach**, currently executive director, business development, has been promoted to vice president, business development.


Becky StewarT


Irwin F. Edenzon

Northrop Grumman, Pascagoula, Miss., has named **Richard Schenk** to the position of vice president, supply chain management, and promoted **Jimmie Haygood, Jr.**, to vice president, unit manufacturing. Previously, Schenk was vice president, material, and Haygood served as director of production manufacturing.


John J. Mazach

— continued on page 96

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

Exhibiting at the AWS Welding Show 2005 is the most cost-effective way to gain broad exposure in a short time. As an AWS exhibitor, you will have the opportunity to meet those buyers who need your products. The AWS Welding Show has more to offer than any other show in the metal-fabricating and construction industries.

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

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

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

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

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

AWS WELDING SHOW 2005

April 26-28, Dallas, Texas
DALLAS CONVENTION CENTER

Circle No. 11 on Reader Info-Card

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Special Metals Welding Fills Key Position

Special Metals Welding Products Co., Bidford, England, a supplier of nickel alloys and welding consumables, has appointed **Christopher Thornton** to the newly created position of global business development manger. Prior to joining the company, Thornton worked for Oerlikon Welding Ltd. in the U.K. for 20 years, most recently serving as its business manager.

Mosier Named President at Polymet

Bill Mosier

Polymet Corp., Cincinnati, Ohio, a manufacturer of solid and cored welding wires, has promoted **Bill Mosier** from general manager to president. Mosier previously held positions at Stoody and the American Welding Institute.

Inductotherm Names Rep for Radyne Induction Systems

Brian Locktiski

The Inductotherm Group, Madison Heights, Mich., has appointed **Brian Locktiski** to represent its Radyne Corp., Milwaukee, Wis., induction systems in the state of Michigan and parts of Ohio and Pennsylvania. Locktiski has ten years' experience in the induction systems field, including forging, heat treating, brazing, and associated fields.

Two VPs Named at ESAB Welding

ESAB Welding & Cutting Products, Florence, S.C., has appointed **Jeff Hoffart** and **Bill Johnson** to senior vice president positions. Hoffart, a 20-year employee with the company, was named senior vice president of marketing for ESAB North America. Johnson was promoted to senior vice president and general manager of the firm's Florence, S.C., facility.

IMW Appoints President

John W. Shearer, a consultant to the International Machine and Welding, Inc., board of directors, was named president of the Bartow, Fla., company. Shearer previously managed Crawler Tractor Service Co. in Bartow, and Steel Technology and Design, Inc., in Lakeland, Fla.

Black Engineers Honored for Excellence

Darius Bonton

Ronald Wilson

Three Northrop Grumman Corp. engineers were cited for the 2004 Modern-Day Technology Leader Award presented by *U.S. Black Engineer and Information Technology* magazine, at its conference held in Baltimore, Md., February 21.

Michael Ingram

Honored were structural engineer **Darius Bonton**, R & D program director **Ronald Wilson**, and software engineer **Michael G. Ingram**.

Bonton works in the Maritime Technology Center of Excellence in New Orleans where he is responsible for the design, analysis, and construction of ocean-going vessels for the U.S. Navy, Coast Guard, and commercial industry.

Wilson manages the Composite High-Speed Vessel program and the Integrated Engineering Plant.

Ingram, based at Schriever AFB in Colorado Springs, Colo., was cited for his technical support of the Air Force Satellite Control Network.

FKI Logistex Names National Accounts Manager

George Parr was named national accounts manager, East Coast, for the custom engineered systems group at FKI Logistex, Cincinnati, Ohio. Parr, based in Lancaster, Pa., brings to the company more than 25 years of experience in the materials handling industry.

Rexarc Appoints President

Robert Moyer

Rexarc International, Inc., West Alexandria, Ohio, has appointed **Robert Moyer** to the position of president. Previously, Moyer served the company as executive vice president.

Tregaskiss Names Strategic Accounts Manager

Tony Pendino

Tony Pendino has joined Tregaskiss Ltd., Windsor, Ont., Canada, as a strategic accounts manager working out of Kentucky. Pendino has over 20 years of experience in sales, with six years in industrial and welding equipment sales.

Obituary

John Fred Prazen

John Fred Prazen, 63, died May 6, 2003, in Las Vegas, Nev. Mr. Prazen was president of Pioneer Welding and Repair in Price and Salt Lake City, Utah. A born artist, he was renowned for his impressive paintings and welded sculptures. He is survived by his wife, four sons, two daughters, 15 grandchildren, 17 great grandchildren, two brothers, and a sister.

CAREER OPPORTUNITIES

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Houston, TX Jul. 10–16
Sulphur, LA Jun. 26–Jul. 2

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Houma, LA Sep. 13–17 Nov. 8–12
Houston, TX Jul. 12–16
Sulphur, LA Jun. 28–Jul. 2

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Pascagoula, MS Jun. 7–18 Aug. 9–20
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(Test follows on Saturday at same facility)

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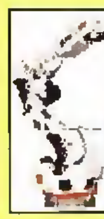

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The Influence of Various Hybrid Welding Parameters on Bead Geometry

Arc power and transfer mode greatly affect bead width, penetration, and reinforcement

BY M. EL RAYES, C. WALZ, AND G. SEPOLD

ABSTRACT. A series of hybrid welding (gas metal arc welding-CO_2 laser beam welding) experiments was conducted in which the two energy sources were coupled in one process zone on the surface of a 316L austenitic stainless steel workpiece. Arc and laser power were varied in order to study their influence on various bead dimensions. Arc power and, consequently, the mode of metal transfer have a great influence on bead width W, arc and laser penetration M and L, and bead reinforcement R. Increasing arc power increases W and L, whereas it reduces M and R. Laser power and hence the laser-induced metal vapor significantly influences the features of the metal transfer mode in the arc process. Higher laser powers prolong the arc burning time T_a at the expense of the short circuit frequency N_{sc}, which assists in increasing M and L. At constant laser power, the contribution of the M solely into the total penetration M+L is always bigger than that of the L.

Introduction

The combination of laser beam welding (LBW) and conventional gas metal arc welding (GMAW) processes, called hybrid (e.g., Refs. 1–3) or arc-augmented laser welding (e.g., Refs. 5–7), has been investigated and in progress during the last two decades. The potential for this combination is to increase the weld bead penetration, width, and welding speed, which is difficult to realize with either laser or arc process by their own. Combining the two processes results in a new one with its inherent features and characteristics, hence widening the areas of its application and increasing its capabilities, once the mutual interaction between the two energy sources is optimized. The arc welding process, characterized by relatively lower power density and wider process zone, gives a wide bead, thus enhancing the joint's root bridging ability and enlarging the manufacturing tolerances for joint preparation. Simultaneously, the laser beam process, characterized by higher localized power density, leads to a deeper penetration. Thus in hybrid GMA-laser beam welding, a wide and deep bead is achieved at higher welding speeds when compared with the GMAW process by its own (Ref. 8). This accordingly leads to less heat input per unit length, less thermal distortion, and therefore, less residual stresses, narrower heat-affected zone (HAZ), and more important, increased productivity.

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Hybrid Welding Principles

Figure 1 shows a sketch of the hybrid welding process (Ref. 10). In hybrid welding, a gas or solid-state laser (e.g., CO_2 or Nd:YAG) is combined with an arc welding process (e.g., GMAW, GTAW, or PAW) (Refs. 2, 3, 9). Both processes supply energy to the work surface. The focused laser beam impinges the workpiece surface converting its energy into heat. This causes vaporization of the workpiece material and formation of a deep vapor-filled capillary, i.e. keyhole, which is stabilized by the pressure of the metal vapor being generated. This metal vapor is capable of becoming hotter and forms a laser-induced plasma (Refs. 2, 9) that emerges from the keyhole causing attenuation of the laser beam above the work surface. This is called plasma-shielding effect, and its extent depends upon the gas type, electron density, and laser wavelength (Ref. 9). In order to reduce the plasma effect, a process gas with high ionization potential, normally helium, is used. In addition, the power of the arc welding process introduces more energy to the zone of laser beam impingement causing the process gas to be ionized, thus enhancing arc stability.

KEY WORDS

Bead Geometry
Gas Metal Arc
Hybrid Welding
Laser
Short Circuit
Stainless Steel

Principally, LBW can be combined or coupled with the arc welding process as shown in Fig. 2 (Ref. 3). When combined, they act separately with respect to time and zone and no mutual interaction takes place. This technique is used in single-side welding of thick-walled components such as pipeline fabrication and in shipbuilding, in which the laser beam bridges the root followed by the arc process (GMAW) (Ref. 3). When the two processes are coupled as one process, the laser beam and the arc process interact simultaneously in one zone and mutually influence one another. Such process coupling is referred to by the term "Hybrid Welding Process."

The gas type used in such process has a significant influence upon the plasma formation and arc stability in the hybrid process. Helium has a higher ionization potential than argon and therefore produces less dense plasma, hence, its use is beneficial in laser welding at low speeds and higher powers as there will be less attenuation of the beam. Conversely, argon produces denser plasma, which hinders deeper beam penetration but is advantageous for arc stability (Refs. 2, 6). It can be concluded that the effects of gas components in hybrid welding are contradictory in their function (Ref. 8), which requires

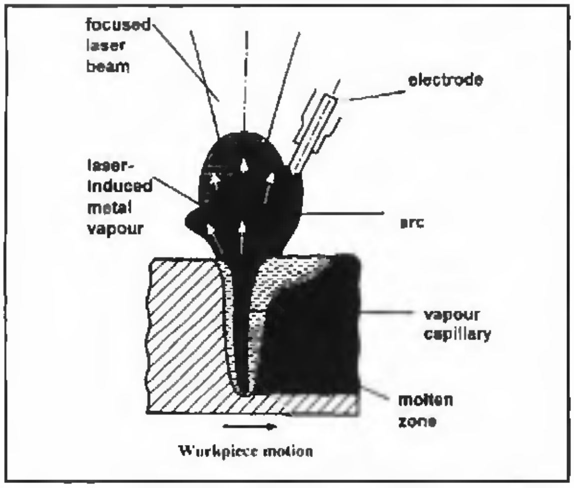

Fig. 1 — Hybrid welding process principles (Ref. 10)

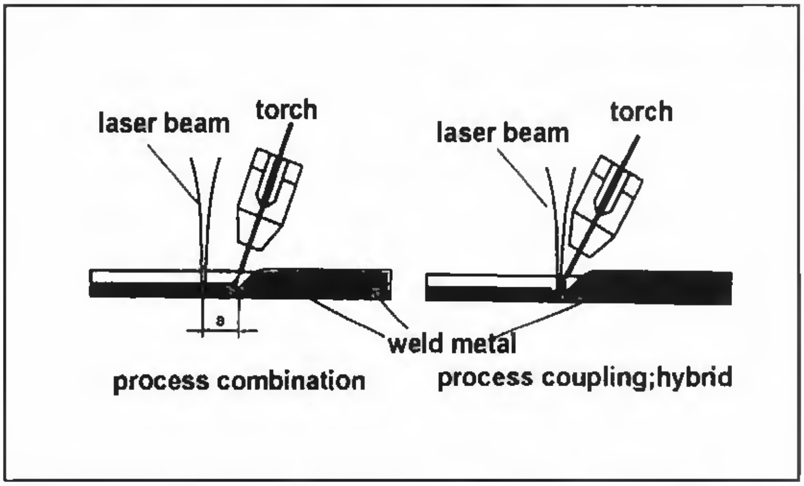

Fig. 2 — Process combination (they are separated by distance a) and process coupling in hybrid welding (Ref. 3).

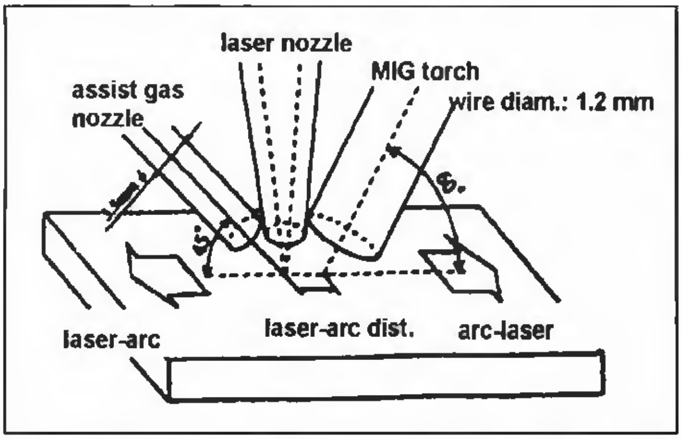

Fig. 3 — Arc-laser or laser-arc arrangement with respect to welding direction (Ref. 8).

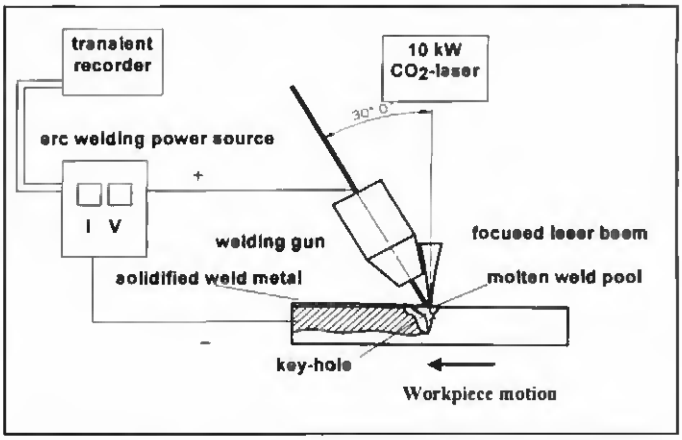

Fig. 4 — Schematic drawing of experimental setup.

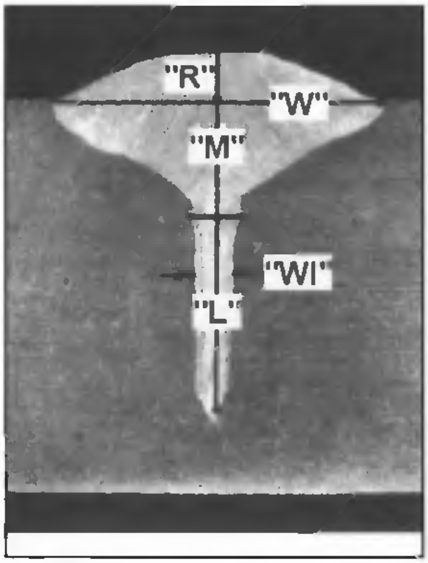

Fig. 5 — Nomenclature of weld bead dimensions (5×).

an appropriate gas composition that optimally reduces the plasma shielding effect and also enhances arc stability. In hybrid welding, there are numerous parameters that should be adjusted. They are classified (Refs. 2, 4) according to the parameters involved in laser (e.g., type, focal length, etc.) and base metal (e.g., type, joint design, etc.).

Influence of Hybrid Welding Process Parameters on Bead Shape

The distance between the arc and the laser beam (arc is leading) was found to influence the bead penetration. The smaller this distance gets, the deeper the penetration. This is because the laser beam impinges and penetrates the hot weld pool more readily than a solid surface, which occurs with longer distances. Varying this distance from 0 to 50 mm for deepest penetration yielded to an optimum value of 0 mm (Ref. 5) and 7 mm (Ref. 8), although the same laser type (CO_2), arc process (GMAW), and welding direction (arc is leading) were used. This range is seen to be relatively wide and needs to be studied further. The location of the laser beam focal point with respect to the workpiece surface in conjunction to welding current was also found to affect the bead penetration. At constant laser power and welding speed, the higher the current, the deeper the focal point should be under the work surface in order to realize deepest penetration (Ref. 5). The reason is basically due to the current increase, which causes an increase in the size and depth of the weld pool. If the focal point of the laser beam is set initially at the work surface, it will be above the surface of the resultant weld pool and not give maximum penetration.

