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Welding INNOVATION

Advancing Arc Welding Design and Practice Worldwide

JOINING TOGETHER:
Public/Private Partnership Forges a New Technology

Rarely does research lead directly to implementation without a significant delay in time. In contrast, I would like to focus on a highly successful government-industry initiative that has resulted in the rapid transfer of an important new technology into actual applications. The research involved the development of high-performance steel, a material that already has been incorporated into 63 bridges that are either in service, fabrication, or planning.

What is the definition of high-performance steel? It is steel that combines high toughness and excellent atmospheric corrosion resistance with good weldability. The first material that was developed was HPS70W, a 70 ksi yield strength steel. Current and future efforts will be devoted to developing HPS50W and 100W.

The Federal Highway Administration first learned about the potential for HPS from a Department of Defense initiative to develop "dual-use" commercial steels for military applications. This prompted an interagency agreement between FHWA and the Carderock Division of the Naval Surface Warfare Center (CDNSWC) to develop a grade of steel for use in bridges and ships. The CDNSWC then instituted a cooperative research project with the American Iron and Steel Institute (AISI). AISI subsequently brought in industry support from the American Institute of Steel Construction (AISC), steel producers, welding suppliers, bridge designers and various consultants to scope out a comprehensive plan to capitalize on high-performance steel technology previously developed for military applications.

Ultimately, one of the biggest technical challenges was the weldability of the new steel. While the heat-affected zone (HAZ) was robust and immune from hydrogen-related cracking, new weld metals that were equally robust had to be developed. Two suppliers cooperated to develop new filler metal combinations, and establish fabrication guidelines. This effort took place under the aegis of a Welding Advisory Group (WAG) which included members of the AWS D1 Structural Welding Committee.

The development of the HPS70W steel itself was overseen by a Steel Advisory Group (SAG). New designs to optimize the use of this steel were required, and a

Photo courtesy of TN DOT

Design Advisory Group (DAG) was also formed. In order to make certain that issues regarding atmospheric weathering resistance of this HPS were properly addressed, a Corrosion Advisory Group (CAG) was also formed. Each group assembled industry experts to make certain that the research generated met the criteria necessary for commercial success.

This effort was begun a short eight years ago, but at the time of this writing, fourteen HPS bridges have already been constructed. A further 49 HPS bridges are currently in the design and fabrication stages.

Key to the success of this project has been the high degree of public/private cooperation, which really made it possible to "cover all the bases" from a technical point of view. The early involvement of government agencies such as Calderock and FHWA, working intensively with industry associations such as AISI and AISC, provided a framework for industry support from steel producers, welding consumable manufacturers, and steel fabricators. Academic colleagues helped to round out a diverse group of experts who were able to simultaneously address key issues of steel production, welding, design, and fabrication.

This particular public/private partnership has been a rousing success. I am pleased to have been involved in the effort, and eagerly anticipate both the development of new grades of high performance steel, and the discovery of exciting new commercial applications for this technology.

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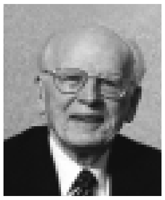
Welding Innovation



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Arc Welding Foundation

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Cover: "Pneumatic Dreamer," a sculpture in bronze, exemplifies the art of welding, from the inside, out. See story on page 23.

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Alaskan Drill Rig Is World's Largest Rubber Tire Vehicle

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Figure 1. Axles and wheels arrive from Columbia Corp. Each bogie is capable of carrying 300–400 tons (270–360 m tons).

Introduction

Oil drilling technology on Alaska's North Slope has changed dramatically over the last twenty years. Drill rigs have developed from skid-mounted pieces of equipment to huge, integrated and highly mobile machines that can move from well to well, from drill pad to drill pad, or even from field to field, on frozen gravel or man-made ice roads.

Previously, North Slope land-based oil drilling rigs were movable two-sided platforms, which spanned over the well head to support the derrick above. These platforms had to be broken down each time the rig was moved to another well. They were trailered and towed by truck or crawler.

Recently, Columbia Corporation of Portland, Oregon, developed a large drive-wheel system that has greatly enhanced the mobility of these large pieces of machinery. The bogie systems consist of twin 11-ft (3.3 m) diameter rubber tires (see Figure 1), set up on an axle with a hydraulic drive motor and steering system. Each bogie is capable of carrying 300–400 tons (270 360 m tons). With their huge tires and wheels, the bogie systems turn the drill rigs into enormous vehicles, capable of moving without disassembly to the next well head.

Directional drilling technology has also influenced the way drill rigs are constructed. Many wells can now be drilled from a single, small gravel pad, constructed to protect the tundra. These wells are placed as close as 10 ft (3 m) on center, and fan out in all directions as far as several miles. Wells even extend under the Beaufort Sea to tap previously inaccessible fields. While directional drilling has made pods of wells possible, the tight spacing of wells has led to strict space constraints on the areas around the wells. Ideally, the derrick and drill floor would be placed above the well on a cantilevered gooseneck with nothing on the ground to interfere with the adjacent wells.

A drilling company, Pool Arctic Alaska, envisioned a new drill rig that would encompass all the new technology. The rig would be completely mobile and would be able to travel at 2.5 mph (4 km/hr) in any direction–forward, backward and side-to-side. Due to the extreme temperatures on Alaska's North Slope, it would be self-contained, carrying its own pipe, fuel, tanks, diesel-powered generators, hydraulic drive units, SCR electrical drive units, stair towers, platforms and all equipment used for operation, processing and transport. It would include a crane-mounted piggyback that would allow operators to build or take the rig apart down to the major frame components without mobilizing another crane.

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The result of this vision was Pool Arctic Alaska Rig #6, a 3,000,000 lb (1,360,800 kg) welded steel behemoth which Firestone Tire asserts to be the largest rubber tire vehicle in the world.

Design Criteria/Features

- Derrick fully cantilevered over the well (no jacking leg).
- The capability to handle a 2,000 horse-power (1,500 kW) draw-works and drills as deep as 25,000 ft (7620 m).
- Derrick capable of handling 600,000 lb (272,160 kg) of pipe set back in the mast.
- Derrick capable of handling a hook load of 850,000 lb (385,560 kg) when the draw-works is pulling up the drill stem.
- Casing house capable of storing drill pipe.
- Rig rides on six sets of bogies with a toal load capacity of 3,600,000 lb (1,632,960 kg).
- Twin welded steel box girders to support a cantilevered deck and drill floor.
- Separate 2,000,000+ lb (907,200 kg), 4-bogie mud module used for: drill mud processing, power generation, fuel and water tanks, boilers, and storage for other mechanical equipment.
- Steel and welding procedures were specifically selected for cold weather conditions.
- Rapid erection and disassembly was achieved by modular steel component design, and preassemby of all welded steel.
- Rig to have a piggyback 100-ton (90.7 m ton) crane for self-disassembly.
- All components truckable: no piece to weigh over 60,000 lb (27,216 kg) or to be longer than 60 ft (18.3 m).

Operationally, the rig would have to be capable of moving in several different configurations, depending upon the road or pad configuration and stability. On a wide drill pad, the rig would move from well to well with the derrick up and positioned over the cantilevered box beams. All six bogies would be necessary to carry the load. When longer moves on the narrow roads were required, the derrick would be slid off the cantilever to a central position on the rig and lowered to a horizontal position. This would move the center of gravity to a position in the middle of the rig, balancing the load between the front and back wheels. The outside sets of wheels on the rear would not be usable on the narrow roadways, so four sets of bogies could carry the rig in this configuration. The design had to take into account many load combinations for the drilling operation as well as transportation.

The bogie systems turn the drill rigs into enormous vehicles

Description of the Structure

Two 10 by 6 ft (3.0 by 1.8 m) box girders located 18 ft (5.5 m) above the ground form the structural backbone of the rig (see Figure 2). Box girders were selected over box trusses because they offered superior vertical and torsional stiffness, and are lighter weight, considering the geometry of the structure and anticipated drilling loads. Also, the interior of the box could serve as a heated corridor and utilidor from the front to the back of the rig. In addition, fuel and water could be stored in built-in tanks inside the box girders.