In addition, the arrangement of the two welding processes, laser-arc or arc-laser, in the welding direction (Fig. 3) has

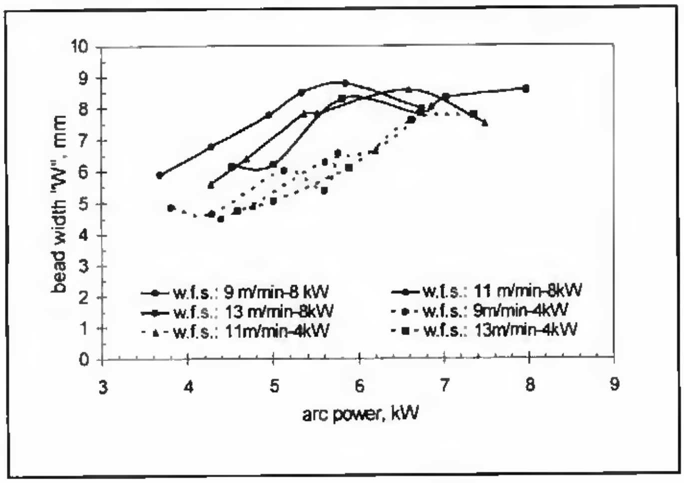

Fig. 6 — Relationship between arc power and bead width, W.

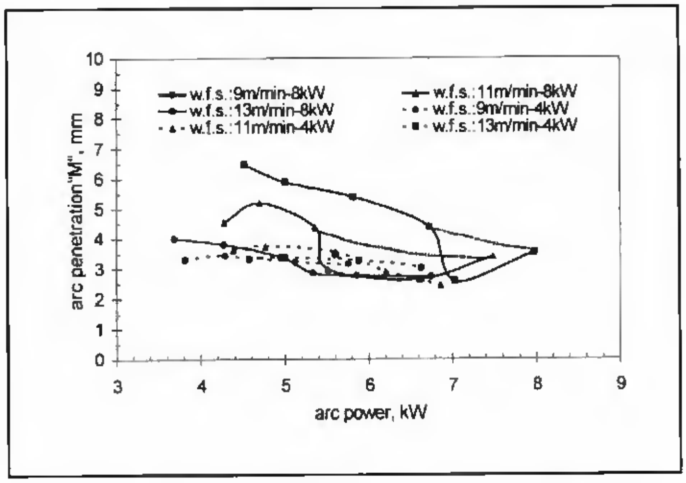

Fig. 7 — Relationship between arc power and arc penetration, M.

a significant importance in the hybrid process (Ref. 8). The former arrangement (the laser beam precedes the arc) was found to be superior regarding the bead appearance, because the assist gas flow does not affect the molten pool created by the arc. Whereas, in the later arrangement, the shape of the bead surface is disrupted by the assist gas blowing into the molten pool. Nevertheless, it was reported that arc-laser arrangement gives a more stable arc (Ref. 2).

The mutual influence between laser and arc energy sources differs in intensity and form depending upon the utilized parameters of each process (Ref. 11). Therefore, an important characteristic of hybrid welding is the ratio of power between the two energy sources, which determines if the laser or arc process is more dominant as to penetration depth and width. This depends upon the selected power for each process that in turn influences the bead shape (Ref. 12). It has been noted from the available literature that the dependence of the mutual interaction, between the laser and arc processes, upon the power ratio was not sufficiently clarified. This is probably due to the displacement created between the laser beam and arc column in the earlier work, thus demanding further investigations with zero displacement.

In spite of the increased number of variable parameters due to the process coupling, the large number of mutual interactions of individual factors and the lack of reference data, the present work is devoted to three main objectives. 1) Establish and ascertain basic relationships between the hybrid process main parameters (arc and laser power) and various bead dimensions. 2) Correlate these relationships with the possible interactions between the two processes. 3) Widen the scope of the hybrid process with respect to base material type and thickness; through exploiting the process advantages (e.g., high welding speeds, deep penetration, gap bridging ability, less distortion, etc.) on thick base metals. The base material type chosen is austenitic stainless steel, which is often used in pipeline, tank, and offshore structure fabrication.

Table 1 — Hybrid Welding Parameters Varied during Experiments

Laser Power, kW	Arc Power = Mean Welding Current × Mean Arc Voltage														
	wfs(a) = 9 m/min, I_m(b) – 230 A, Set Arc Voltage					wfs = 11 m/min, I_m – 260 A, Set Arc Voltage					wfs = 13 m/min, I_m – 290 A, Set Arc Voltage				
4	19	21	24	26	28	19	21	24	26	28	19	21	24	26	28
6	19	21	24	26	28	19	21	24	26	28	19	21	24	26	28
8	19	21	24	26	28	19	21	24	26	28	19	21	24	26	28
9	19	21	24	26	28	19	21	24	26	28	19	21	24	26	28

(a) wfs = wire feed speed.
(b) I_m = mean welding current.

Experimental Work

Energy Sources and Materials

In this work, a 10-kW, CO_2 laser was used. The laser beam was focused with a parabolic reflective 90-deg optics via an O_2-free copper mirror of a 300-mm focal length. The spot diameter of the focused beam was 0.8 mm. In conjunction, a multifunctional GMAW power source was used, which supplies 400 A/34 V at 100% duty cycle. The base material used was commercial austenitic stainless steel plates (DIN: 1.4404, AISI: 316L), which were sawed into 220 × 100 × 10 mm strips. An austenitic stainless steel filler metal (DIN: 1.4302, AWS: ER308) was used having 1.2-mm diameter and direct-current, electrode-positive (DCEP) polarity. A standard mixture of shielding gas (75%He-23%Ar-2%O_2) flowing at 30 L/min was used.

Experimental Setup

Figure 4 shows the experimental setup of the present work. The GMAW gun position was fixed during the experiments, having an inclination of 30 deg from the vertical laser beam, and an electrode extension of 15 mm. The specimen mounted on a carriage was moved at a speed of 30 mm/s, which was kept constant during the experiments. Welding current and arc voltage traces were recorded via a transient recorder. After welding, macrosections of the weld beads were ground, polished, and etched according to the standard procedures. All these sections were cut midway from the welded specimen. The bead dimensions corresponding to each welding parameter were measured using a stereo microscope with 0.1 mm sensitivity.

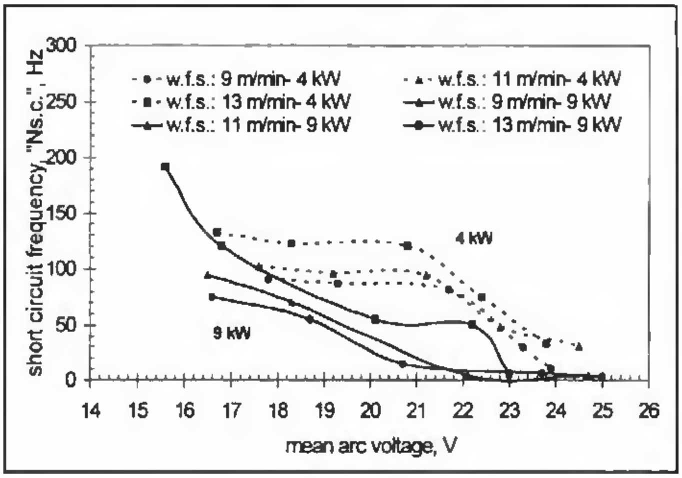

Fig. 8 — Relationship between short-circuit frequency, N_{sc} and mean arc voltage.

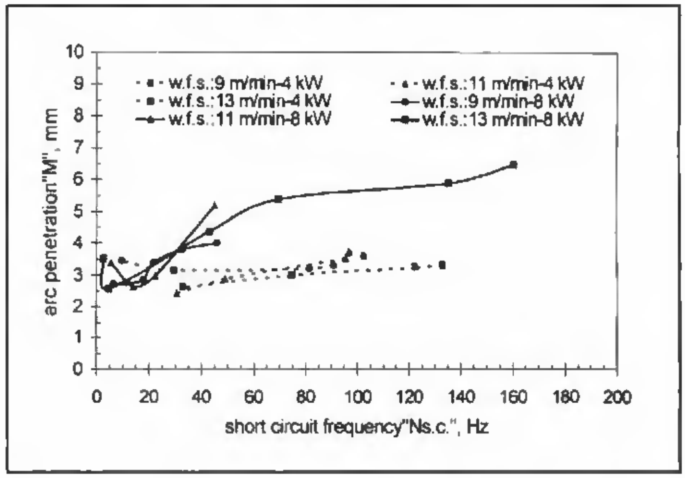

Fig. 10 — The dependence of arc penetration M upon the short-circuiting frequency N_s.

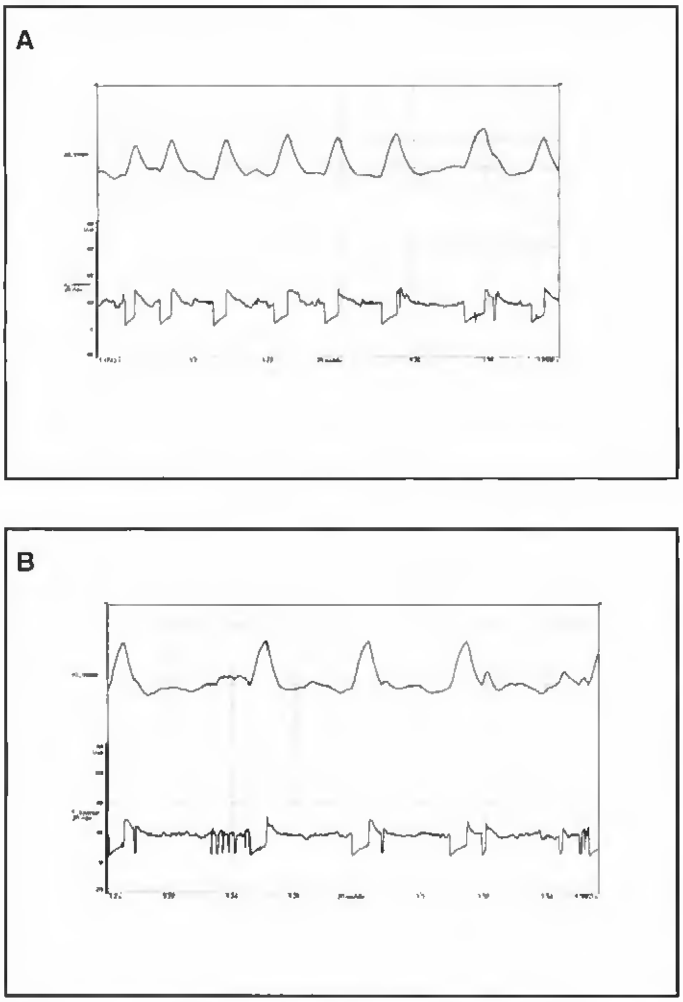

Fig. 9 — Current (upper)–voltage (lower) signals recorded with time (ms) during hybrid welding at laser power of: A — 4 kW; B — 9 kW.

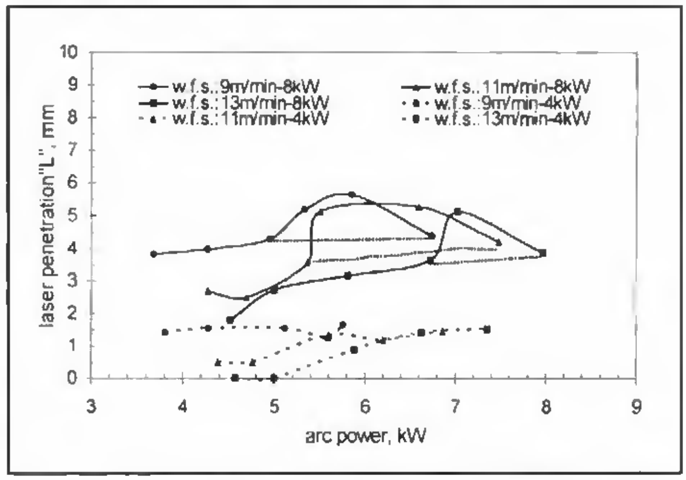

Fig. 11 — Relationship between arc power and laser penetration L.

Experimental Parameters

Table 1 presents the welding parameters that were varied during experiments. For each combination of laser power, wire feed speed, and arc voltage, a power ratio was calculated by dividing arc power hy laser power.

Bead Dimensions Nomenclature

In this study the bead geometry was divided into five dimensions, as shown in Fig. 5. W is bead width, measured between the two weld interfaces intersecting with the workpiece surface. R is bead reinforcement, measured from the workpiece surface to the top of the bead. M is arc penetration measured from the work surface to the extent of the weld cast structure. L is laser beam penetration calculated as the protruding penetration beyond M, measured from the end of M, until the end of penetration. M+L is total penetration as the sum of M and L. Wl is laser beam penetration width.

Results and Discussion

Effect of Arc Power on Bead Geometry

At constant wire feed speed (called wfs hereafter) and laser power, increasing arc power increases the bead width W until a maximum is reached. Beyond this maximum value, W decreases with wfs of 9 and 11 m/min, or stays unchanged with 13 m/min — Fig. 6. As presented in Table 1, the arc power was mainly increased by increasing arc voltage at a constant wfs, thus creating longer arc lengths, which is followed hy increasing the arc diameter and consequently widening the wetting zone on the workpiece surface. This causes a wider bead until a maximum width is reached. With still higher arc power, the wetting zone is further widened, but the

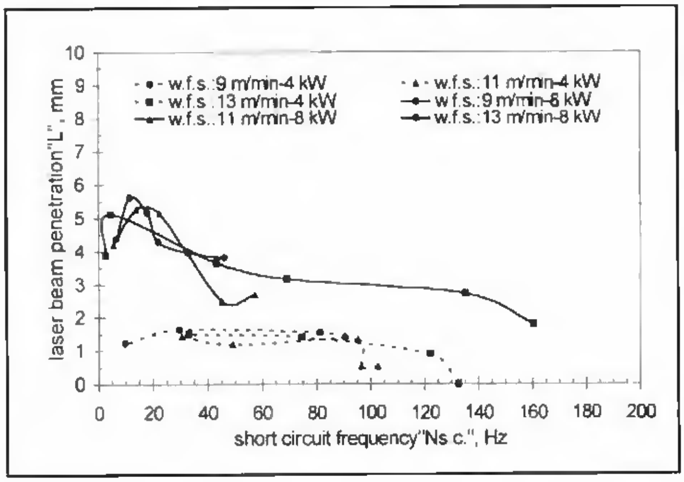

Fig. 12 — The dependence of laser penetration L upon the short-circuit frequency N_{sc}.

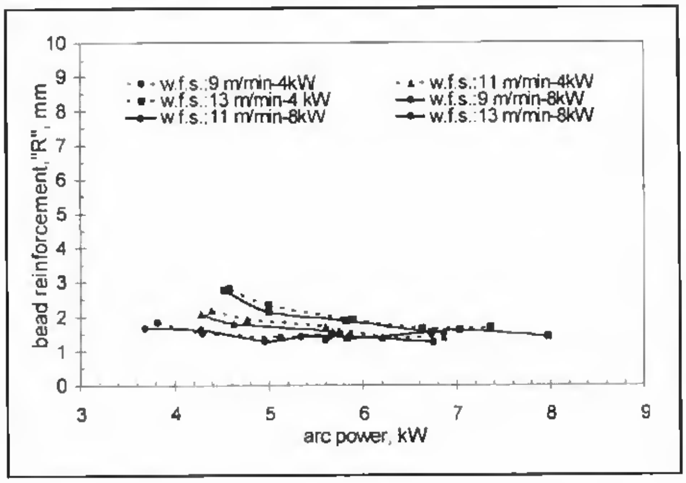

Fig. 13 — Relationship between arc power and bead reinforcement R.

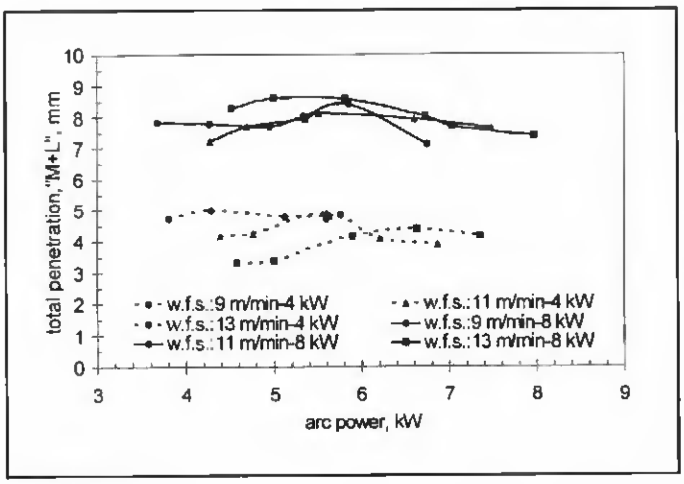

Fig. 14 — Relationship between arc power and total penetration M+L.

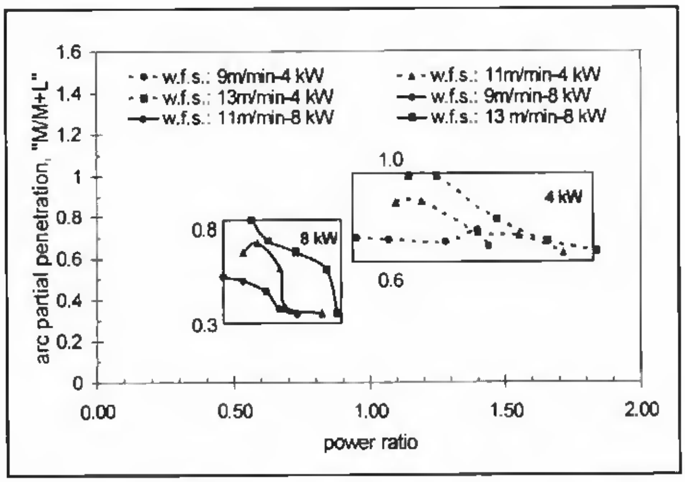

Fig. 15 — Relationship between power ratio and arc partial penetration M/M+L.

metal deposited has become insufficient with wfs of 9 and 11 m/min or just enough, with 13 m/min to fill that zone. Figure 6 also shows that at a constant laser and arc power, increasing the wfs reduces the W. Figure 7 correlates this result with arc penetration M. At constant laser and arc power, increasing the wfs deepens the M. In the same figure, increasing the arc power reduces the M penetration. The mode of metal transfer is an explanation for the reduction of M. At low arc power, i.e., low current and voltage, a short-circuiting transfer mode with its accompanying strong weld pool dynamics occurs causing a relatively deeper M. On the other hand, with increased arc power, a spray transfer mode is reached with calmer weld pool resulting in a shallower M. In order to clarify the above-mentioned explanation, the relationship between arc voltage and the short-circuit frequency N_{sc} is presented in Fig. 8. Increasing arc voltage is accompanied by a gradual change from short-circuiting transfer toward a spray transfer mode. In addition, the N_{sc} occurring with the 4-kW laser power is relatively higher than that with 9 kW. The reason is perhaps due to the greater amount of metal vapor produced by 9 kW than that by 4 kW. This metal vapor enhances current conduction and also reduces the arc voltage, based on the fact that metal vapor possesses relatively lower ionization potential than a shielding gas does (Ref. 13). As a consequence, the arc burning time, defined as the time elapsed during which the arc burns between two consecutive short circuits, is prolonged at the expense of the N_{sc}, for a constant recording time. Figure 9 shows two current-voltage traces occurring at 4- and 9-kW laser power, respectively, using the same welding parameters. Longer arcing times are noticed with the 9-kW signal than with 4 kW.

Furthermore, Fig. 10 shows the dependence of arc penetration M upon the N_{sc}. Generally, as the N_{sc} increases, M also increases. This result is clearer when higher laser powers (8 kW) are used, where the variation of M is more pronounced than that with 4 kW. This is probably due to the higher heat input per unit length and consequently higher heat content of the weld pool. This causes the weld pool to be more dynamic leading to a deeper M especially within the short-circuiting mode.

The laser beam penetration L generally increases with higher arc power, as seen in Fig. 11. The reason can also be attributed to the mode of metal transfer occurring with the arc process. As already known, the end of a short-circuiting period, i.e. the moment of arc reignition, is characterized by an explosion of the molten bridge that had connected the molten electrode wire tip with the weld pool and also by a sudden and intensive current flow through the arc. These two incidents have a double effect. First, they disturb the shielding gas flow, which the

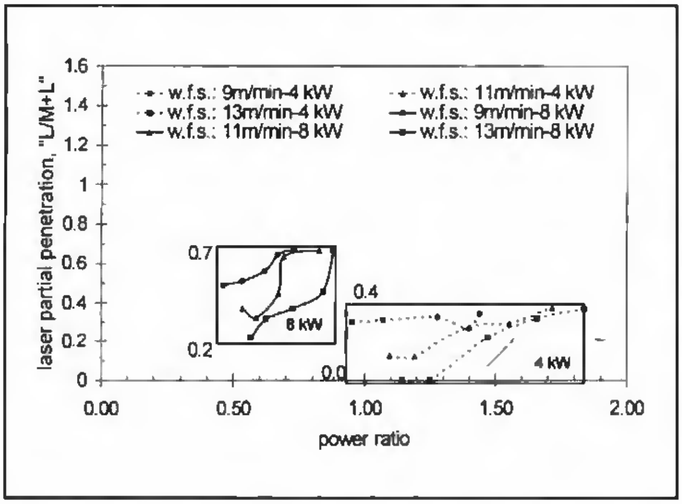

Fig. 16 — Relationship between power ratio and laser partial penetration, L/M+L.

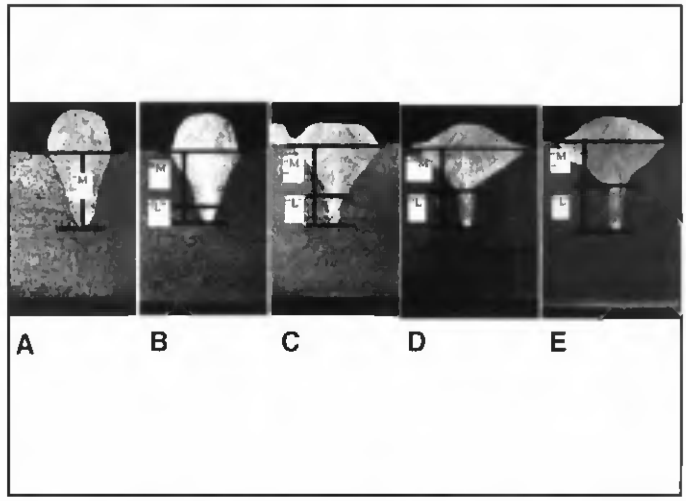

Fig. 17 — General influence of short-circuiting frequency N_{sc} on bead geometry at constant laser power (6 kW) and wfs (13 m/min). A — 173 Hz; B — 106 Hz; C — 89 Hz; D — 45 Hz; E — 19 Hz.

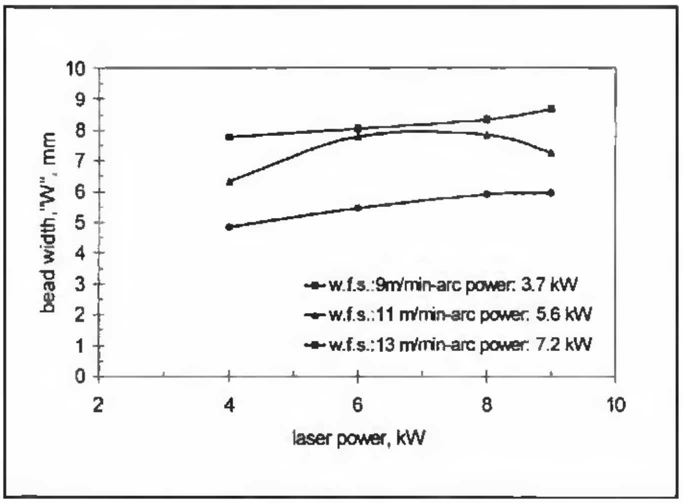

Fig. 18 — Relationship between laser power and bead width W.

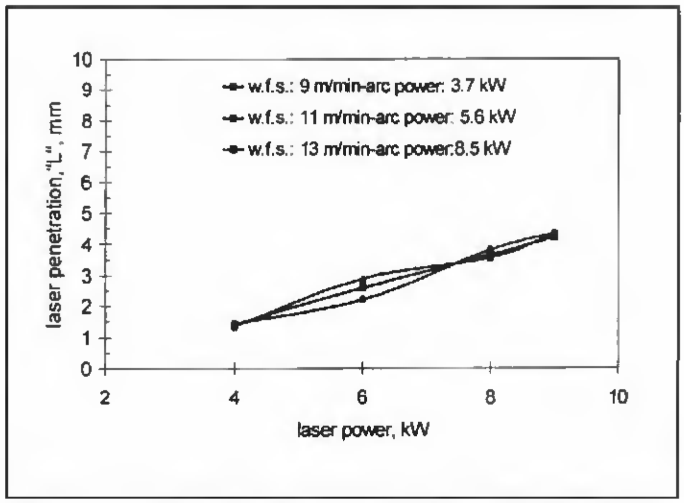

Fig. 19 — Relationship between laser power and laser beam penetration L

laser beam requires to realize its deep penetration. Second, they depress the weld pool surface leading to a wavy motion, thus changing the interaction with the laser beam at a frequency similar to that of the short circuits. Figure 12 shows the dependence of L upon the N_{sc}. At low N_{sc}, i.e., almost spray transfer mode, L penetration is maximum, where the molten pool is less dynamic, beyond which it gradually declines with higher N_{sc}.

It is obvious that with 8-kW laser power, M and L were subjected to abrupt change when plotted against arc power — Figs. 7 and 11. For both dimensions, these changes occurred at the same arc powers of 5.3, 5.5, and 7.0 kW corresponding to wfs of 9, 11, and 13 m/min, respectively. These values of arc power are specific and are only valid for 8-kW laser power, because at 4 kW, no abrupt changes took place as seen in the same figures. By omitting the abrupt fall or rise of M or L, and extrapolating the rest of the curves, dotted lines in Figs. 7 and 11, they take smooth trends without further abrupt changes.

Figures 10 and 12 show, at their extreme left in a narrow range between 5–20 Hz, similar changes in M and L when plotted against the N_{sc}. In this range, the transfer is described as spray with occasional short circuits. This possibly indicates that the shielding medium occurring with 8-kW laser power has the highest ionization potential compared to media occurring with 4-, 6-, and 9-kW laser powers. High-ionization potential gas mixture possesses relatively low current conduction, thus limiting M, and also low-density plasma, thus enhancing L. In this respect, further investigations covering a wider range of parameters with closer process monitoring is presently conducted.

The relationship between arc power and the bead reinforcement R is presented in Fig. 13. The higher the arc power is, i.e., going toward the spray transfer mode, the more the reduction in R occurs, where the bead becomes flatter and also wider as shown in Fig. 6.

Figure 14 shows that with increasing arc power the total penetration M+L is slightly reduced, whereas increasing laser power markedly increases it. Worth noting that in spite of the sudden changes of M and L when varying arc power (Figs. 7 and 11), the M+L showed a continuous trend, i.e. without abrupt changes. This means that M compensates L or vice versa. Therefore, it is important to distinguish between the contribution of M solely and similarly L with respect to M+L. For this reason the terms are partial penetration and laser partial penetration were introduced. The former term is expressed by dividing M by M+L and the later L by M+L. Figures 15 and 16 show these terms in enclosed windows when plotted against the power ratio at different wfs and laser powers. At constant laser power, e.g., 8 or 4 kW, increasing power ratio reduces the M/M+L. This is because of the increased arc power leading to spray transfer, as mentioned in Fig. 7, hence reducing M with respect to M+L. The same reason also causes the L to increase with increasing power ratio as in Fig. 16. The comparison between the locations of the windows indicate that with 4-kW laser power, the M value contributes between 60~100% in the M+L (100% means no protruding laser penetration), whereas L contributes between 0.0~40%. With 8 kW, the contribution of M and L became similar, however, the M share (30~80%) is still higher than that of L (20~70%). Therefore, it could be stated that at low laser powers M dominates the M+L, whereas, at higher ones, M and L have similar shares.

Within the entire range of arc power investigated, it has almost no effect on the laser penetration width Wl, whereas the laser power is slightly more influential. Higher laser powers result in wider Wl, because of the greater melting and evaporation capability. According to the hitherto discussion, the N_{sc} has generally a great influence on bead geometry. Figure 17 shows this influence on beads welded at different N_{sc}, at constant laser power (6 kW) and wfs (13 m/min).

Effect of Laser Power on Bead Geometry

Although the effect of laser power is mentioned in the previous section, the results of the investigated full range laser power will be presented. Figure 18 shows the effect of laser power on W at three different arc powers. Increasing the laser power increases the amount of molten metal causing the bead to become wider. At constant laser power, increasing arc power increases the bead width. This result is in good agreement with that mentioned in the previous section — Fig. 6.

The effect of increasing laser power on L, R, and Wl has been studied. Increasing laser power significantly affects the penetration L, as seen in Fig. 19, whereas it has almost no influence upon R and Wl. At constant laser power, the arc power more or less has a negligible influence upon L, R, and Wl.

Conclusions

According to the chosen set of welding parameters in hybrid GMA-CO_2 laser beam welding and referring to the aforementioned results and discussions, the conclusions are as follows:

1) A relationship exists between arc power and W, M, and R. Increasing arc power increases W and reduces both M and R.

2) The mode of metal transfer occurring with the arc process plays an important role in determining the extent of not only M but also L.

3) Laser power and consequently the amount of laser-induced metal vapor influence the features of metal transfer in the arc process. It prolongs the arc burning T_a time on the expense of the short-circuit frequency N_{sc}.

4) Although the share of M in M+L is more dominant than the L share, increasing the laser power increases the L share in the M+L.

5) Increasing laser power increases W and L, whereas, it has a negligible influence upon R and Wl.