The box girders are supported by transverse bolster beams to which the wheel sets attach. The rear bolster (the fulcrum point of the cantilever) is supported by four sets of bogies. Two bogies support the front bolster. The box girders cantilever 40 ft (1.2 m) over the bolster at the rear of the rig to support the derrick and drill floor. The

Figure 2. First test drive of the completed substructure. Box beams cantilever from the rear end of the rig.

total load supported on the cantilevered girders is in excess of 2,000,000 lb (907,000 kg). The rig floor, derrick and crane are clamped to rails on top of the box girders and can be slid to various positions atop the box girders. Landing trusses and sill beams extend to the ground and distribute loads to the gravel pad when the wheels are retracted for drilling operations. Underslung between the front and rear wheel sets and below the box girders is a 55 by 58 ft (16.8 by 17.7 m) casing house. The casing house has a steel orthotropic deck capable of supporting live loads of 500 psf (2,440 MPa).

Twin welded steel box girders support a cantilevered deck and drill floor

Design

The modules were welded into assemblies as large as possible without overloading available transportation. Both Rollagon tundra vehicles and C-130 aircraft transports are limited to approximately 60,000 lb (27,000 kg), which dictated the maximum size weldment. The modules were erected and broken down many times; subassemblies were bolted or pinned to form the modules.

Connections were carefully reviewed with consideration given to: minimizing construction difficulties; providing for erection and disassembly a number of times in a remote Arctic environment; minimizing the potential for cold-weather fracture (either during fabrication or in service); and the economics of fabrication. It was foreseen that the structure might have to be erected under Arctic winter conditions, by workers wearing full Arctic gear including heavily insulated mitts, which could make installation of bolts cumbersome and slow.

Also affecting the design, detailing and choice of materials was the fact that many of the loads on the structure are dynamic. Moving loads generally are not significant because of the rig's low velocity, except in the event the 26 ft (8.0 m) wide rig went off the 30 ft (9.0 m) wide roads of the North Slope. During operation, the drill module can develop significant dynamic forces. Careful consideration was given to providing load-path redundancy, particularly for the dynamically loaded elements. The box girder sections of the substructure provide excellent stiffness and redundancy.

Due to the type of anticipated loads and the Arctic environment, it was deemed acceptable to design using the AISC Specifications and the AWS Structural Welding Code-Steel (AWS D1.1) while including detailing and material practices more typical of cold-weather bridges. Design parameters included load-path redundancy, use of notch tough materials (particularly at connections) and nondestructive testing of critical connections and members. Due to the tight fabrication schedule, care was taken to provide multiple material specifications where possible.

Fabrication

Materials were carefully chosen to exhibit good mechanical properties including notch toughness at low temperatures. Most of the steel used was A572 Grade 50 with a supplemental notch toughness specified at a minimum of of 15 ft-lb @ -40°F (20 J @-40°C) for plate and 15 ft-lb @ -20°F (20 J @ -30°C) for rolled shapes. The fabricator elected to build many of the sections from plate because of the difficulty in obtaining rolled sections that would meet the cold-temperature specification. Tubular members, typically used for structural bracing, were specified as API 5LX-52.

To minimize erection difficulties, the bolts and studs were typically 1-1/2 in (38 mm) in diameter or larger. The bolts chosen for low temperatures were ASTM A320 L7 or L43 or A193-S2 B7. All the connection materials were required to provide a minimum CVN impact value of 20 ft-lb @ -150°F (34 J @-100°C).

Shear pins 1-1/2 in (38 mm) or less in diameter were permitted to be A320 L7 or L43. Pins greater than 2-1/2 in (63 mm) in diameter were used in areas of less structural redundancy.

Weld Design

Welding was specified to conform to AWS D1.1-96. To provide required notch toughness, fairly specific welding filler materials were required. For weld throats 1-in (25 mm) thick or less, the use of E7018-1 or E8018 was permitted for SMAW, and E71T8-Ni 1% or Ni 2% was permitted for FCAW. Welds with a greater than 1-in. throat, and/or Complete Joint Penetration (CJP) groove welds, required a root pass using E6010, followed up with SMAW E8018 or FCAW E71T8-Ni 2%. Web to flange fillets were permitted to be SAW F7A2-ENi1K. All filler metals were required to provide a minimum as-welded CVN value of 20 ft-lb @ 20°F (40 J @ 10°C). These materials,

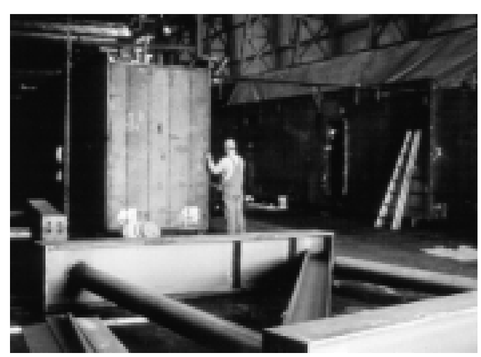

Figure 3. Fabrication of the 6 by 10 ft (1,800 mm by 3,000 mm) box beam sections.

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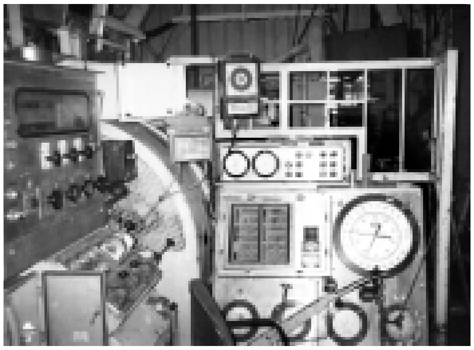

Figure 4. The drill rig control room.

as well as notch-free joint details and lower stresses, help provide a fracture-resistant joint even in cold Arctic temperatures.

Splices or joints in materials greater than 1-in (25 mm) thick were required to maintain preheat and interpass temperatures of 150°F (83°C) during welding. All Welding Procedure Specifications (WPSs) were required to be prequalified per AWS D1.1 or qualified by test.

Modules were erected and broken down many times

Members were fabricated into sub-assemblies (Figure 3). Sub-assembly bolt-holes were sub-punched during fabrication, and were temporarily supported. Bolted and pinned connections were match-marked and accurately drilled.

The structure was fully erected prior to shipment to the field. The fabricator chosen by Pool Arctic Alaska was Thompson Metal Fabricators of Portland, Oregon.

Inspection

All weldments were required to be visually inspected by a CWI inspector. Visual inspection was performed per AWS D1.1. All CJP welds were fully non-destructively tested ultrasonically or radiographically. Flange splice connections of all primary beams and girders were required to meet AWS requirements for cyclic loaded members and connections, confirmed by ultrasonic or radiographic testing.

Conclusions

In the Alaskan Arctic, prefabricated welded structural steel continues to provide designers with reliable and efficient solutions to difficult technical and logistical problems. In this case, welded steel significantly reduced the budget and schedule, while improving the constructibility of Rig 6 (Figures 4 and 5). Prefabrication of the substructural components in Portland was very cost-effective. The ability to truck the components over the North Slope haul road also provided a savings over barging. The welded steel structure provides the owners with savings in cost as well as maintenance and operational expenses, versus other types of standard construction materials.