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Development and Evaluation of an In-Situ Beam Measurement for Spot Welding Lasers

Comparative measurements demonstrate that multiple shots on Kapton™ film yield a focused laser beam diameter that is 99% of the actual beam diameter

BY P. W. FUERSCHBACH, J. T. NORRIS, R. C. DYKHUIZEN, AND A. R. MAHONEY

ABSTRACT. A straightforward and accurate method for measuring the laser beam diameter at focus is desired in order to develop fundamental understanding and for routine process control. These measurements are useful for laser materials processing by assuring laser performance consistency at the workpiece. By employing multiple-shot exposures on Kapton™ film, an unambiguous and precise measurement of the focused Nd:YAG laser beam diameter for spot welding lasers was obtained. A comparison of focused beam measurements produced with the Prometec laserscope and an ISO variable aperture method found that these two methods, which both measure the 86% energy contour, do closely agree. In contrast, Kapton film was found to measure the 99% beam energy contour and to diverge from measurements made with the other two methods. The divergence between Kapton and the other two methods was shown to be due to changes in the laser irradiance distribution that do not affect the location of the 99% energy contour. Since the 86% beam diameter was seen to not always be representative of the true beam diameter, the 99% Kapton film diameter can provide a more representative measurement of the focused laser for in-situ process control.

Introduction

Laser beam spot welding is widely used for electronics packaging, electrical interconnects, medical devices, and other high-value-added components. To develop predictive models of the process, maintain process control, and wisely choose optimized process parameters, measurement of the incident laser spot size at the workpiece is essential. Commercial instruments are available for this task but are often prohibitively large, too expensive, or too time consuming to be readily used. Moreover, the commercial instruments available do not have a NIST traceable calibration, despite the recent publication of an ISO standard for measurement of focused laser beams (Ref. 1).

Certainly the measurement task is problematic. The spot diameter at the focal plane of a typical pulsed Nd:YAG welding laser is only about 0.4 mm. With several joules of laser energy focused into such a small spot, the irradiance is easily sufficient to melt and vaporize most metals. Even instruments designed for this environment can be easily damaged if exposure to the focused beam is not carefully restricted. Measurement of this beam without attenuation can be a very difficult task. Attenuation of the incident laser beam with reflective optics using interference coatings can be effectively applied, but only for lasers with open beam paths and available working space. For many materials processing lasers, these methods are unworkable and a straightforward in-situ method is desired.

The placement of a thin foil of Kapton polyimide directly at the focal plane has been widely employed as an in-situ method to measure focal spot size. However, the accuracy of this technique is the subject of some discussion since focused-beam calibrations are still uncommon (Refs. 2–4). Kapton can be faulted since it cannot be used to determine the irradiance distribution or the spatial mode of the laser. These characteristics are important selling points in the more comprehensive commercial instruments (Ref. 5).

KEYWORDS

Laser Beam Welding
Laser Focus
Spot Weld
Laserscope
ISO 11146
Beam Quality
Process Control

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Nonetheless, this study furthers the development and evaluation of Kapton film because it is simply a very compelling method. The encouraging earlier study led to routine beam-characterization efforts at Sandia National Laboratories on several different lasers as a new element of process control. The results were insightful and informative, yet uncertainty remained because of the reported divergence in spot size between Kapton and the Prometec laserscope at high laser-pulse energy. The need for another comparative measurement technique became necessary in order to unequivocally verify the accuracy of the methods. Successful experiments with a variable aperture technique in the past (Ref. 6) pointed to a credible third method for comparison.

With the employment of a third calibration method as well as new Kapton measurement techniques, this study continues the qualification of Kapton film as an important in-situ instrument in laser spot welding process control.

Experimental

Transmittance through four thicknesses (25, 50, 75, 125 μm) of Type HN Kapton film was measured with a Cary 5E spectrophotometer. It was equipped with a Labsphere integrating sphere (150-mm diameter) as an optional accessory. The integrating sphere accessory enables the measurement of the total, normal, hemispherical transmittance, and total, near-normal, hemispherical reflectance, of the Kapton material at the laser wavelength λ. The measurement methods employed followed procedures outlined in ASTM standard test method E903-96 (Ref. 7).

Tests to determine Kapton hole enlargement and preferred number of laser shots were made with a Rofin/Baasel SWP5002 Nd:YAG spot welding laser with no fiber and a 120-mm focal length lens. Pulse energy was varied from 0.9 J to 2.9 J with a set 2-ms pulse duration.

In the evaluation testing, three distinct

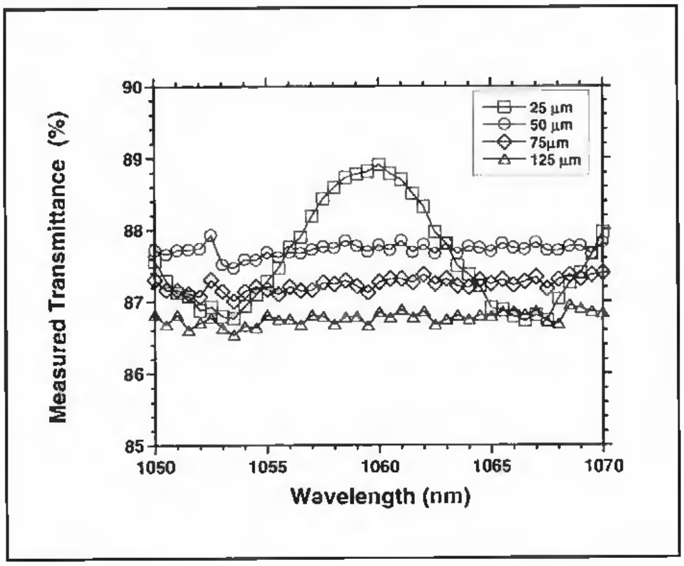

Fig. 1 — Transmittance through undamaged Kapton film for four thicknesses, measured with a spectrophotometer.

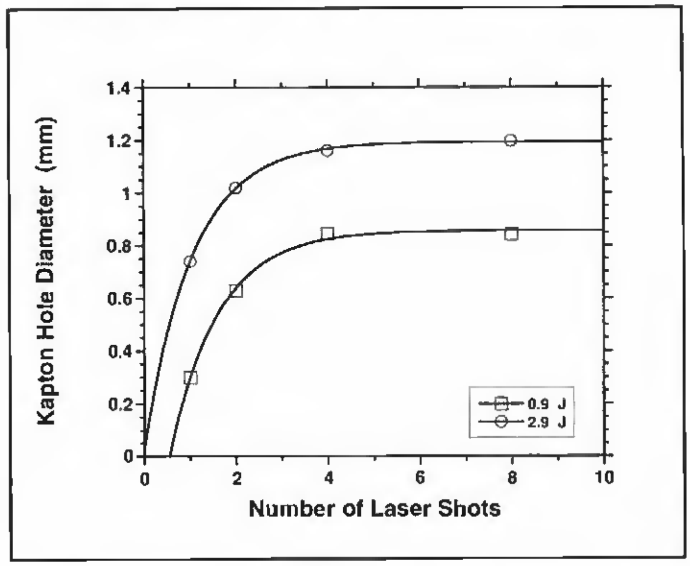

Fig. 2 — Dimensional change of burn-through hole after each shot in Kapton film for two Nd:YAG laser beam intensities. SWP5002 laser, 2-ms pulse.

methods were used to measure focused laser spot size, including Kapton film, the Prometec laserscope, and a variable-aperture method based on the international standard ISO11146 (Ref. 1). All comparative measurements were made with the same 250-W Raytheon SS525 pulsed Nd:YAG laser without fiber-optic delivery. The laser is designed for both spot welding and seam welding and includes variable pulse frequency from 1 to 200 pulses per second (pps). Pulse duration was set at 3 ms for all SS525 measurements. The Prometec laserscope outputs a 25-Hz synchronization pulse, which requires that all comparative measurements be made at this same frequency. Average power was varied from 33 to 315 W by adjusting the laser pulse energy from 1.3 to 12.6 J while maintaining the constant pulse frequency of 25 Hz. A 150-mm plano-convex focusing lens was used for these three-way comparative measurements. For the two-way comparison between Kapton film and variable apertures, a 100-mm focal length lens and 15-pps frequency were chosen in order to obtain a smaller beam diameter due to size limitations in the aperture set. For single-shot measurements on Kapton film, the control panel on the laser was set so that the shutter would allow from one to several pulses to be released from the laser cavity when the laser was fired. This was done by utilizing the laser's shutter/ramp timer.

Measurements of the unattenuated focused beam were made using the Prometec UFF100 laserscope. This instrument utilizes a rotating pinhole aperture and photodetector sensor, which scan and map the irradiance distribution. The resulting data files are processed with a personal computer to yield the beam cross-sectional area that includes 86% of the total beam power. The radius of the beam is determined by calculating the radius of a circle containing the same area. To synchronize hollow needle rotation of the laserscope with the laser pulsation required the construction of a timing circuit (Ref. 4), which assured that the laser fired at the same instant that the laserscope pinhole was located under the focused laser beam.

Beam diameter measurements of the unattenuated focused beam were also made with Type HN Kapton film. Based on results in the earlier study (Ref. 4) and evaluation of new beam transmittance data to be given later, film thickness for all beam diameter measurements was fixed at 50 μm. The Kapton film was cleaned with ethyl alcohol and placed into a 35-mm film slide mount to make the Kapton easy to handle and keep flat. The slide mount was rigidly attached to an x-y stage, which was positioned so that the Kapton film was directly in the focused beam's path. A CNC controlled the stage's motion. No inert shielding gas was used for the Kapton burn measurements. The diameters of the Kapton-burned holes were measured using an Olympus STM measuring microscope at a magnification of approximately 100×. Due to the irregularity of burns on the Kapton film, appropriate backlighting was used to help illuminate the through-hole. Two orthogonal measurements were taken for each spot and were then averaged to obtain an overall spot diameter.

A set of gold sputter-coated diamond wire dies in 25-µm increments were used to aperture the laser beam about the focal plane (Ref. 6). Diamond wire dies are ideal for this application, since diamond has a very high thermal conductivity and an extremely low thermal expansion coefficient. The gold coating assures that laser energy that is not transmitted through the aperture is reflected away, since the diamond is transparent to Nd:YAG radiation. To prevent damage to the apertures, the laser beam was attenuated with a beam splitter that delivered about 0.6% of the laser power to the focusing lens. The diamond apertures were placed over the entrance port of a Labsphere Model LIS-DG integrating sphere. The beam diameter was determined by first measuring the transmitted power using an aperture larger than the full laser beam diameter and then substituting smaller apertures to obtain two transmission values — one above and one below the 86% transmission value as specified in the ISO standard. To measure the laser power transmitted though the diamond apertures, a silicon photodiode detector was placed at one of the exit ports of the sphere. Beam power was measured with a LeCroy Waverunner digital oscilloscope, which was set to compute a 500-pulse average of the RMS value of each pulse waveform. Each aperture was centered on the sphere by adjusting an x-y stage and maximizing the oscilloscope pulse waveform.

$$w^2(z) = w_0^2 + M^4\left[\frac{\lambda^2}{\pi^2 w_0^2}\right](z - z_0)^2 \quad (1)$$

For all the Kapton, laserscope, and variable aperture tests, multiple measurements about the focal plane were made at the same set of pulse energies and dura-

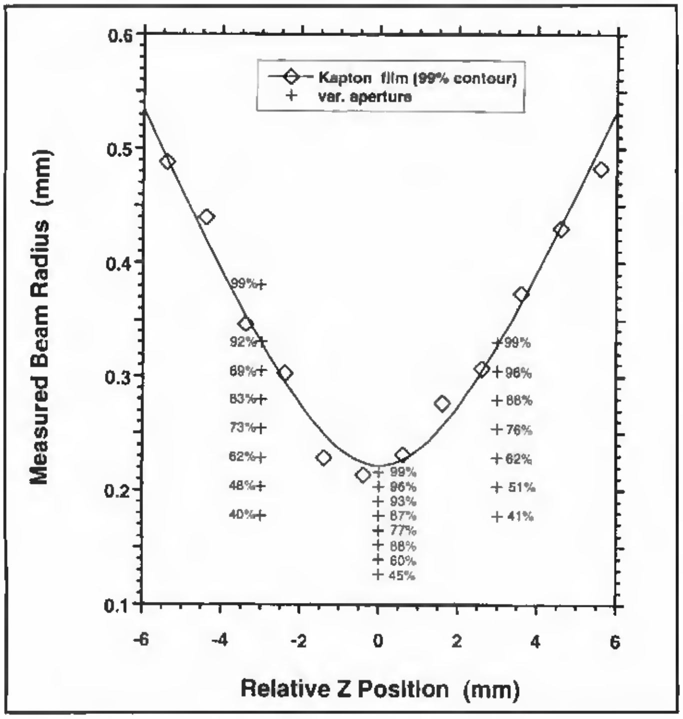

Fig. 3 — Hyperbolic curve-fit of Kapton-measured beam dimensions, along with aperture-measured beam transmission values for the same laser conditions at the same axial location and output power: f=100 mm, 4.0 J, 3 ms, 15 pps.

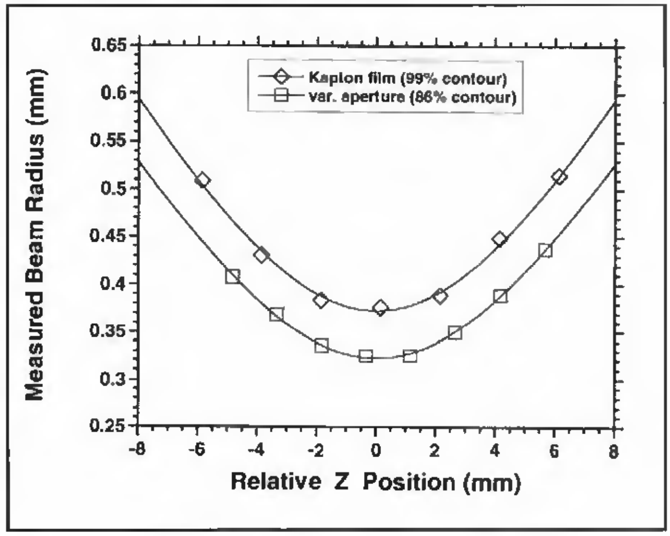

Fig. 4 — Hyperbolic curve-fit of Kapton- and aperture-measured beam radius for identical laser conditions; f=150 mm, 4.0 J, 3 ms, 25 pps.

tions, and usually with four to six spots above and below the focal plane. This typically resulted in a z-axis range of ~10 mm. The spot size measurements and focal plane position values for all three methods were fitted to the hyperbolic laser beam propagation Equation 1, where w_0 is the minimum spot radius at the focal plane, z_0 is the axial position of the focal plane relative to the lens, λ is the laser wavelength, and M^2 is a beam quality factor for the combined laser/optical system (Ref. 8). This approach to finding the minimum spot radius served to average the laser performance and more accurately estimate the minimum waist spot size and effective focal length. The curve-fits also provide a common method of comparison for the three experimental methods including statistical correlation coefficients.

Results and Discussion

Kapton Development

In the previous investigation (Ref. 4), a limitation to the largest beam diameter that could be measured with Kapton film was at times observed when the single-shot irradiance was insufficient to burn through the film. Measurements in that study and in trials with other lasers have indicated that it is often difficult to obtain cleanly burned holes in Kapton. To test whether a high reflectance or high transmittance was responsible for the robust behavior of Kapton, the optical properties were measured with a spectrophotometer. The results are given in Fig. 1. The high threshold irradiance of 50-μm Kapton can be understood when one considers that almost 88% of the laser beam passes through at the Nd:YAG (1060 nm) wavelength. The figure also shows that transmittance decreases as Kapton film thickness increases. This can be explained by absorptance in the film, which naturally increases as the thickness increases. It also is apparent in Fig. 1 that the 25-μm-thick Kapton has strong wavelength dependence that is thought to be due to constructive and destructive phase effects at the second surface during transmittance and reflectance. This thickness is exhibiting "thin film" behavior and probably should be avoided for beam diameter measurements. The pronounced variability observed for 25-μm-thick Kapton in Fig. 1 may account for the difference in beam diameters observed with 25 μm when compared with the other thicknesses examined in the earlier study (Ref. 4). Since the 50-μm Kapton film does not appear to show thin film behavior and has a low burn irradiance, it was chosen as the only thickness for use in subsequent tests in this study.

The transmittance data presented in Fig. 1 can be used to determine the optical properties of Kapton for the wavelength tested. The transmitted energy can be analytically expressed as a function of the surface reflectivity r and the material absorptance constant a:

$$T = \exp(-t/a)\left(\frac{1-r}{1+r}\right)\frac{1-r^2}{1-r^2\exp(-2t/a)} \quad (2)$$

where t is the material thickness (Ref. 9). A good fit to the data is obtained by using a material reflectivity of 0.06 and an absorptance constant of 0.6 mm.

The high transmittance of Kapton (see Fig. 1) makes it impractical for use with spot welding lasers when single low-irradiance laser pulses are selected. The high transmittance explains cases where Kapton is not burned through with a laser pulse that is otherwise sufficient to melt the surface of many metals. To expand the practical range of irradiance for Kapton film, a different measurement approach was conceived. Tests were made to determine the effect of multiple laser pulses on the measured beam diameter. Figure 2 shows the effect of multiple shots on Kapton hole diameter for two levels of irradiance. One can see that after about four shots, the hole diameter asymptotically reaches a maximum value. Since the maximum diameter is self limiting, and because shot-to-shot variability will be mitigated by the larger sample size, it is thought that a multiple-shot upper-limit diameter will be a more precise measurement than the single-shot measurements used in previous Kapton investigations (Refs. 3, 4). Figure 2 also shows that the single pulse diameter ranges from 61 to

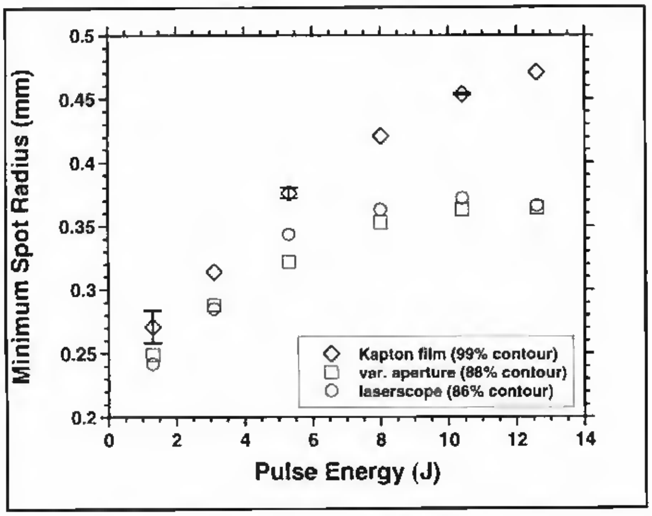

Fig. 5 — Minimum Nd:YAG spot radius for three focused-beam measurement methods. All at f=100 mm, 3 ms, 25 pps.

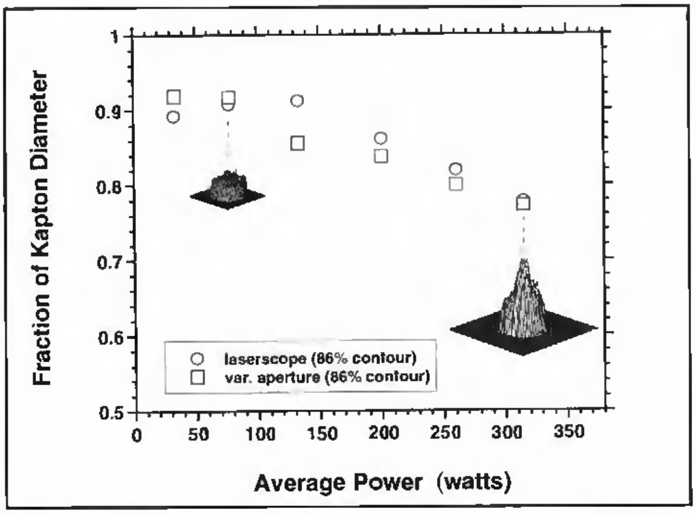

Fig. 6 — Ratio of the measured 86% beam diameter to the Kapton 99% beam diameter. Isometrics indicate significant change in beam mode as lamp power is increased. All at f=100 mm, 3 ms, 25 pps.

67% of the maximum beam diameter. Clearly the actual beam diameter is greater than this and must be close to the maximum diameter measured after repeated shots, but not significantly greater since a plateau is reached.

Because of Kapton's excellent transmittance at 1.06 µm, there is potential for a small fraction of the beam energy to pass beyond the outer edge of the largest hole diameters in Fig. 2. In other words, the actual beam diameter could be somewhat larger than the diameter measured with multiple shots on Kapton. Consequently, indirect measurements were made to try to determine the actual percentage of laser pulse energy transmitted through a Kapton-burned hole after exposure to five shots. Kapton-measured beam radius as well as aperture-measured transmission results for a 100-mm focal length lens are given in Fig. 3. The figure contains the hyperbolic curve-fit for Kapton film measurements about the focal plane for a 4.0-J pulse. By subsequently placing sequential diamond apertures of a known radius in the path of the same power beam at the same axial position, measurements of beam transmission were made that directly correlate with the Kapton-measured radius.

One can see in the figure that the hyperbolic fit intersects with the transmission measurements at values of approximately 99%. At focus, the aperture and Kapton values are nearly identical and a 99% beam transmission is a valid hypothesis for these results. In addition, separate curve-fits that are not shown estimate the minimum spot radius for the Kapton and the 99% aperture in Fig. 3 to be within 4% of each other with values of 222 and 213 µm, respectively. It is thought that experimental error may account for the relatively low 92% (–3 mm, converging beam) transmission measurement in Fig. 3.

For a slightly different set of conditions, a comparison of the 86% aperture-measured radius and the Kapton-measured radius is shown in Fig. 4. In this higher average power case (100 W vs. 60 W), the Kapton diameter measurements closely match the theoretical hyperbolic curve-fit. It should be noted that this laser design is often more stable at higher power levels. The 99% value obtained by the Kapton measurements is shown to be offset by a nearly constant amount from the 86% value obtained from the variable aperture measurements. This is not consistent with a Gaussian profile where the offset would grow as the beam size grows. Indirectly, Fig. 4 shows that the beam profile is not Gaussian.

It is evident from Fig. 4 that the Kapton measurement is always larger than the 86% contour and certainly very close to the maximum beam contour. The high transmission of 99% indicates that the multiple-shot Kapton-measured diameter represents the very outer edge of the bell-shaped laser beam. Since the outer edge of the laser beam is excluded, the diameter does not include low-irradiance azimuthal ring modes near the periphery that likely have little effect on welding. The transmittance values in Fig. 3 also indicate that the Kapton hole is not burning beyond the outer edge where the last percent is contained.

To understand why the laser-burned hole is not greater than the actual beam diameter, heat conduction in the Kapton can be examined. We can estimate the importance of thermal conduction during the laser pulse by evaluating the distance the heat is conducted for a single laser pulse. Kapton has a heat capacity (C_p) of 1.09 J/g/K, a thermal conductivity (k) of 0.12 W/m/K and a density (ρ) of 1.4 g/cc. The heat conductance distance can be estimated from the following equation:

$$x = \sqrt{\frac{kt}{\rho C_p}} \quad (3)$$

This results in a distance of 15 µm for a 3-ms pulse. This is reasonably small when compared to the spot diameter, so conduction into the surrounding Kapton is probably minimal. It is also evident from Equation 3 that the use of short-duration laser pulses can be effective in minimizing conduction into the Kapton film and preventing a misleading enlargement of the hole.

Kapton Evaluation

A direct comparison of the three measurement methods is given in Fig. 5. The spot weld beam irradiance examined ranged from 0.23 to 1.0 MW/cm^2. One can see that the multiple-exposure Kapton measurements have a larger diameter than both the laserscope and the variable aperture methods for all laser conditions. This result is expected, since the Kapton measurement indicates the diameter where approximately 99% of the laser energy is contained within (see Fig. 3). In contrast, both the laserscope and the aperture methods compute the diameter within which only 86% of the laser beam energy is contained. Not surprisingly, the laserscope and the aperture results in Fig. 5 are very close in magnitude. Clearly, both methods can be used equally as well to obtain the 86% contour for a large range of laser conditions. The close correlation between these two methods is in fact a calibration of both, and a validation of the laserscope's utility. Concerns in Ref. 4 about the reliability of the laserscope measurements are now alleviated with these new results.

The error bars included on three of the Kapton data points in Fig. 5 indicate the variability that was observed for conditions where replicates were made. In one case, the error bar is less than the data point symbol. Replicates were not required for the laserscope or aperture methods since each value given is in fact an average of many hundreds of laser pulses. The variability at low power shown in Fig. 5 is probably due to laser instability at low power more than to Kapton variability at low irradiance. If shot-to-shot variability in laser beam diameter is expected with a lamp-pumped Nd:YAG laser, then multiple exposures of Kapton film should be made in order to obtain a more accurate measurement.

The strong correspondence between the laserscope and aperture measurements in Fig. 5 also reveals an apparent swing away from the Kapton values. The divergence between Kapton and the other two methods in Fig. 5 appears to occur at average powers greater than 100 W. The divergence is likely due to a change in laser beam mode that results in a larger beam that does not produce a corresponding increase in the 86% contour. Pulsed Nd:YAG materials-processing lasers without fiber delivery typically will change in transverse mode as the pumping power increases (Ref. 10). The change in mode shape is apparent in Fig. 6 where irradiance distributions are presented for the 3-J and 12-J pulses. The isometrics were obtained from the laserscope output files at locations near the beam minimum waist. Since more of the beam energy is concentrated near the center for the 12-J beam, it is understandable that the 86% beam diameter does not increase in the same proportion as the 99% Kapton diameter does in Fig. 5.

To compare the 86% values with the Kapton 99% values, it is useful to examine the standard Gaussian beam profile. The irradiance distribution of the single-mode Gaussian laser beam is given (Ref. 11) as:

$$I(r,\theta) = I_0 \exp -2\left(\frac{r}{w}\right)^2 \qquad (4)$$

where I_0 is the irradiance at the center of the beam, r is the radial coordinate, and w is the Gaussian beam waist (radius), which is a constant. If we integrate the irradiance distribution, we can find the power contained within a circle of radius r_1:

$$P = \int_0^{2\pi}\int_0^{r_1} I_0 \exp -2\left(\frac{r}{w}\right)^2 r\, dr\, d\theta \qquad (5)$$

For the total power, we have

$$P_0^{\infty} = \frac{\pi}{2} w^2 I_0 \qquad (6)$$

For the power contained within the Gaussian beam radius w,

$$P_0^{w} = \frac{\pi}{2} w^2 I_0 (0.865) \qquad (7)$$

For the power contained within any aperture r,

$$P_0^{r} = \frac{\pi}{2} w^2 I_0 \left[1 - \exp -2\left(\frac{r}{w}\right)^2\right] \qquad (8)$$

The ratio of the power passing through the Gaussian beam radius w to the total power gives the familiar 86% beam transmission, T_w.

$$T_w = \frac{P_0^w}{P_0^{\infty}} = 0.865 \qquad (9)$$

For the Kapton transmission of 0.99 established in Fig. 3, we have

$$T = \frac{P_0^r}{P_0^{\infty}} = 1 - \exp -2\left(\frac{r}{w}\right)^2 = 0.99 \qquad (10)$$

which can be rearranged to yield the theoretical ratio of Gaussian radius to the 0.99 transmission Kapton radius:

$$\frac{w}{r_{99}} = 0.66 \qquad (11)$$

In other words, the 86% beam diameters (or radii) should be 66% of the 99% beam diameter if we are comparing true Gaussian beams.

Figure 6 shows the ratio of the measured beam diameter to the Kapton-measured beam diameter for both the laserscope and the variable aperture methods. The fraction of Kapton diameter varies from about 0.77 to 0.92. At high energies, the measured diameters become closer in magnitude to the 0.66 theoretical value for Gaussian beams in Equation 11. The more Gaussian-like isometric in Fig. 6 at high energy is also consistent with the decreased value of the ratio.

If we accept that the Kapton measured contour is representative of the actual beam dimension, then the pronounced variations in the 86% contour shown in Fig. 6 further indicate how subjective the universal measurement truly is. In contrast, the 99% Kapton contour is unbiased and unambiguous as laser conditions change.

Notwithstanding substantive differences in measurement technique, both the laserscope and aperture methods describe a fundamentally different characteristic of the focused laser beam than that measured with Kapton. For both methods, the 86% energy contour is used to designate the $1/e^2$ beam diameter. It is the value referenced universally for characterizing laser beams in science and industry as well as in the ISO standard. Yet the 86% energy contour really only indicates the $1/e^2$ beam diameter for single-mode beams, which by definition exhibit a Gaussian irradiance distribution. In practice, the 86% contour provides an effective measure for beam comparison purposes, since it represents a circle that contains a very large fraction of the laser energy. Nonetheless, it is clearly an arbitrary measure. There is no body of evidence to suggest that an 86% diameter is any more or less significant than a 99% diameter for laser materials processing. While there may be subtle differences in processing for laser beams with different irradiance distributions, an accurate measurement of the beam at either the 86% or 99% diameter will likely yield the most desired first-order effects.

For process control purposes, the 99% Kapton diameter may be preferred since it can be measured in-situ, it represents the entire laser beam, and as shown in Figs. 3 and 4, it can be both precise and accurate. Since the 99% diameter represents the very outer edge of the laser beam, significant changes in beam diameter, as shown in Fig. 5, will always be apparent in the Kapton measurement. Moreover for fiber-delivered beams where mixed beam modes result in a top-hat distribution, the 99% diameter may be a more useful indicator of laser performance. Finally, the Kapton burn represents an actual physical process. It is a functional measure, somewhat similar to spot welds on thin metal sheets that are often used to check irradiance. But since Kapton yields the 99% beam diameter, the values are independent of laser energy and provide a focused laser beam measurement that is both fundamental and useful in providing a high degree of confidence in laser performance at the workpiece.

Conclusions

1) Multiple shots on Kapton film have been shown to give an unambiguous and precise measurement of an unattenuated spot welding laser beam at focus.

2) Direct comparisons of the focused laser beam diameter have been given based on measurements obtained from Kapton film, the Prometec laserscope, and an ISO standard established variable aperture method.

3) Unlike the laserscope and the variable aperture methods, which locate the 86% energy contour, Kapton film locates the contour that contains 99% of the laser energy.

4) The Prometec laserscope and the ISO variable aperture method have been shown to closely correlate for laser beam irradiance that ranges from 0.23 to 1.0 MW/cm^2.

5) Divergence between the Kapton-measured beam diameter and the laserscope 86% beam diameter has been shown to be due to changes in the laser beam mode at high lamp power.

6) Transmittance measurements with a spectrophotometer at the 1.06-µm laser wavelength found that 88% of the incident energy passed through 50-µm-thick Kapton film.