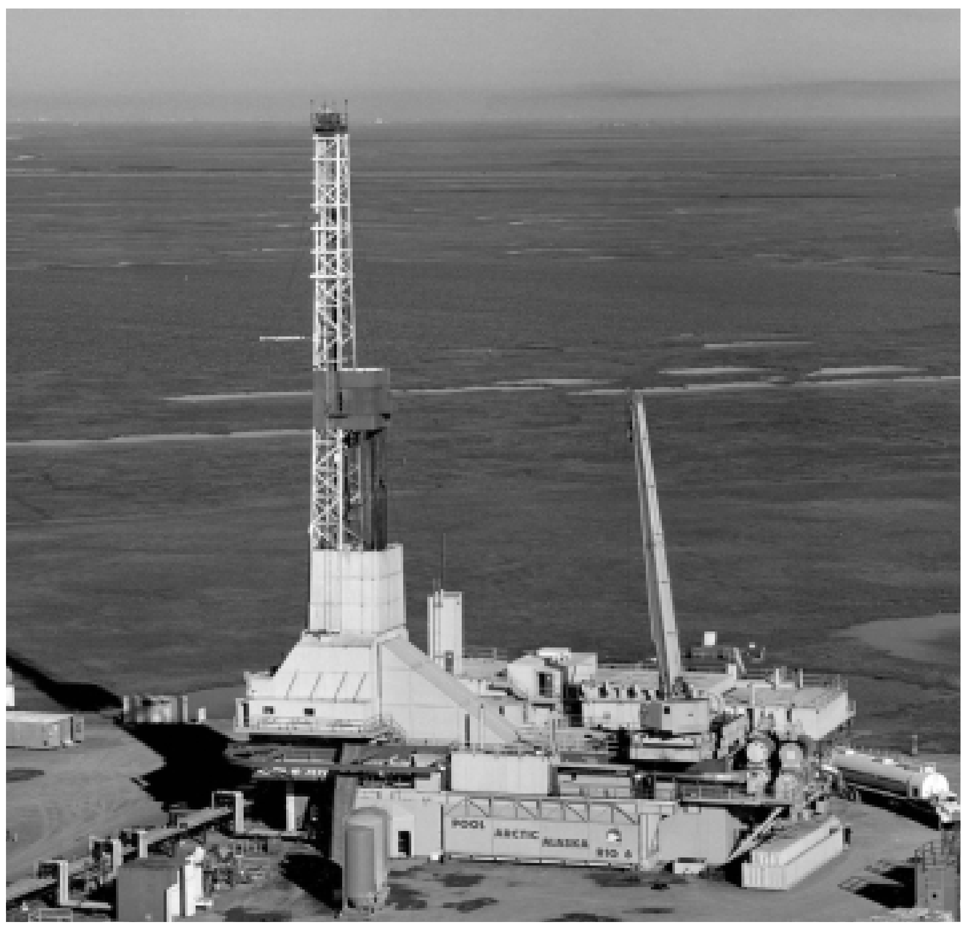

Figure 5. The completed drill rig module, with 100 ton (90.7 m ton) crane sitting piggyback. The mast extends 80 ft (24.4 m) above the drilling floor.

Lessons Learned in the Field

by Omer W. Blodgett, Sc.D., P.E.

Don't Assume Ductility is Inherent

Introduction

At this point in my life, I am in the happy position of being able to continue to do the work I love, while also having a long career to look back on. Although I was the fortunate recipient of an excellent engineering education, from this vantage point, it seems that my most significant learning experiences actually took place not in the classroom, but in the field. I would guess that the same is true for many readers of *Welding Innovation*. Therefore, the staff of the magazine and I are asking you, our readers, to share these valuable lessons with your colleagues and associates. In future issues, this column will provide a forum for that exchange.

Here's the idea: sometimes we engineers act a little like horses with blinders on. We concentrate so single-mindedly on the problem at hand, that we can't really see what's going on around us. For this column, I'm looking for stories that illustrate how critical it is for us as engineers to take our blinders off, expand our limited world view, and test our assumptions. Often, we find that the "evident" solution turns out to be a deadend, and pursuing a path that at first seemed counter-intuitive will actually solve the problem. Can you think of any examples from your own experience? Those are the "lessons" we'd like to publish.

Often, the "evident" solution turns out to be a deadend

To launch this feature, and in future issues, I'll share some of my "ah-ha!" moments. But don't leave me alone on this page—we're looking for the added value that only you, our colleagues, can provide. Your submissions may be accompanied by photographs or drawings. Simple hand-sketches are fine—our artist will re-draw them and check with you to make sure the rendition is accurate.

Here's just one example of the type of item you might submit.

Ductility May Not Be Inherent

Engineers have been taught that the yield point property of a material is the prime factor relating to ductility. This, however, offers a limited view. Figure 1 shows a stress-strain curve applied to a steel specimen which is loaded in

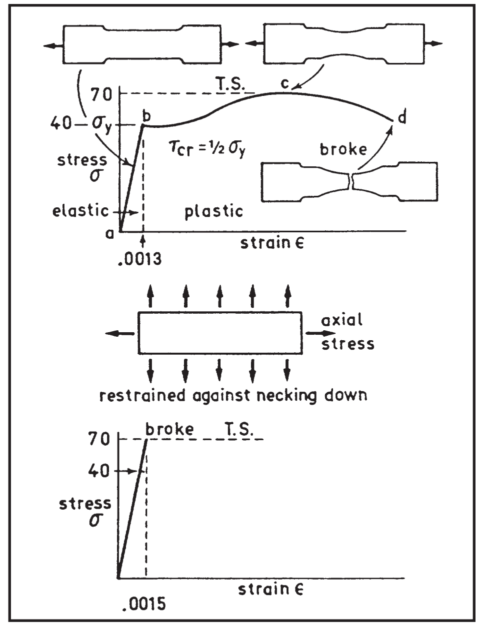

Figure 1.

tension parallel to its length. In this type of test, the specimen is free to neck-down once the yield strength is reached (b). As it plastically yields, it strain-hardens to a higher strength (b to c). This stress continues to increase to (d), but because of a reduction in the cross-section, its apparent strength drops from (c) to (d).

If the load is removed, the specimen will not return to its original dimensions. Within the limit of elastic behavior occurring from (a) to (b), however, movement is small and would not be noticed unless measured. If the specimen's load is removed, it will return to its original dimensions with a spring-like movement. For example, if a steel

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plate has a yield strength of 40 ksi, elastic deflection would be:

$$\varepsilon = \frac{\sigma}{E} = \frac{40{,}000 \text{ psi}}{30\text{x}10^6 \text{ psi}} = 0.0013 \text{ in./in.}$$

In the laboratory, it is typical to think of applying a force to a tensile specimen so that its resulting strain or movement may be observed. But this is not what really happens with a tensile lab testing machine. When the machine is activated, a motor gradually turns a screw feed which slowly strains or stretches the specimen in the longitudinal direction. The resisting force of the specimen against this straining movement is indicated on a gauge. Yield strength is reached when the applied stress exceeds the critical point, and the specimen is free to plastically neck-down. If the material is restrained, as it may be in real-world applications, the stress-strain curve indicated in Figure 1 may continue to the point of ultimate tensile strength in an almost straight path, until it ultimately fails without exhibiting much apparent ductility.

Engineers have been taught that the yield point property of a material is the prime factor relating to ductility... this offers a limited view

When an axial force (F) is applied to a test specimen, it will cause a normal stress (σ) on a plane 90 degrees to the direction of the force. It also causes a shear stress (τ), which reaches its maximum on a plane 45 degrees to this force, and is equal to one-half the value of normal or tensile stress. If this shear exceeds a critical value equal to one-half of the yield strength, a sliding action takes place, allowing the specimen to become longer in the direction of the force and more narrow across its width. If the resulting shear value is low, based on design, and the critical shear stress point cannot be reached, then an increased load will mean failure when the critical tensile point is exceeded.

Sliding action can also take place on the 45 degree plane in the other direction. If the action continues, a necked-down elongation results in a tensile-tested specimen as Figure 2 indicates. The slip plane lies at 45 degrees, forming a reduced section, initially having a square outline. If the unrestrained length (L) of this section is at least equal to or greater than the width (W), the specimen will be free to neck-down and show full ductility. If the unrestrained length (L) is less than the width (W), the shear component (τ) will decrease. A greater applied force will be necessary for the critical shear value to be exceeded, reducing its ductility. This is one reason the AISC LRFD and ASD Specifications require the weld access hole to extend a distance on each side of the weld equal to three times the web thickness for jumbo shapes. Doing so provides an unrestrained length of flange, giving the specimen increased ductility.

In the field, specimens do not usually exist independently. Steel plates are often restrained and not free to neck-down. The weld solidifies and shrinks as it cools, similar to a steel casting. When this shrinkage or strain is restricted, a high residual tensile stress results, sometimes sufficient to cause some part of the joint to pull apart and crack.

Instead of focusing on stresses which might cause such a crack in the welded joint, the engineer would be better advised to consider strains and how they can be reduced to avoid cracking. Minimizing distortion due to welding and residual stress factors will help reduce these strains when a restrained member is welded.

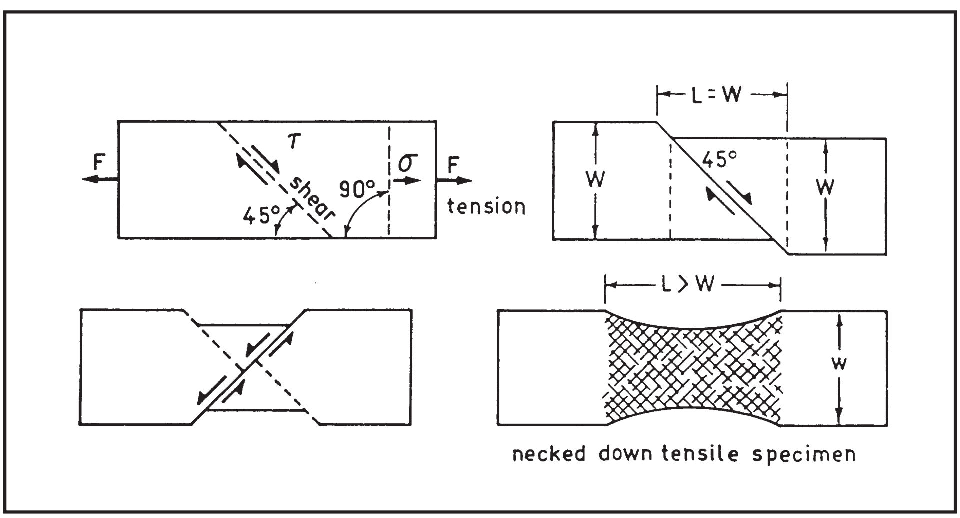

Figure 2.