Acknowledgments

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Microstructure-Property Relationships in HAZ of New 13% Cr Martensitic Stainless Steels

An assessment of mechanical properties showed a relatively low HAZ hardness and high notch toughness could be obtained

BY O. M. AKSELSEN, G. RØRVIK, P. E. KVAALE, AND C. VAN DER EIJK

ABSTRACT. In the present investigation, the properties of new low-carbon (0.01–0.1 wt-% C), 13 wt-% chromium, martensitic stainless steels have been examined. The major focus has been put on an assessment of the mechanical properties of weld simulated specimens, including Charpy V-notch (CVN) toughness and tensile properties. The steels included are different types of martensitic grades, ranging from the "old, conventional" type with 0.1% C to the new low-carbon (< 0.02% C) steels with balanced additions of Cr, Ni, and Mo to improve corrosion resistance and to maintain phase balance.

The results showed that a relatively low heat-affected zone hardness (HV_5 < 300 kg/mm^2) can be obtained, depending on the steel's chemical composition, weld simulation parameters, and the application of a tempering cycle. Single values as low as about 270 kg/mm^2 have been achieved for the lowest carbon-containing steels. The notch toughness, which is of primary concern, was quite high (> 50 joules), with the exception of the steel with the highest carbon content (0.11% C). After a tempering pulse (600°, 700°, and 800°C for 60 s), the steels behave quite differently. While hardness was reduced for most of the steels, toughness was reduced for one of the steels and improved for two of them, and with some embrittlement phenomenon for two of them. The low-carbon, high-alloy-type steel E with 12Cr-6Ni-2.5Mo, and the lean alloy-type steel A with 13Cr-4.7Ni-1.7Mo appeared to have the best overall notch toughness after short pulse tempering. The compositions of these two steels are very close to those now commercially available.

Introduction

Background

At present, the 13% Cr martensitic stainless steels have been used in many subsea production systems and satellite fields, e.g., *Haltenbanken* and *Gullfaks* fields at the Norwegian continental shelf (Refs. 1–3). These are connected to production platforms through interfield flowlines with outer diameters between 8 and 12 in. (~203–305 mm), only a few lines are in the range of 16 to 24 in. (~406–610 mm) diameter . The martensitic 13% Cr class of stainless steels has been regarded as a possible material candidate due to its very high potential for cost savings compared with the more familiar duplex grades. The present investigation was, therefore, carried out as part of a larger qualification of the 13% Cr steel class. The investigation is based on a study of the relationship between the weld thermal program (cooling rate, peak temperature, subsequent tempering) and heat-affected zone (HAZ) mechanical properties (Charpy V-notch toughness, tensile strength and ductility, hardness), using the weld simulation technique. A wide range of martensitic steels is included, ranging from the "older" class with relatively high carbon content (~0.1% C) and no alloying with the exception of Cr, to the new so-called "supermartensitic" grades with improved weldability, based upon low carbon (< 0.02%) content and balanced additions of alloying elements such as Ni and Mo to improve the corrosion properties and to maintain the microstructural balance.

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Transformation Behavior of Martensitic Stainless Steels

The peak temperature corresponds to a certain point within the HAZ, which can be divided into six separate regions according to the Fe-Cr-Ni phase diagram shown in Fig. 1 (Refs. 4–6). The temperature range of stability for the different phases is also outlined in Table 1, and can be defined as follows under heating of the base metal up to the melting point:

1) Subcritical/tempered region, where no transformation takes place (below Ac_1), but with possible carbide precipitation.

2) Low-temperature, two-phase region with austenite and ferrite ($\gamma + \alpha$), between 460°–600° and 630°–700°C.

3) Single-phase austenite region, with the temperature range from about 630°–720°C to about 1200°–1260°C, though strongly dependent on the steel composition.

4) High-temperature, two-phase region with a mixture of delta ferrite and austenite ($\delta + \gamma$), within the temperature range between 1200°–1260° and 1310°–1390°C, depending on the actual chemical composition.

5) Single-phase δ ferrite region, within the temperature range between 1310°–1390° and 1440°C.

6) Partially melted region, within the temperature range between 1440° and 1470°C.

It is important to point out that the existence regime of the different regions is strongly dependent on the steel's chemical composition. In addition, the heating rate is important, and substantial superheating may be required compared with the Fe-Cr-Ni alloy equilibrium diagram in Fig. 1.

Supermartensitic steels are normally divided into three types, i.e., lean (11Cr-2Ni), medium (12Cr-4.5Ni-1.5Mo) and high alloyed grades (12Cr-6Ni-2.5Mo) (Refs. 7, 8). In the present investigation, all grades are included, in addition to two Cr (11% and 13% Cr) steels with low Ni (0.8% and 0.5% Ni), but with no Mo. One of these contains high carbon (0.11%), as the representative of the "old, traditional" martensitic stainless steels.

KEYWORDS

Martensitic Stainless Steels
13% Cr Steels
HAZ Properties
Weld Simulations
Tempering
Supermartensitic Steels
Pipeline Steels
Weld Toughness

Materials and Experimental Procedure

Materials

Five martensitic stainless steels have been included in the present study. Their chemical composition and mechanical properties are outlined in Tables 2 and 3, respectively. Table 2 reveals that there are relatively large differences between the steels when it comes to the contents of C, Mn, Cu, Ni, Cr, Mo, and N. This may, in turn, influence the transformation behavior and, hence, the mechanical properties. The position of the different steels in the Schaeffler diagram is indicated in Fig. 2, and implies that most of the steels (B, C, and E) fall within the martensite-rich region of the two-phase martensite-ferrite regime. Steel A contains a mixture of martensite and ferrite stringers, possibly with retained austenite, which is not readily visible in the light microscope. Steel D falls within the martensite region. The different base metal microstructures are exemplified by the micrographs of steels A and D in Fig. 3.

Table 3 shows that the strength of the selected steels is relatively high, particularly for steel A, with yield and tensile strengths of 619–762 and 915–950 MPa, respectively. Modern supermartensitic steels are now made to satisfy requirements set to the X80 pipeline grade (Ref. 8).

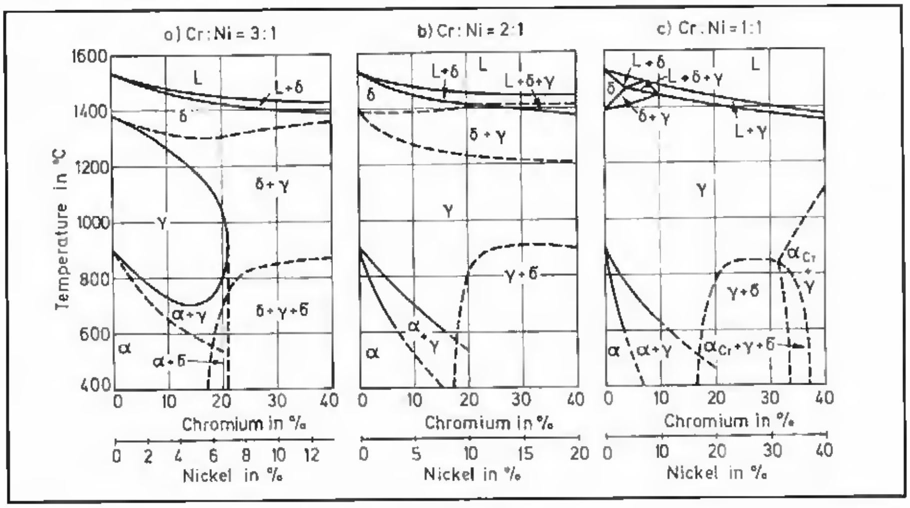


Fig. 1 — The Fe-Ni binary phase diagram, with 12% Cr [4].

Weld Simulation

The weld simulation experiments were carried out by two different techniques:

1) Resistance heating of specimens with 10.5 × 10.5 mm^2 cross section and 100 mm length for subsequent Charpy V-notch (CVN) testing

2) Induction heating of specimens with 10–12 mm diameter and 100 mm length for subsequent tensile testing.

The investigation included weld simulation with different peak temperatures, T_p, and cooling times between 800° and 500°C, $\Delta t_{8/5}$. The heating rate was 200°C/s. In addition, the potential effects of tempering pulses were examined using a first weld cycle with T_p of 1350°C followed by a second tempering cycle with various peak temperatures and holding times. In this case, the heating rate in the first and second cycle was 200° and 50°C/s, respectively. The cooling rate during the tempering pulse was 20°C/s. In spite of the lower heating rate in the case of tempering pulses, some overheating (between 15° and 20°C) occurred before the temperature was stabilized (after 3–5 s) at the preprogrammed level. The associated phase transformation temperatures were recorded by dilatation, including the Ac_1 and Ac_3 temperatures during heating and the M_s and M_f temperatures during cooling.

Assessment of the HAZ strength and ductility was done, as indicated above, on the basis of tensile testing of weld simulated specimens. Bars of 8 mm diameter and 70 mm length were heated by induction to various peak temperatures, followed by controlled cooling in helium. Originally, a peak temperature of 1350°C was desired, but this was reduced to 1250°C, since partial melting occurred. In spite of the reduced peak temperature, the austenite grain size is large due to the very slow heating rate obtained through the high-temperature range (> the Curie temperature, i.e., > about 670°C). By contrast, the heating rate is rapid until the Curie temperature is reached. The cooling time, $\Delta t_{8/5}$, was adjusted to 12 s. The temperature-time cycles were recorded by chromel/alumel thermocouples spot welded at the midlength of the bar surface. Due to the small bar dimensions involved, specimens exhibited a uniform microstructure and hardness over the entire specimen length and cross section after weld simulation.

Table 1 — Phase Stability in the HAZ of Fe–Cr–Ni Alloys

Phase	Temperature Range Cr:Ni = 3:1	Temperature Range Cr:Ni = 2:1	HAZ Region
α[α′]	RT–~600°C	RT–~460°C	Subcritical region
α + γ	~600°–~710°C	~460°–~630°C	Low-temperature, two-phase region
γ	~710°–~1200°C	~630°–~1260°C	Single-phase austenite region
γ + δ	~1200°–~1310°C	~1260°–~1390°C	High-temperature, two-phase region
δ	~1310°–~1440°C	~1390°–~1440°C	Single-phase ferrite region
δ + liq.	~1440°–~1470°C	~1440°–~1470°C	Partially melted region

Table 2 — Steel Chemical Composition (wt-%)

Steel	C	Si	Mn	P	S	Cu	Ni	Cr	Mo	Al	N
A	0.020	0.28	0.18	0.015	0.0006	0.09	4.70	13.62	1.66	0.016	0.077
B	0.020	0.22	1.51	0.013	0.002	0.49	0.80	10.94	—	0.023	0.0092
C	0.11	0.15	0.54	0.006	0.001	0.15	0.49	13.10	—	0.003(a)	0.066
D	0.028	0.30	0.49	0.012	0.001	1.43	3.76	11.16	1.17	0.020	0.0082
E	0.010	0.30	0.44	0.016	0.001	—	6.11	11.99	2.47	—	—

(a) Reported as soluble Al.

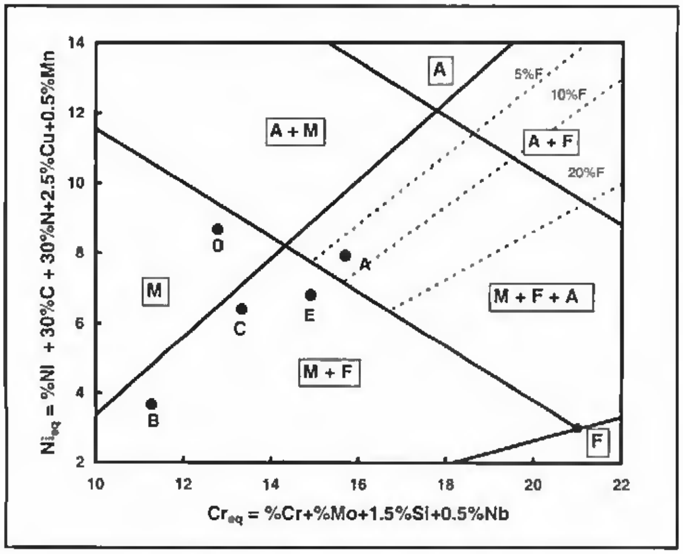
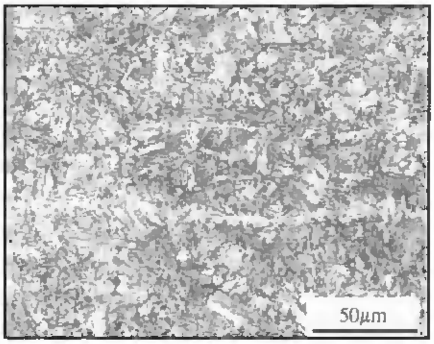


Fig. 2 — Schaeffler diagram, location of the investigated steels.



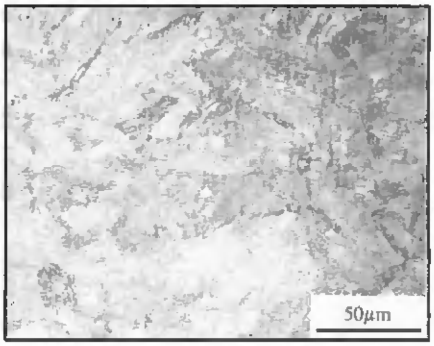


Fig. 3 — Base metal microstructures, steels A (above) and D (below).

Table 3 — Base Metal Mechanical Properties

Steel	Yield Strength $R_{p0.2}$ (MPa)	Tensile Strength R_m (MPa)	Elongation at Fracture (%)	Hardness (kg/mm²)
A	619–762	915–939	33	296
B	545	641	–	207
C	582–659	711–786	22.3	259
D	614	821	–	265
E	563–613	892–902	28	290

Table 4 — Microstructures(a) of Weld Simulated Specimens

Steel	Weld Thermal Cycle T_p = 1350°C	T_p = 1000°C	T_p = 800°C
A	M + F	Fine new M + F stringers + C ($M_{23}C_6$)	Fine-tempered M + F stringers + C ($M_{23}C_6$) [similar to the base metal microstructure]
B	Coarse M + F	Fine new M + F retained grain boundary C	Fine-retained tempered M + new M [finer than the base metal microstructure]
C	M + F	Fine new M + F + retained C ($M_{23}C_6$)	Coarse-tempered M [similar to the base metal]
D	M + F (+ TiN)	Fine new M + F + tempered M + retained C ($M_{23}C_6$)	Coarse-tempered M [similar to the base metal]
E	M + F (+ TiN)	Fine new M + tempered M + retained C ($M_{23}C_6$) + F stringers	Tempered M + F stringers [similar to the base metal], grain boundary C dissolved partially

(a) M = martensite, F = ferrite, C = carbides

Testing and Characterization

All weld thermal simulated specimens were machined down to either the standard 10 × 10 × 55-mm Charpy V-notch dimensions for resistance-heated specimens or selected dimensions of tensile test specimens for induction-heated specimens prior to testing, i.e., L_0 = 35 mm, d = 5 mm. The CVN test temperature was 0°C. Tensile testing was carried out with a constant crosshead speed of 2 mm/min.

Standard metallography techniques were used in the preparation of specimens for microstructure characterization, using Vilella's reagent for etching. Hardness measurements were carried out with a 5-kg load (HV_5).

Results and Discussion

Transformation Behavior

In general, it is seen from Fig. 4 that the transformation temperature decreases with an increase in the peak temperature. This observation is not surprising, since an increase in the peak temperature normally causes austenite grain growth and, hence, a certain hardenability increase (reduction of M_s). The fact that M_s is reduced with increasing peak temperature is partly a kinetic effect due to smaller grain boundary area available for nucleation, and partly a compositional effect since precipitated chromium carbides, $M_{23}C_6$, will dissolve at the highest temperatures and provide more carbon and alloying elements in solution. In the case of steels A and E, substantial scatter in the transformation temperatures was recorded. This was probably caused by the large variations in base metal microstructure, i.e., austenite grain size varies significantly. Apparently, the cooling time, $\Delta t_{8/5}$, appears to have only a small effect on the transformation behavior.

It is also seen in Fig. 4 that the transformation behavior of the steels under examination was quite different. The recorded M_s temperatures of steel A are below about 210°C for all thermal programs. The transformation temperatures of steel E were between 200° and 300°C, which is higher than that of steel A. The M_s level is higher for steels C and D, which

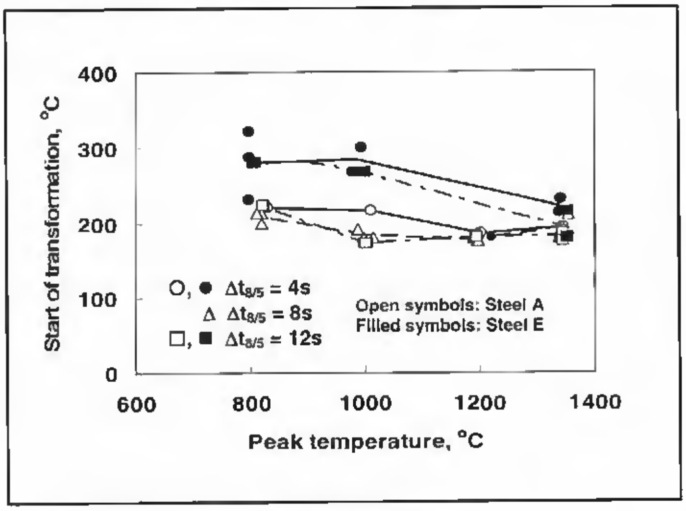


Fig. 4 — Transformation temperatures, steels A and E.

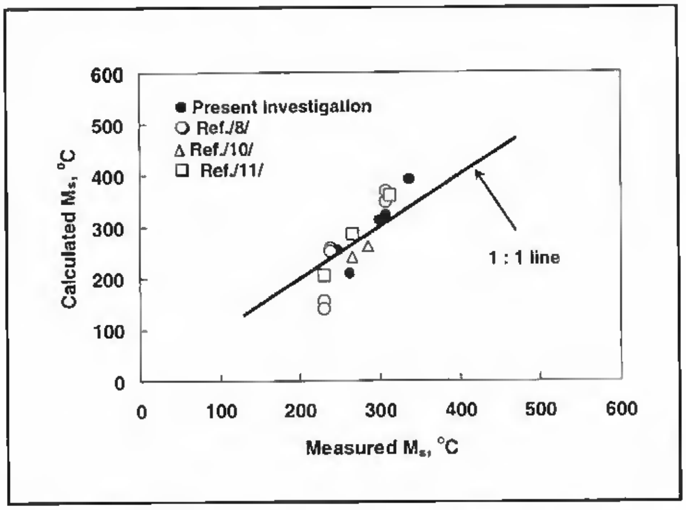


Fig. 5 — Comparison between calculated and measured temperature for start of martensite transformation, M_s. Mean values are used for steels A, B, C, D and E.

show M_s temperatures between about 360° and 300°C. Steel B has the highest M_s temperatures (between 390° and 420°C, depending on the peak temperature), probably due to the lower alloying content of this steel. Thus, the transformation behavior of the steels reflects their respective alloying level. The high alloyed grades will have low M_s levels, say below 220°C, while medium grades will transform to martensite between 250 and 300°C. Finally, the lean grade will have M_s values above 300°C.

The transformation temperature M_s is very important, since it may strongly influence the evolution of residual stresses and strains, as well as the hydrogen transport and distribution during and after welding. Moreover, it strongly influences the selection of interpass temperature; the interpass temperature should be below M_s to ensure that all weld beads transform to martensite before the next bead is deposited, allowing tempering effects in multipass welding. It is, therefore, of interest to be able to predict the M_s temperature. In the literature, there are several empirical equations published to calculate the M_s value. According to Ref. 9, the best fit was obtained with the Andrews equation (quoted in Ref. 10). This equation is as follows:

$$M_s\,(^\circ C) = 539 - 423\,(\%C) - 30.4\,(\%Mn) - 12.1\,(\%Cr) - 17.7\,(\%Ni) - 7.5\,(\%Mo) \quad (1)$$

The correlation between measured and calculated values, using Equation 1 and the data in Table 2, is shown by the plot in Fig. 5. It is shown that the correlation is quite good, although the data imply that the M_s temperature is underestimated at low temperatures and overestimated at higher transformation temperatures. This is not necessarily due to an insufficient accuracy in the calculation, but also due to a wide scatter in measurements of the M_s.

When considering the end of transformation, the M_f point was found to be on average about 130°C below M_s:

$$M_f\,(^\circ C) = M_s - 130 \quad (2)$$

This is not far from the 120°C, which is reported for low-carbon microalloyed and low-alloy steel (Ref. 12). However, the difference between M_s and M_f seems to vary between 120° and 150°C when comparison is made with published CCT diagrams with a much lower austenitization temperature than used here (Ref. 8).

Fig. 6 — Grain-coarsened HAZ (T_p = 1350°C) microstructure, steel B.

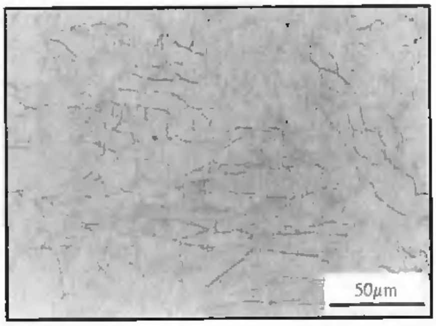


Fig. 7 — Grain-coarsened HAZ (T_p = 1350°C) microstructure, steel A.

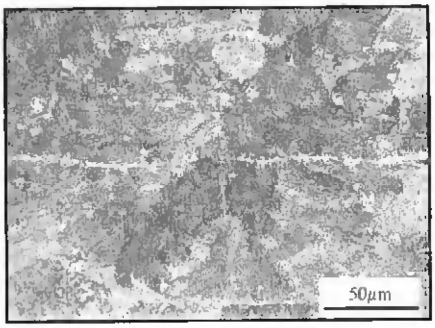


Fig. 8 — Grain-refined HAZ (T_p = 1000°C) microstructure of steel E.

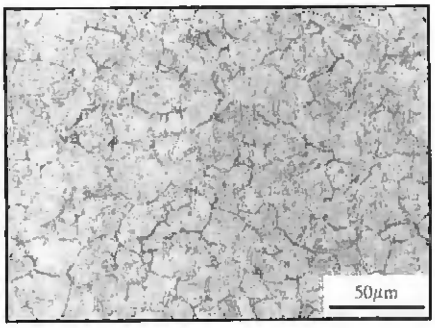


Fig. 9 — Microstructure of steel C after tempering at 800°C for 1 h (T_p = 1350°C/$\Delta t_{8/5}$ = 5 s).

Microstructure Characterization

Weld Simulation with Peak Temperature of 1350° and 1200°C

Inspections of the grain-coarsened HAZ (1350°C) microstructures shown in

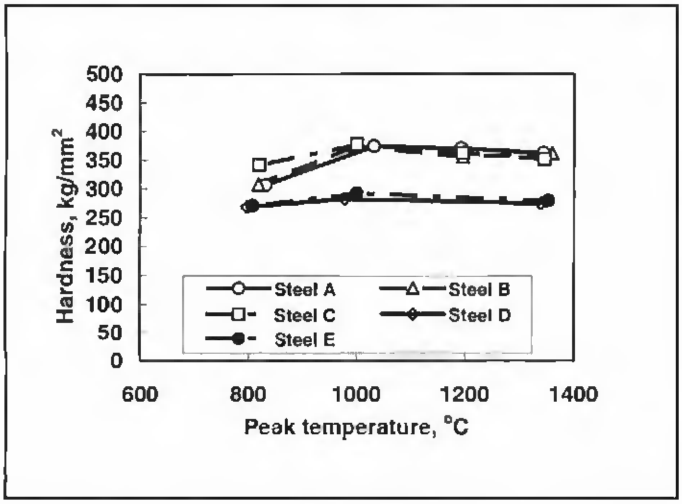


Fig. 10 — Effect of peak temperature on hardness.

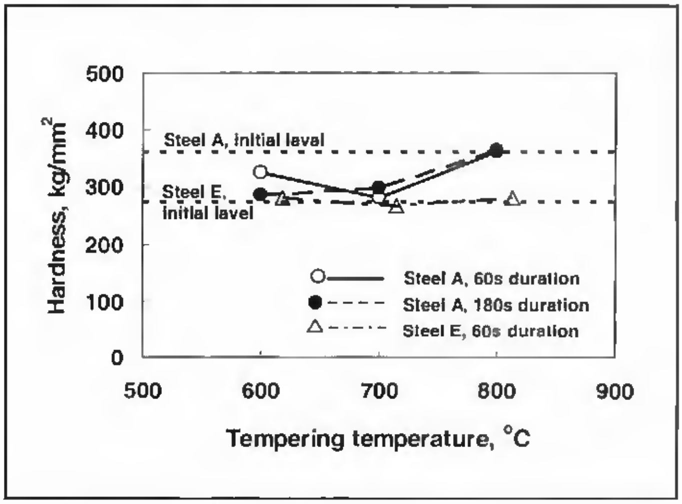


Fig. 11 — Effect of tempering temperature on hardness, steels A and E.

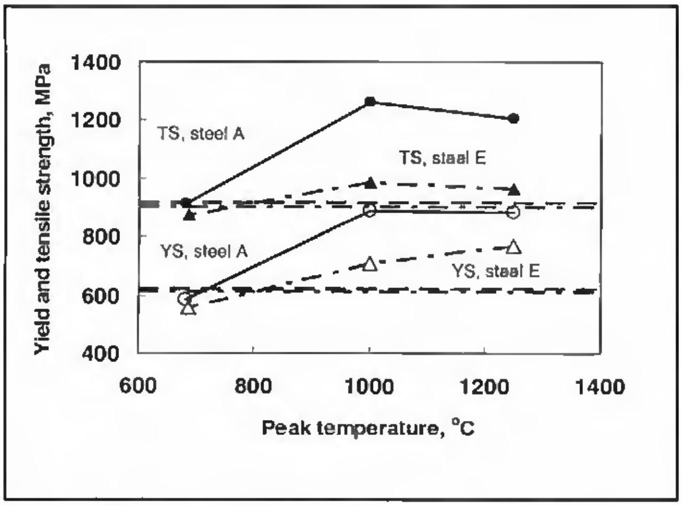


Fig. 12 — Effect of peak temperature on strength, steels A and E.

Figs. 6 and 7 reveal that they can be divided into two main categories: 1) coarse martensite within large prior austenite grains for the low-nickel-containing steels B, C, and D (Fig. 6); and 2) finer network of martensite with ferrite aligned at prior austenite grain boundaries in steels A and E — Fig. 7. These results may imply that the peak temperature of 1350°C for the two latter steels falls within the $\alpha + \gamma$ region (α = ferrite, γ = austenite), where γ transforms to martensite on cooling. At the peak temperature, the presence of the two phases tends to inhibit grain growth. There is small evidence of ferrite in steel B, also; some ferrite areas were observed in the base metal in the form of retained initial ferrite stringers. Apparently, the cooling time $\Delta t_{8/5}$ did not affect the microstructure systematically; the small differences observed are probably caused by local material inhomogeneities and insufficient regulation during weld simulation (occasional local melting). Still, the amount of ferrite in steel A seems to decrease with slower cooling rates. The microscopic observations are also summarized in Table 4.

As stated above, a peak temperature of 1350°C may fall within the $\alpha + \gamma$ two-phase region, depending on the steel chemical composition. The austenite formed at the peak temperature will transform to martensite on cooling, but usually with a much coarser lath structure than that of the base metal due to the large austenite grain size. By contrast, the ferrite will be stable down to ambient temperature. This observation is in agreement with recently published results (Ref. 13). Ferrite was not observed in steels B and C, which is in agreement with the low chromium equivalent values. However, it should be noted that steel D, which falls within the single-phase martensite region, contains substantial amount of ferrite after weld simulation, and its position in the Schaeffler diagram in Fig. 2 should be moved downward toward the border between M+F and M+F+A. The Schaeffler diagram should, therefore, be used with care for these steels, at least as far as the HAZ transformation behavior is concerned.

Few specimens were subjected to a peak temperature of 1200°C. This will be very close to full austenitization for all steels. In the case of steel A, the austenite grain size increased considerably when the cooling time $\Delta t_{8/5}$ increased from 4 to 12 s. On cooling, both martensite and ferrite formed.

Weld Simulation with Peak Temperature of 1000°C

With a peak temperature of 1000°C one may expect that the specimens were heated to the single-phase γ regime. The austenite formed will transform to martensite on cooling, but usually with a finer lath structure than that of the base metal. The presence of any undissolved chromium carbides may locally reduce the chromium equivalent value, and thus extend the austenite area. This may explain why the amount of ferrite was apparently reduced compared with the 1350°C cycle. However, nontransformed ferrite stringers were found, as shown by Fig. 8 (steel E).

Weld Simulation with Peak Temperature of 800° and 650°C

In general, the microstructures formed at 800°C are similar to those of the respective base metals, but with certain refinement. Although the Ac_1 temperature is not determined for steels A, D, and E, indications are that a small refinement of the initial base metal microstructure has occurred, which means that a small fraction has been austenitized during heating with subsequent martensite formation on cooling. A further evidence of this point would require scanning electron microscopy to obtain the necessary magnification to identify the small martensite islands. The refinement of the base metal microstructure is relatively clear in the case of steel B, and is in agreement with the increased hardness level (increased

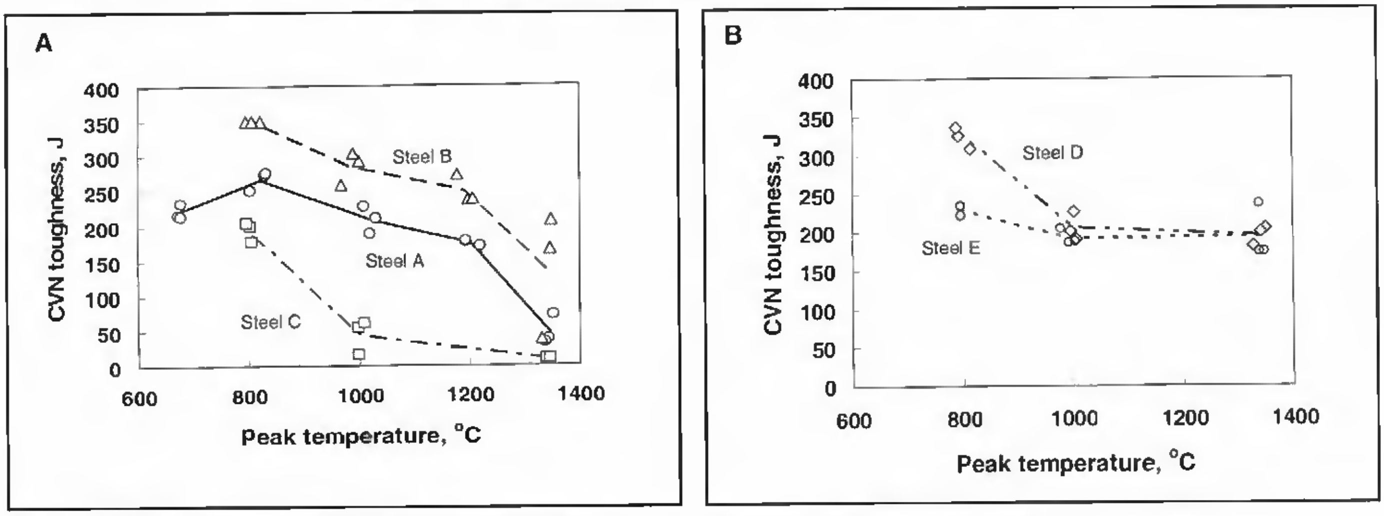


Fig. 13 — Effect of peak temperature on CVN toughness at 0°C; $\Delta t_{8/5}$ = 5 s. A — Steel A, B, and C; B — steels D and E.