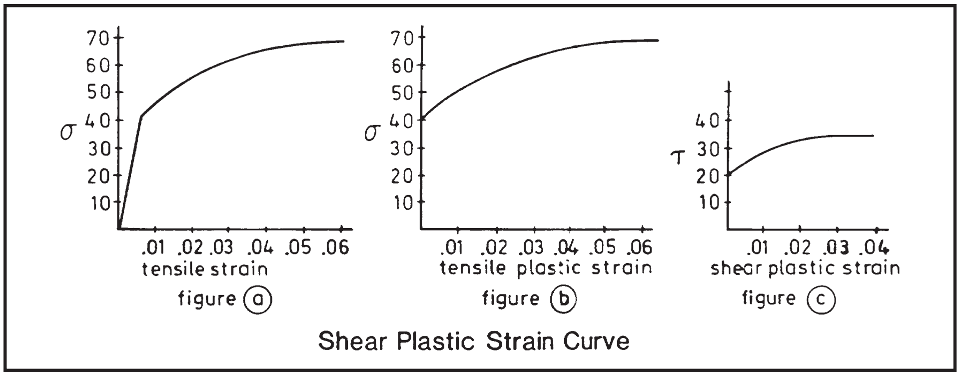

Figure 3.

It is possible to take a representative stress-strain curve for mild steel (Figure 3a), separate the plastic strain portion from it (Figure 3b), and convert this into a shear stress-plastic strain for any given shear stress (τ) once it exceeeds the critical shear value. The shear stresses (τ_{1-3}) and (τ_{2-3}) can now be converted into plastic strain plus elastic strain as the value of the applied normal stress (σ_3) is increased. A stress-strain curve for any combination of triaxial stresses may be constructed. Figure 4 contains curves for the conditions already discussed. This makes it possible to "see" the ductile behavior of these details. Notice the beneficial effects of the wide access hole as recommended by the AISC specifications.

The way in which a designer selects structural details under particular load conditions greatly influences whether the condition provides a high enough shear stress component so that the critical shear value may be exceeded first, producing sufficient plastic movement before the critical normal stress value is exceeded. This will result in a ductile detail and minimize the chances of cracking.

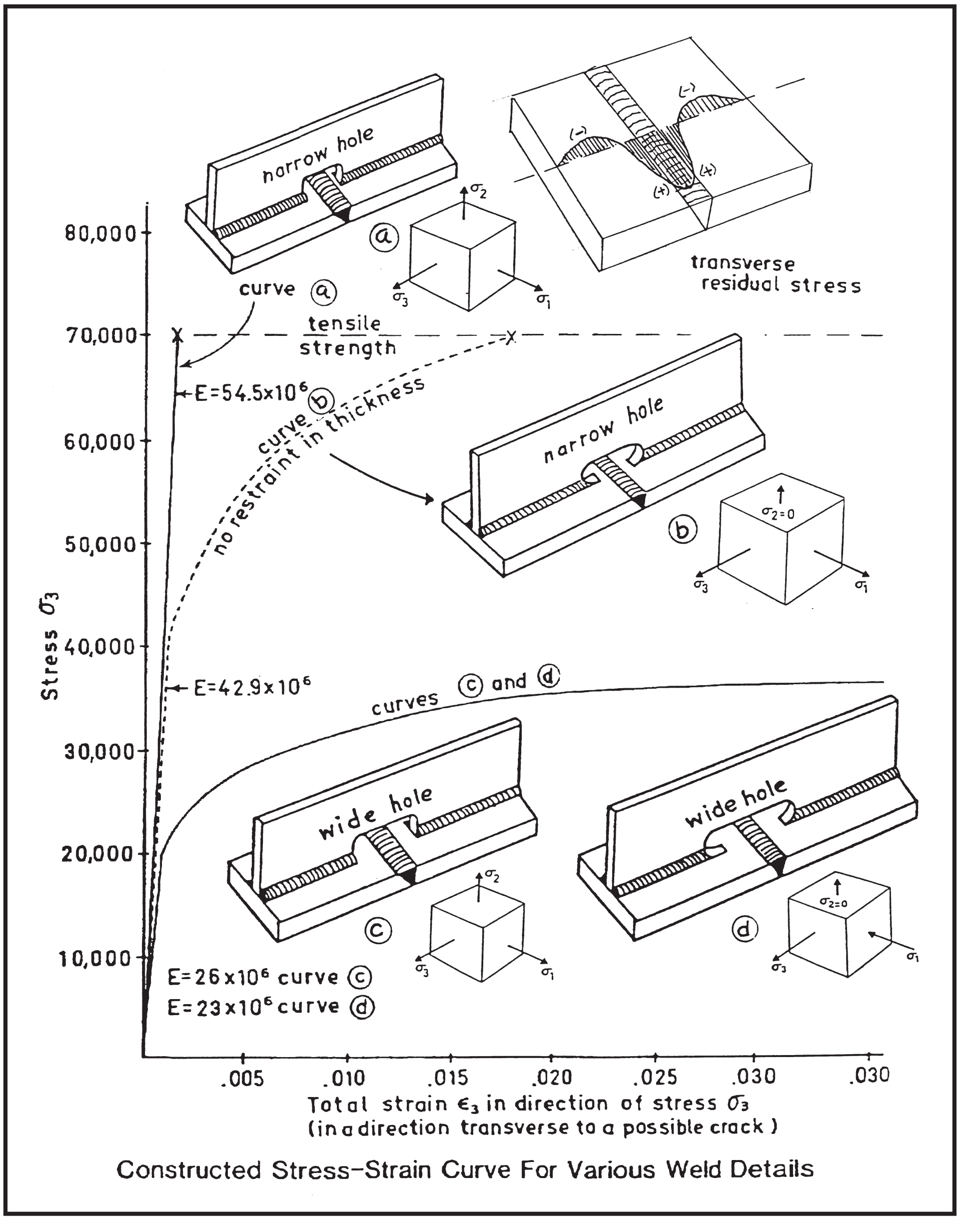

Figure 4.

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Design File

Carefully Evaluate "Code Requirements"

Practical Ideas for the Design Professional by Duane K. Miller, Sc.D., P.E.

Codes, specifications, and contract documents provide fabrication requirements that must be maintained when applied to welded construction. However, some provisions are perceived as "requirements" when they are not applicable, or when alternatives are permitted. Under these conditions, it is prudent to carefully evaluate such "requirements" and, when appropriate, consider alternatives that may provide fabrications of equal or better quality, and at reduced cost.

Consider, for example, the requirements as they relate to Complete Joint Penetration (CJP) groove welds made in accordance with the American Welding Society Structural Welding Code – Steel (AWS D1.1:2000). A review of the prequalified joint details in AWS D1.1, Figure 2.4 reveals that all CJP groove welds (with one exception which will be discussed below) utilize either single-sided joints with steel backing, or double-sided joints that involve back gouging (see Figures 1 and 2). Either option is permitted, and when properly made, both should result in a weld throat that is equivalent to the thickness of the thinner base metal joint.

The single exception to this is the B-L1-S detail (see Figure 3), which is limited to a maximum thickness of 3/8 in (10 mm). This detail relies on the penetration of the submerged arc welding process to achieve a CJP groove weld.

It would be easy to conclude that AWS D1.1 requires either (a) steel backing for one-sided joints, or (b) double-sided joints that use back gouging. However, this conclusion would be incorrect, and a careful evaluation of code "requirements" with respect to this criterion will reveal that the code permits alternatives.

The key principle that provides understanding in this particular instance is the difference between prequalified Welding Procedure Specifications (WPSs) and those that are qualified by test. In order for a WPS to be prequalified, it must comply with all the criteria of Chapter 3 in the AWS D1.1 Structural Welding Code. However, it is also possible to qualify WPSs by test in conformance with AWS D1.1, Chapter 4 - Qualification. Such qualification testing could

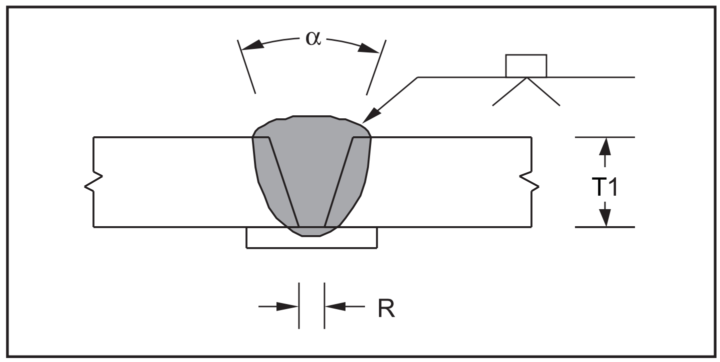


Figure 1. Single-sided CJP weld with steel backing.

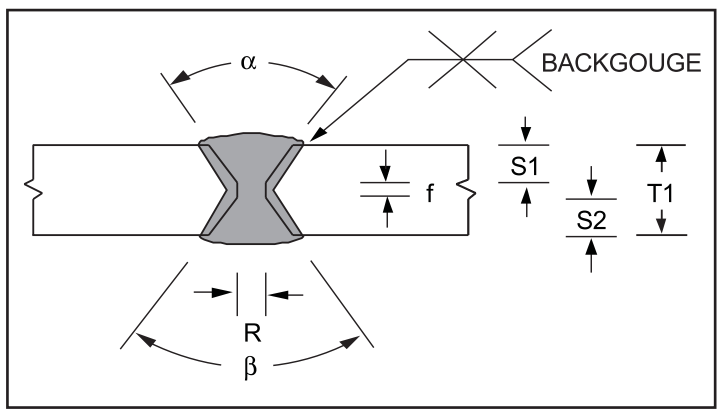


Figure 2. Back-gouged double-sided CJP weld.

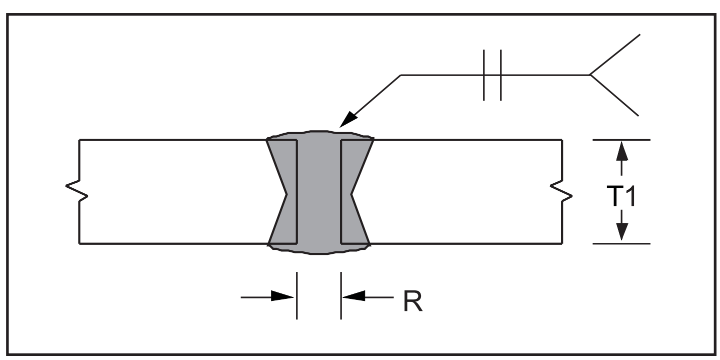


Figure 3. Prequalified AWS D1.1 joint detail B-L1-S (used with permission of the American Welding Society).

thereby permit the use of other materials for backing, including ceramic, glass tape, copper and iron powder (see AWS D1.1, Section 5.10).

Qualification testing could similarly permit the use of double-sided joints without back gouging. This is specifically addressed in AWS D1.1, Table 4.5 – "PQR Essential Variable Changes Requiring Requalification for SMAW, SAW, GMAW, FCAW, and GTAW," Item 35. This provision states that "the omission, but not inclusion, of backing or back gouging" would require qualification of the WPS.

Case Study

For many years, a fabricator had made CJP groove welds in T-joints for offshore applications, using double-sided joints with back gouging, consistent with the prequalified AWS D1.1 joint detail TC-U5-GF (see Figure 4). Rather than incorrectly assuming that back gouging of two sided CJP groove welds was a "requirement," this fabricator took advantage of the D1.1 Code alternative which permitted WPS qualification without the use of back gouging.

The alternative approach replaced the back gouging operation with a unique root pass procedure that ensured a CJP groove weld. The overall joint was a tee, composed of two 3 in (75 mm) steel members, and was prepared with a double bevel groove preparation, using a 50 degree included angle, no root opening and no root face. Two pulsed GMAW arcs, operating from opposite sides of the web, simultaneously made the root passes. Longitudinal spacing for the opposed arcs was approximately 1/2 in (12 mm). Figure 4 shows the root passes, with complete penetration. Figure 5 shows the completed joint that was filled with pulsed GMAW as well.

Such techniques necessitated WPS qualification testing, but the potential cost savings greatly outweighed the expense of the WPS qualification testing.

Conclusions

Reevaluation of "requirements" such as backing or back gouging for AWS D1.1 CJP groove welds may permit the use of cost-effective alternatives. Once a WPS is qualified, it then may be submitted to the Engineer for approval, consistent with AWS D1.1, Section 4.1.1.

In other situations, Code provisions can be waived and alternatives permitted when approved by the Engineer. For example, AWS D1.1, Section 6.8 permits the Engineer to use alternative criteria for specific applications. Approving alternatives should not be casually approached, and the Engineer is encouraged to rely upon prior experienced engineering judgment, in addition to analytical or experimental data. However, alternatives can be approved in this manner, permitting viable alternatives.

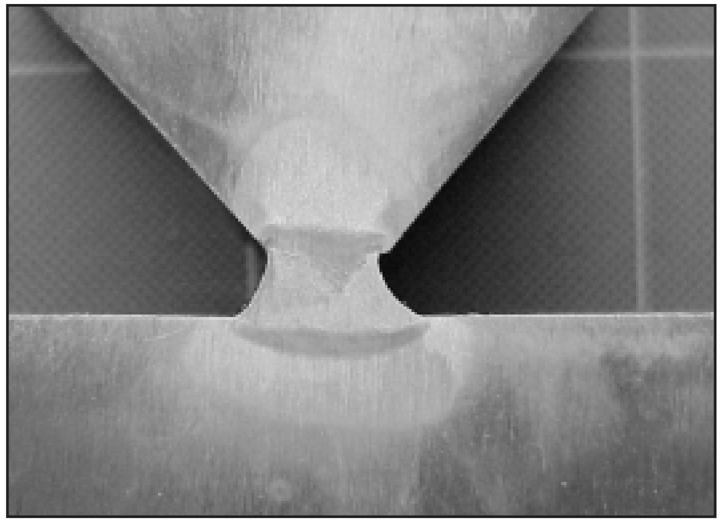


Figure 4. Pulsed GMAW root passes on 3 in. (75 mm) thick members.

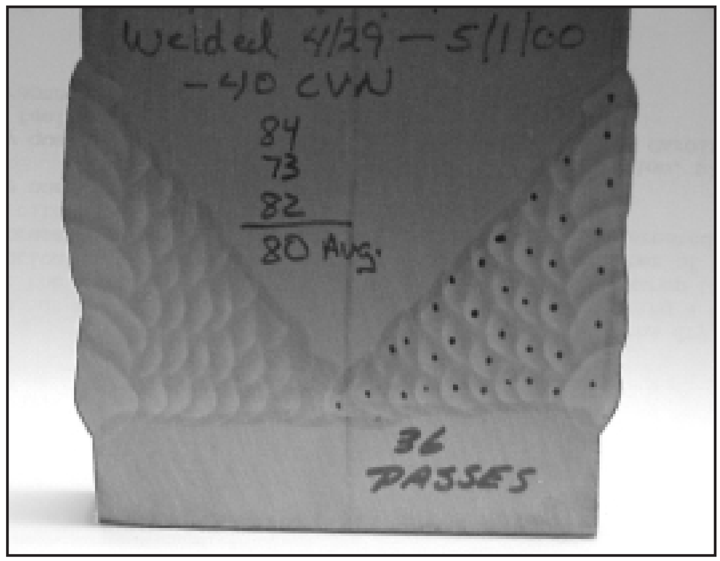


Figure 5. CJP groove weld completed by pulsed GMAW without back gouging.

In the preceding case study, the cost savings achieved were impressive. Equally important, overall quality is expected to be enhanced since reliance is made upon a system that includes careful control of the welding procedures for the root pass, rather than on back gouging operations that are inherently subject to variations in operator skill. As is frequently the case, this cost-saving effort also improved quality.

Return to TOC

1999 Professional Awards Program

The Jury of Awards, meeting in October of 1999, selected the entries described here for their respective awards. The Trustees of the Foundation appreciate the effort and expertise the Jury brought to this task.