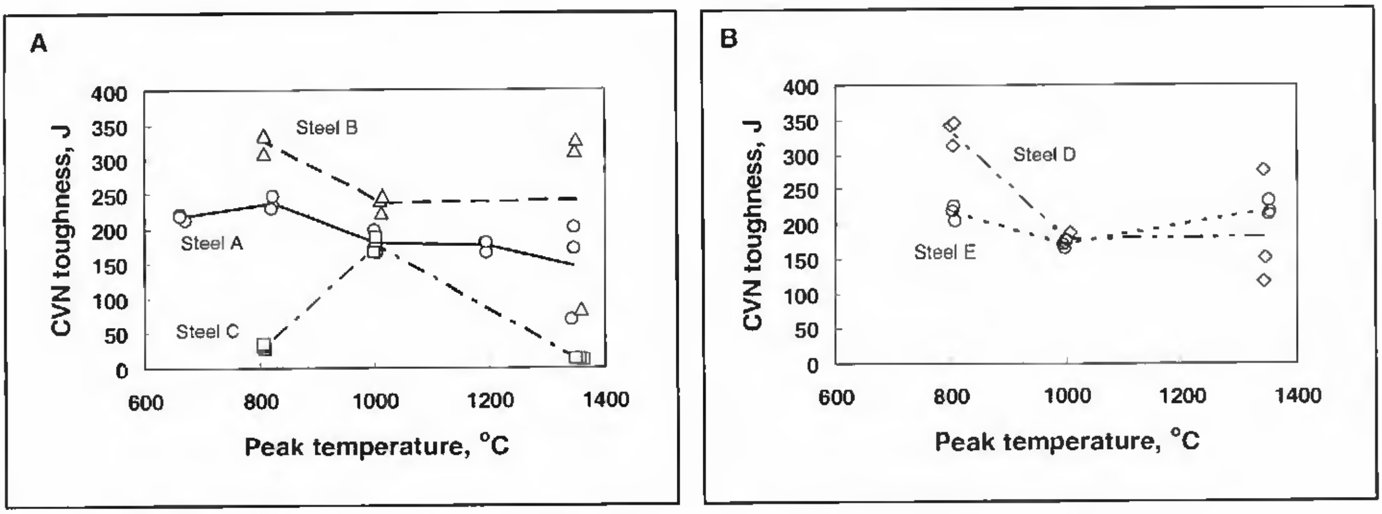


Fig. 14 — Effect of peak temperature on CVN toughness at 0°C; $\Delta t_{8/5}$ = 12 s. A — Steels A, B, and C; B — steels D and E

from 207 to 252–262 HV). A similar hardness increase has been found for steel A (increase from 289 to 306–341 HV). By contrast, the base metal hardness is reduced after simulation for the other steels. It is reasonable to suggest that this observation is due to a stronger softening effect by tempering than a hardness increase from new martensite formation.

In the case of steel A, when using peak temperature of 650°C, the microstructure appeared to be very similar to that of the base metal. No visible effect of the cooling rate was found.

Weld Simulation with Subsequent Tempering Pulses at 600°, 700°, and 800°C

In contrast to the previous weld simulation experiments, with the base plate microstructure as a basis for discussion, the initial microstructure for the tempering pulses is the one formed under single cycle with peak temperature *Tp* of 1350°C (left column in Table 4). For the high-Ni-containing steels A, D, and E, the microstructure after tempering at 600°C consisted of tempered martensite with some ferrite. Steel C showed tempered martensite with extensive bulk and grain boundary carbide precipitation due to its high carbon content. At 700°C, however, the carbides were mainly found at grain boundaries for all steels. Steel B appeared to be relatively resistant to tempering, and its response to chemical etching is much more sluggish than that of the other steels. For a peak temperature of 700°C, it is possible to see that some austenitization has taken place with some new formation of martensite with nontransformed residual austenite. At 800°C, an even larger fraction has been retransformed. The reformation of martensite was confirmed by the hardness increase for steels A, B, C, and E when increasing the tempering temperature from 700° to 800°C. This observation can be seen in the micrograph in Fig. 9, revealing also grain boundary phases (martensite/retained austenite and $M_{23}C_6$) in steel C.

Hardness

The hardness (HV_5, 5-kg load) values have been plotted against the peak temperature in Fig. 10. It can be seen from the figure that the hardness level is relatively similar for all peak temperatures, which also would be expected if the microstructure was fully martensitic with a low M_s temperature, i.e., with negligible autotempering during cooling. An exception is found for a peak temperature of 800°C for steels A, B, and, partly, C, where the hardness level has been significantly reduced.

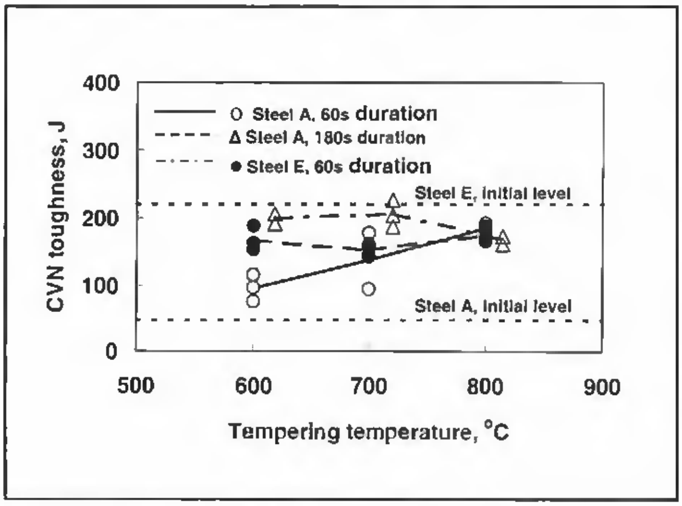


Fig. 15 — Effect of tempering temperature on CVN toughness at 0°C, steels A and E.

It is reasonable to suggest that this observation is linked to a stronger hardness reduction effect of tempering than hardness increase as a consequence of reaustenitization with subsequent formation of new martensite on cooling.

The hardness level was in general reduced by the following tempering pulses, particularly for steel C where the initial level after the 1350°C cycle (shown as the dashed line in Fig. 11 for all steels) was very high. An exception is found for the tempering pulse carried out at 800°C. In this case, the initial hardness level is restored for all steels except for steel C. Data for steel A may imply that the tempering time has only marginal influence on hardness, but the effect is larger at lower tempering temperatures.

Strength and Ductility

The data from tensile testing of weld simulated (induction heated) specimens are shown in Fig. 12. Here, the base metal yield and tensile strength levels are also included for comparison. It is seen from the figure that both yield and tensile strength levels have been substantially increased for the highest peak temperatures of 1250° and 1000°C, which is also expected since the new martensite is not subjected to tempering during cooling from the peak temperature. At the lowest peak temperature (680°C), only tempering is expected to occur, and the slight reduction in yield strength in this case is therefore not surprising. These trends were observed for all steels (exemplified by steels A and E in Fig. 12), with exception of steel C, where the strength level was similar to the initial base metal strength, independent of the peak temperature, i.e., yield and tensile strength level of 620–660 MPa and 780–800 MPa, respectively. The highest HAZ strength was found for steel A, represented by the values of 887 and 1260 MPa for yield and tensile strength, respectively.

For all steels, the initial base metal elongation at fracture appeared to be slightly reduced with peak temperatures of 1000° and 1250°C, while they were unchanged at the lowest temperature of 650°C. In the case of the reduction in area, a very small reduction was found for steels A, B, and D, while a negligible increase was seen for the two other steels C and E.

CVN Toughness

In general, the CVN toughness at 0°C of weld simulated (resistance heated) specimens were relatively high, as shown by Figs. 13 and 14 for a cooling time $\Delta t_{8/5}$ of 5 and 12 s, respectively. An exception is low values observed for the 1350°C cycle for steel C, and occasionally also for steels A and B. The data in Fig. 13 showed typically a CVN toughness deterioration with increasing peak temperatures, which is possibly related to the finer microstructure, as discussed previously.

In the case of subsequent tempering heat treatment, the steels responded quite differently. Here, steel A was the only one where tempering gave rise to a notch toughness enhancement for all temperatures employed. The results for steel A are shown in Fig. 15. Included in the figure are data for steel E, which showed an opposite trend, i.e., tempering deteriorated impact toughness at all temperatures. However, the toughness of this steel is still higher than that of steel A, with an exception of tempering at 800°C.

Steels B, C, and D were susceptible to embrittlement. Steel B appeared with low toughness at 700°C, which means an average impact strength of 28 J. Steel C had very low values for both 600°C (< 10 J) and 800°C (25 J average). Finally, steel D had low toughness at 600°C (14 J average), with large scatter at 700°C (three parallels of 17, 30, and 218 J).

It is very difficult to explain this different behavior of the examined steels. Various mechanisms are probably involved, possibly ranging from temper embrittlement by impurity element segregation (e.g., phosphorus), new formation of nontempered martensite, or islands of stable austenite. A clarification of the mechanisms involved will be important in further work on these steels, since it may influence their behavior during fabrication and subsequent service.

Implications of the Present Work

The present investigation has been a part of a large qualification program of 13% Cr martensitic stainless steels for applications in offshore flowline and risers, where extensive corrosion testing and welding experiments have been included (e.g., Refs. 14–20). The results obtained show that the "old, traditional" 13% Cr steels (steel C) contain too high carbon content, which gives a very high hardness level of about 500 kg/mm^2. This is far beyond an acceptable level, even after tempering. With a hard martensite present, the steel will be very susceptible to hydrogen cracking, and expensive operations like preheating and postheating may be necessary, as well as certain precautions regarding welding consumables and shielding gas moisture must be taken. In addition to the very high hardness, steel C was the only one with low CVN impact values (< 50 J) in the as-weld-simulated condition. After tempering, only the high-alloy steel E (12Cr-6Ni-2.5Mo) and the lean alloy steel A (13Cr-4.7Ni-1.7Mo), both with low carbon (< 0.02% C) content, revealed good toughness (between 100 and 200 J). The compositions of these steels are very close to those now commercially available.

Note that the short pulse tempering is used since long-time postweld heat treatment is not possible in the present application.

Conclusions

Based on the present investigation the following main conclusions can be drawn:

- The heat-affected zone hardness level is strongly dependent on the steel's chemical composition and the weld thermal program. A relatively low hardness (270–290 kg/mm^2) can be obtained for the low-carbon (0.01–0.02 wt-% C) steels B and E even in the as-weld-simulated condition. Steels A, C, and D showed values beyond 300 kg/mm^2, possibly due to high carbon (steels C and D) and high chromium content (steel A).
- The hardness levels are reduced by subsequent tempering pulses.
- In general, the Charpy V-notch toughness was high (> 200 J), with exception of the very high carbon-containing steel C and some low values for steels

A and B for a peak temperature of 1350°C. The CVN level varies with the applied peak temperature, with less influence of the cooling time $\Delta t_{8/5}$ (comparison between Figs. 13 and 14).

- The effect of subsequent tempering pulses is dependent on the initial CVN toughness after the first weld cycle of $T_p \sim 1350$°C.

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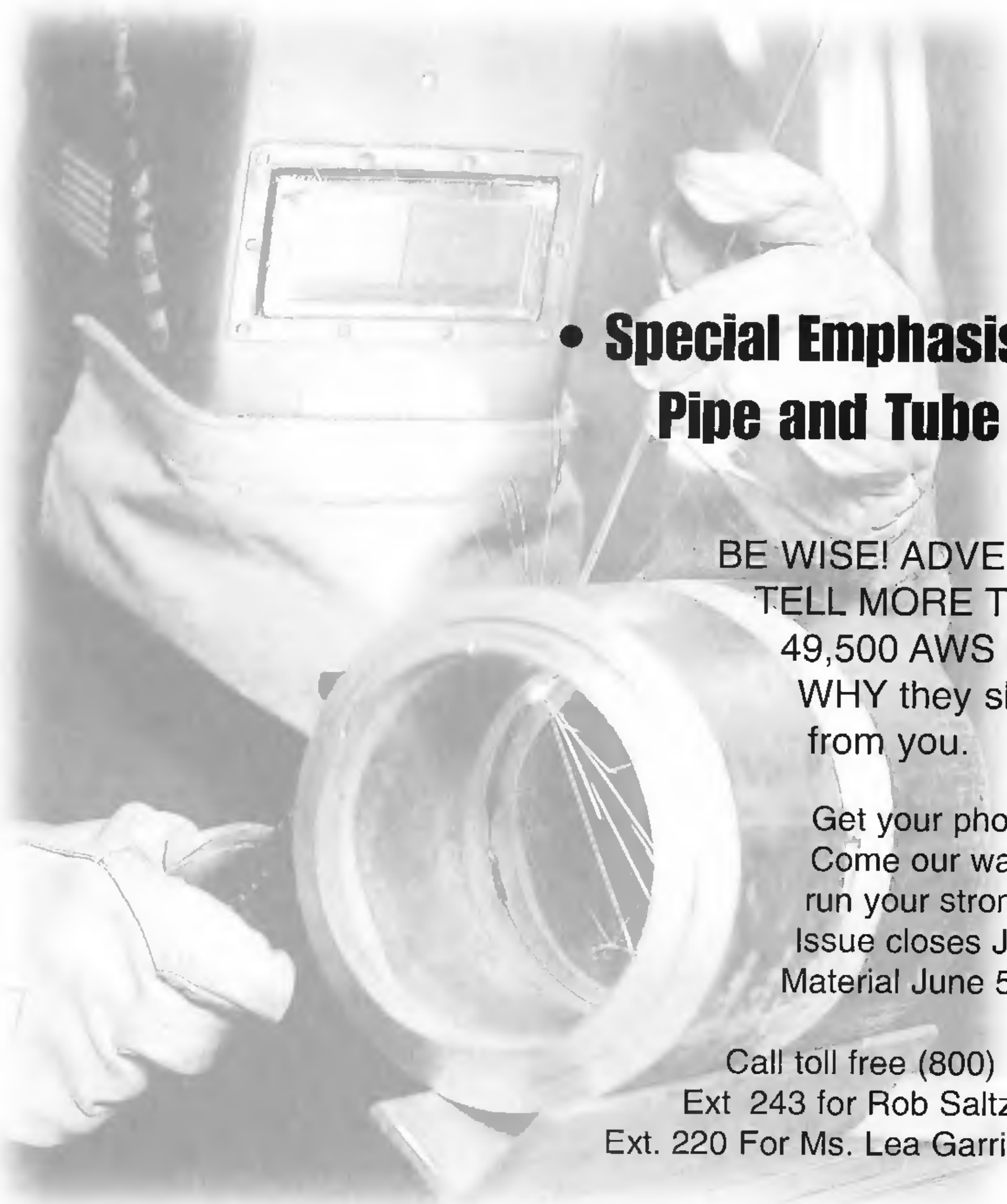


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