JURY OF AWARDS

Dr. Neil Ault
Engineering Consultant
Holden, Massachusetts

Dr. John Fernandes
Engineering Consultant
Tiverton, Rhode Island

Dr. William Highter
Head, Civil Engineering Dept.
University of Massachusetts

Dr. Donald N. Zwiep
Chairman of the Jury
Chairman, The James F. Lincoln Arc Welding Foundation

Best of Program — $25,000

Pool Arctic Alaska Drill Rig #6

Weighing more than 3 million lbs (1.36 million kg), this new drill rig designed for Alaska's North Slope is the largest rubber tire vehicle in the world. A unique feature of the rig is the complete cantilever of the derrick and drill floor 18 ft (5.5 m) above the well, which leaves clear working space around the well head. Twin welded steel box girders are used to form the cantilever. Due to the lack of available rolled steel shapes with the ductility and Charpy V-Notch toughness to meet design requirements, built-up welded sections were extensively utilized. The rig was constructed in components weighing less than 60,000 lbs (27,216 kg) each and transported to the North Slope by barge and truck.

F. Charles Kenley
Garth K. Howlett
Peratrovich, Nottingham & Drage, Inc.
Anchorage, Alaska

Return to TOC

Gold Award — $10,000

Safeco Field Roof Trusses

Arc welding technology permitted the design and construction of the spectacular tri-chord roof trusses that crown Seattle's new Safeco Field baseball stadium. The three independent roof panels cover 8.7 acres (3.5 hectares), with the largest center panel 275 ft (84 m) above the playing field. The two lower panels that slide underneath the center panel in the retracted position have downturned trusses with a bottom chord 165 ft (50 m) above the field. For quality control and higher production rates, components were shop welded wherever possible. Fabricators developed detailed welding procedures that minimized distortion of the plates and chord elements, resulting in excellent fit-up of the trusses in the field, with a minimum number of field modifications required.

Kurt A. Norquist
Skilling Ward Magnusson Barkshire, Inc.
Seattle, Washington

Silver Award — $5,000

Fatigue-Resistant Connection for a Cable-Stayed Bridge

One of the most critical members in a 2,100 ft (640 m) cable stayed bridge is that connecting the steel plate girder web to the stay cable. Due to changing forces in the stay, this member is subject to fatigue. The problem was to design a connecting member that did not pierce the top flange of the plate girder. It was decided that the connection should go around the top flange and connect to the girder web. Attention to detail and the use of arc welding made possible the design and erection of a very fatigue-resistant connection which eliminated the need to pierce the top flanges of the steel plate girders.

William B. Caroland
American Consulting Engineers
Lexington, Kentucky

Return to TOC

Silver Award — $5,000

North America's First Curved Welded Steel Orthotropic Bridge

A 250-foot radius horseshoe shape welded steel orthotropic bridge was designed as an interchange at the intersection of two California freeways. Steel was chosen by the state department of transportation to minimize travel delays or lane closures during bridge erection. An orthotropic design with trapezoidal ribs was selected by the consulting engineering firms. The unique 180-degree curve forming the horseshoe shape of the bridge made a closed cell structure the most economical shape to resist the torsional forces.

Carl Huang **Alfred Mangus**
Tony Marquez **James E. Roberts**
Caltrans
Sacramento, California

Michel Benoit
Buckland & Taylor COWI Group
Walnut Creek, California

John Williams
ICF Kaiser Engineers
Oakland, California

Bronze Award — $2,500

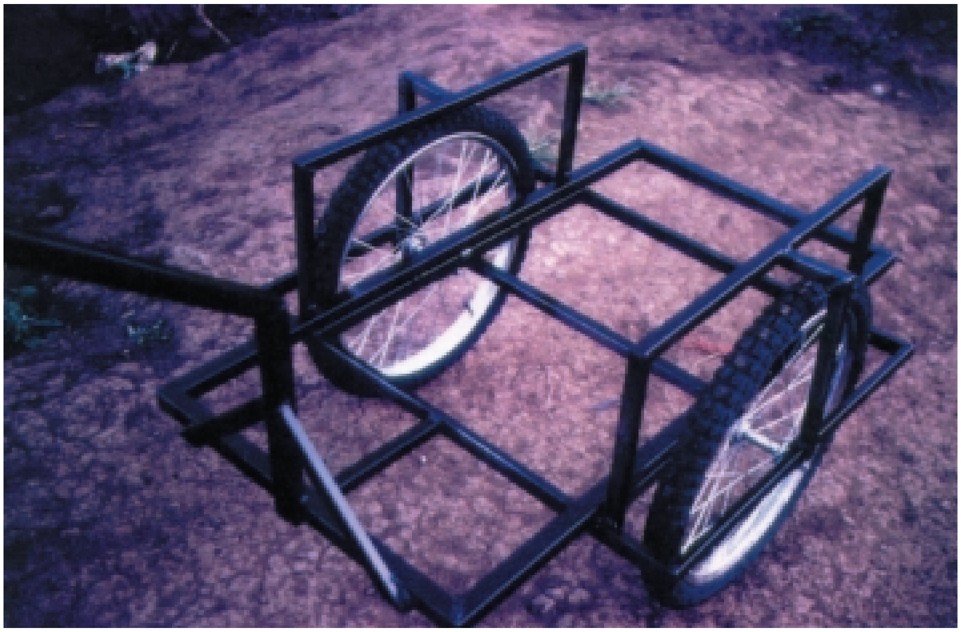
Kuparuk River Submersible Bridges

The design and construction of innovative submersible bridges on the North Slope of Alaska saved the owner $10 million over the cost of elevated bridges for the crossing of two river channels in a flood plain nearly two miles (3.2 km) wide. Extreme environmental conditions, design vehicle weights approaching 4 million lbs (1.8 million kg), impact loading from river ice 5 ft (152 cm) thick, and discontinuous permafrost soil conditions all combined to provide unusual design and construction challenges. The design of a welded steel structure allowed rapid construction, field welded joints, compact girder sections, a streamlined shape for reduced ice impact loads and low maintenance in the future.

Kenton W. Braun
Alan B. Christopherson
Dempsey S. Thieman
Peratrovich, Nottingham & Drage
Anchorage, Alaska

Bronze Award — $2,500

The Xtracycle Sport Utility Bicycle



The Xtracycle is a MIG-welded (GMAW) tubular-steel frame which permits the economical conversion of an ordinary bicycle into a load-hauling sport/utility vehicle. A fixture that attaches to (and detaches from) virtually any existing bicycle, the Xtracycle creates a vehicle that can haul groceries, packages, lumber, computers, passengers, firewood, and many other types of cargo on rugged terrain with loads of up to 200 lbs (90 kg). It is particularly applicable to the needs of people living in developing countries (where bicycles are a common mode of transportation) and has been designed to be easily replicated in local welding and machine shops using readily available tools, materials and skills.

Ross Evans
Kipchoge Spencer
Xtracycle International
Nevada City, California

Opportunities

2001

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…as soon as they are available.

The Xtracycle Sport Utility Bicycle

By Ross Evans and
Kipchoge Spencer
Co-Founders
Xtracycle International
Nevada City, CA

Figure 1. The Xtracycle can turn virtually any existing bicycle into a load-carrying vehicle.

Introduction

While the standard bicycle is well-known as a low-cost, non-polluting mode of transportation available to most of the world's population, its value as a utility vehicle is yet to be fully realized. The Xtracycle (Figure 1) is a fixture that can be attached to, or detached from, virtually any existing bicycle, elongating its frame and readying it for a burden. The resulting extended-wheelbase vehicle retains the simple efficiency of the bicycle while greatly increasing its effectiveness. A modular plug-in rack system makes it possible to configure the Xtracycle for hauling loads that were previously considered too long, heavy, bulky, perishable, fragile, or important to be transported by bicycle. An Xtracycle-equipped bike can haul groceries, packages, lumber, computers, passengers, water, firewood, cellos, bread, and nearly any other cargo on rugged terrain. The device will handle loads of up to 200 lbs (400 lbs with an optional heavy-duty rear wheel), while maintaining the handling characteristics of a mountain bike.

The Inspiration

Many of the world's poor have little or no means of transporting cargo other than on foot, and thus spend several hours per day carrying such loads as goods, firewood, and water on their backs—and heads. Yet many of these same people own or have access to a bicycle, a vehicle that is extremely efficient for transportation but unsuited for carrying substantial loads. One inspiration for the development of the Xtracycle, then, was to augment the bicycle's cargo-carrying capacity, thereby freeing hundreds of millions of people from extreme physical drudgery. The challenge was to develop a device that would accomplish this task, while also being affordable to the target market.

The conversion takes from five to thirty minutes...and is completely reversible...

In wealthy countries (especially in Western Europe), businesses, community services, and individuals are increasingly turning to the bicycle as a means of travelling more quickly through areas gridlocked by automobile traffic. In this setting, increasing the bicycle's load carrying capacity will enable even those who have a choice of transportation methods to use the bicycle to meet more of their needs. For example, in the gridlocked traffic typical of some urban environments, the bicycle can provide an ideal means of reaching heart attack or accident victims and stabilizing them in preparation for the arrival of an ambulance. The Xtracycle permits paramedics to carry life-saving equipment (e.g., defibrillator, oxygen, and a backboard) that will save precious minutes during the anxious wait for an ambulance making its way through heavy traffic.

Figure 2. The modular, TIG-welded FreeRadical™ model is intended for use primarily in developed countries.

How the Xtracycle Works

The Xtracycle is installed on a bicycle by first removing the bike's rear wheel. Then the Xtracycle is attached to the bike's frame at three points using quick-release bolts.

> **..the ability to weld prototypes for user testing led to rapid advancement of the design...**

Two attachment points are the dropouts where the rear wheel had been; the other is near the bottom bracket, home of the pedal crank spindle. Then the rear wheel slips into the Xtracycle's own dropouts. A section of chain is added, brakes and derailleur are moved, and the Xtracycle is ready to haul. The conversion takes from five to thirty minutes, depending upon the particular bike. Installation is completely reversible, but it is anticipated that most users will choose to leave the Xtracycle installed, since it doesn't detract from the bike's rideability.

Two Models

Xtracycle International has developed two base frames, one intended primarily for developed countries called the FreeRadical™ (Figure 2), and another designed for developing countries, the extrabike™ (Figure 3). The FreeRadical is more modular; the engineering behind its lighter-weight construction makes it more complex to manufacture and not as well suited to small-scale production as the extrabike. The FreeRadical is primarily TIG-welded using round 4130 chromoly steel tubing with a wall thickness of 0.039 in (1 mm) in diameters of 0.75 (20 mm) and 1.0 in (25 mm), which gives it a sleeker look than the square tubing of the extrabike. However, what the extrabike lacks in modularity, it gains in versatility: with its permanent fold-down racks and solid top-frame construction, it carries a wide range of loads without modification.

The Contribution of Welding

For the inventor, Ross Evans, learning to weld was the genesis of the Xtracycle concept. Even more importantly, the ability to weld prototypes for user testing led to rapid advancement of the design, and to significant innovations. He has taught the skill of

Figure 3. The sturdy extrabike™ model is well-suited to the small scale production situations typical of developing countries.

Return to TOC

welding to farmers in Nicaragua and fishermen in Senegal, recognizing the true empowerment of people as they see the implications of their ability to weld. As Rafael Solis, a trainee in Managua, Nicaragua, exclaimed, “Now I can make anything!” (Figure 4)

The advent of small, inexpensive, portable MIG welders has aided the design, growth and spread of the Xtracycle concept around the world. Although stick welding can be used to fabricate the square-tubed extrabike model, Xtracycle International recommends the use of portable MIG welders for their low cost, ease of use and quality finish. In flying overseas to teach workshops, the authors have found it optimal to stow a Lincoln SP-125 in the overhead bin of the airplane. They are often working in village settings where electricity is rationed to only a few hours a day. Therefore, the ability of workers to plug in an SP-125 and become immediately productive is an important asset. Ross Evans also invented a square tube bending machine that is easy to replicate in a low-tech environment from parts readily available in scrap metal yards. Bent square tubing is not commonly seen, and people in the third world find it very attractive.

The world’s rural poor often spend up to half their waking hours carrying water, firewood, and food

Figure 4. Nicaraguan Rafael Solis is excited about the wealth of applications for the welding skills he has acquired while producing Xtracycles.

Markets

The product addresses the needs of two distinct groups. First, it enables people with no alternative to foot and bicycle transportation to carry substantial cargo loads that would otherwise be immensely time-consuming, unwieldy, or impossible to manage. While there are only about 4 million cargo bikes in the world (including pedicabs), in developing countries alone there are an estimated 500 million bicycles that, using the Xtracycle, could be converted to carry cargo.

The world’s rural poor, especially women, often spend up to half their waking hours carrying water, firewood, and food. In many cases, both time expended and physical hardship could be significantly reduced with the use of a cargo bike. The Xtracycle could also enable the creation of small businesses such as parcel couriers and delivery services.

Second, the Xtracycle permits an alternative even for those with access to an automobile. Forty percent of all vehicle trips in the United States are two miles or shorter, and more than twenty-five percent are less than a mile. Many of these trips could be taken using an Xtracycle to carry whatever load might be necessary, from groceries to surfboards. In the developed world, the product fills a void between large, cumbersome utility tricycles and small, ineffective racks and bags.

Significance of Results

The Xtracycle marries low cost and high performance in a unique and easy-to-manufacture product. Its introduction has led numerous small communities in the developing world to discover the value of welded design. In addition, the small scale sale of locally produced Xtracycles has become a revenue source for many artisans and mechanics, providing an economic incentive to open small welding shops.

For further information, see:
www.xtracycle.com

Key Concepts in Welding Engineering

by R. Scott Funderburk

Selecting Filler Metals: Low Hydrogen

This is part two in a series on selecting filler metals. When selecting filler metals, the specifier may elect to require “low hydrogen electrodes.” Such electrodes may be required to minimize the possibility of hydrogen related cracking. In some cases the engineer may specify low hydrogen electrodes because he believes these electrodes will also provide weld deposits exhibiting a high minimum level of notch toughness. While this may be true, it can not be assumed. This article will address specifying filler metals that resist hydrogen related cracking while also providing good mechanical properties.

“Low hydrogen” can be understood differently by engineers, contractors, or inspectors....

The term “low hydrogen” has been around for about 60 years. It was first introduced to differentiate this classification of shielded metal arc welding (SMAW) electrode (e.g., E7018) from other non-low hydrogen SMAW electrodes (e.g., E6010). They were created to avoid hydrogen cracking on high strength steels, such as armor plate.[1]

Confusion About the Term

Although so-called “low hydrogen electrodes” have been around for many years, there is some confusion about what is meant by the term. Many codes and specifications use the designation, however, neither “low hydrogen” nor “low hydrogen electrodes” are listed in the American Welding Society’s (AWS) *Standard Welding Terms & Definitions* (AWS A3.0-94)[2]. This may come as a surprise to some, especially to engineers that have been specifying that “only low hydrogen electrodes shall be permitted,” or “all welds shall be low hydrogen”, or that “all welding processes shall be low hydrogen.” Without a formal definition, the term “low hydrogen” can be understood differently by engineers, contractors, or inspectors, which can lead to confusion and conflicts.

“Low Hydrogen Electrode” Means SMAW Electrode

The closest thing to a formal definition for low hydrogen SMAW electrodes is found in the AWS A5.1 filler metal specification[3]. This specification lists several electrode classifications with “low hydrogen” coatings. These classifications must have a coating moisture level of less than 0.6% when tested at 1800 °F (980 °C), according to AWS A5.1. This moisture level corresponds to a relatively low diffusible hydrogen level in the deposited weld metal, typically less than 16 mL/100g. For example, AWS A4.3, Standard Methods for Determination of Diffusible Hydrogen[4], shows that when E7018 is welded at 70 °F and 60% relative humidity a 0.6% coating moisture equates to approximately 12 mL/100g of diffusible hydrogen. Many of today’s E7018 products have actual coating moisture content levels much lower than the maximum of 0.6% in the as-received condition. Table 1 lists the SMAW electrodes with low hydrogen coating contained in A5.1.

Table 1. AWS SMAW Electrodes with Low Hydrogen Coverings

EXX15-x
EXX16-x
EXX18-x
EXX18M-x

Can Hydrogen Affect Mechanical Properties?

The influence of hydrogen can be observed in mechanical testing; however, its effects on the test results are limited. A high hydrogen content in a tensile specimen can produce “fish-eyes” on the fracture surface as seen in Figure 1.

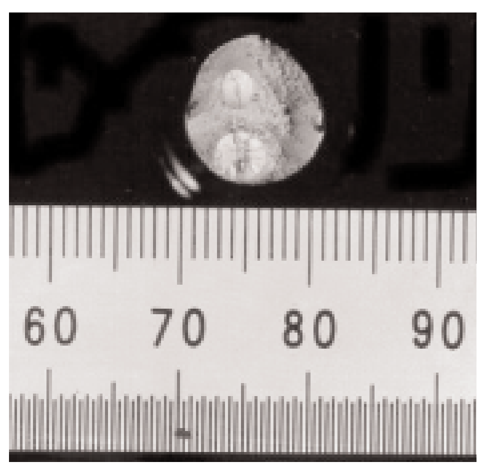

Figure 1. “Fish-eyes” on an all-weld-metal tensile specimen fracture surface.

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Additionally, the presence of hydrogen can reduce ductility (as expressed by elongation and reduction in area). Hydrogen, however, does not typically influence the impact toughness, ultimate tensile strength or yield strength results. It is only in severe cases that it can influence the ultimate tensile strength.

Hydrogen does not typically influence the impact toughness, ultimate tensile strength or yield strength results

Since low hydrogen SMAW electrodes like E7018 are also required to have a minimum specified level of Charpy V-notch (CVN) impact energy, low hydrogen is sometimes equated with a minimum CVN level. This has led some people to specify low hydrogen when the real desire is for notch toughness. The better approach is to specify notch toughness requirements since there is no automatic link between low diffusible hydrogen content in the weld and CVN values. Actually, some deposits with high hydrogen levels can deliver relatively high levels of notch toughness. For example, the E6010 classification (non-low hydrogen, 30-50 mL/100g) has a minimum CVN requirement of 20 ft-lbs at minus 20°F.

Use of the Term in Codes and Specifications

Some codes and specifications refer to hydrogen control in terms of either (1) requiring low hydrogen SMAW electrodes or (2) placing specific limits on diffusible hydrogen. The *Structural Welding Code – Steel* (AWS D1.1-2000)[5] has provisions related to hydrogen in the preheat table (Table 3.2). In the table, Category "A" is applicable to "shielded metal arc welding with other than low hydrogen electrodes." The minimum preheat temperatures listed in Category "A" are higher than Category "B" because Category "B" is for "shielded metal arc welding with low hydrogen electrodes, submerged arc welding, gas metal arc welding, flux cored arc welding."

In the *Interim Guidelines: Evaluation, Repair, Modification and Design of Welded Steel Moment Frame Structures*[6] published by the Federal Emergency Management Agency (FEMA), a comparison between low hydrogen SMAW electrodes and FCAW and SAW is made. This document states, "All of the electrodes that are employed for flux cored arc welding (both gas shielded and self shielded), as well as submerged arc welding, are considered low hydrogen." Implied is the assumption that FCAW and SAW will provide weld deposits with diffusible hydrogen levels similar to SMAW electrodes with low hydrogen coverings.

Weld Deposit Hydrogen Levels

As mentioned above, no definition exists for a "low hydrogen weld deposit." The word "low" is an imprecise description. The preferred method of controlling the level of hydrogen in a weld deposit is to use the optional hydrogen designators as defined by the American Welding Society. These designators are in the form of a suffix on the electrode classification (e.g., H8, H4, and H2). The filler metal manufacturer may choose to add the hydrogen designator to the electrode classification if the filler metal meets the diffusible hydrogen requirements in the applicable AWS A5.x filler metal specification. Following are examples of the designator requirements:

Table 2. Optional Hydrogen Designators

	Diffusible Hydrogen, mL/100g
H8	8
H4	4
H2	2

To avoid hydrogen induced cracking, the hydrogen level in the material must be held to a certain maximum level. This level is a function of the microstructure susceptibility, constraint (or restraint), and residual stresses. Microstructure susceptibility to hydrogen induced cracking often increases with increasing steel strength. Therefore, for higher strength steels lower levels of hydrogen are required. To simply state "use low hydrogen" is not enough. For example, "low" for a 50 ksi steel may not be "low" for a 100 ksi steel. Rather than require that "only low hydrogen electrodes can be used," engineers and fabricators are should use statements such as, "only electrodes or electrode-flux combinations capable of depositing weld metal with a maximum diffusible hydrogen content of 8 mL/100g (H8) are permitted."

Codes That Use Hydrogen Designators

The AWS D1.1 Structural Welding Code also has several provisions that utilize hydrogen designators (e.g., H8). For example, Category "D" in the minimum preheat and interpass temperature table (Table 3.2) allows only "…electrodes or electrode-flux combinations capable of depositing weld metal with a maximum diffusible hydrogen content of 8 mL/100 g (H8)." This is a good example of properly using the H-designators.

To simply state "use low hydrogen" is not enough

The AWS D1.1 Code also has an alternate method to determine the minimum preheat temperature (Annex XI) that uses three levels of diffusible hydrogen. In Annex XI, category H1 is called an "extra low hydrogen" at less than 5 mL/100g. Category H2 is labeled as "low hydrogen" at less than 10 mL/100g. The third category, H3, is a hydrogen level that is not controlled. Although category H2 is labeled "low hydrogen," this does not define low hydrogen electrode as less than 10 mL/100g. The actual diffusible hydrogen value can also be used to calculate the minimum preheat temperature with this method instead of using the H1, H2 and H3 categories.

Job specs should be written clearly and precisely regarding the use of "low hydrogen"

The Fracture Control Plan of the AWS *Bridge Welding Code*[7] (AWS D1.5-95) is another fine example of hydrogen control. This code requires the following for welding Fracture Critical Members:

- H16, H8 or H4, when the minimum specified yield strength is 50 ksi or less.
- H8 or H4, when the minimum specified yield strength is greater the 50 ksi.

Furthermore, SMAW electrodes can be used for tack welding without preheat if the electrode has an H4 designator, according to AWS D1.5.

Other agencies such as the United States Military[8] and the American Bureau of Shipping[9] also set limits on the diffusible hydrogen levels. Both use limits of 15, 10 and 5 mL/100g, and the military specification has a stricter limit of 2 mL/100g for some applications. Today, a logarithmic system (i.e., H16, H8, H4, and H2) is preferred in the United States.

Other Issues

Using an H8, or even an H4, electrode with controlled diffusible hydrogen alone provides no guarantee of eliminating problems related to hydrogen during or after welding. In addition to the electrode, several other factors can influence the diffusible hydrogen level and the potential for cracking. These should be considered as well.

- base metal surface condition (contamination from oils, grease, dirt, moisture, acid, rust and other hydrogen containing materials can increase hydrogen levels);
- relative atmospheric humidity (humid conditions generally lead to higher hydrogen levels);
- welding shielding gas (higher moisture content results in higher hydrogen levels);
- consumable storage conditions (improper or prolonged storage can lead to higher hydrogen levels);
- welding procedures (electrical stickout, arc voltage, wire feed speed and other parameters can influence diffusible hydrogen).

Conclusions

1. A "low hydrogen electrode" refers only to a SMAW electrode that has a coating moisture of less than 0.6%.

2. The maximum diffusible hydrogen level associated with low hydrogen SMAW electrodes has been a point of confusion because SMAW electrodes with low hydrogen coatings are not tied to any specific hydrogen level.

3. "Low hydrogen" should not be specified in order to achieve specific impact properties. If notch toughness is required, then it should be listed separately from the hydrogen limits (if any).

4. Job specifications should be written clearly and precisely regarding the use of "low hydrogen." The intent of the specifier should be listed in such a way that the contractor will understand what is required.

5. If a contractor has any questions regarding in the intent of the engineer, or if the specifications are not clear, the contractor should seek clarification before welding. For example, if "use low hydrogen electrodes only" is listed on the contract, then the contractor may want to ask: "Is only SMAW allowed, or can other processes also be used?"

6. Supplemental hydrogen designators (e.g., H8 and H4) are the preferred way to define a specific level of diffusible hydrogen in the weld deposit and should be used when needed.

7. Finally, there are applications where low hydrogen electrodes are not required or where non-low hydrogen SMAW electrodes, like E6010, are preferred. Therefore, utilizing the blanket statement "use low hydrogen" should be avoided.

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[2] American Welding Society. *Standard Welding Terms and Definitions*. (ANSI/AWS A3.0-94), 1994.

[3] American Welding Society. *Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding.* (ANSI/AWS A5.1-91), 1994.

[4] American Welding Society. *Standard Methods for Determination of Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding.* (AWS A4.3-93), 1993, p. 16.

[5] American Welding Society. *Structural Welding Code – Steel.* (AWS D1.1:2000), 2000.

[6] Federal Emergency Management Agency. *Interim Guidelines: Evaluation, Repair, Modification and Design of Welded Steel Moment Frame Structures*. (FEMA 267), August 1995, p. 8-11.

[7] American Welding Society. *Bridge Welding Code.* (AWS D1.5-95), 1995.

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[9] American Bureau of Shipping. *Rule Requirements for Materials and Welding, Part 2*, 1997.

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"Pneumatic Dreamer" Sculpted of Bronze—and Air

By Carla Rautenberg
Welding Innovation Contributing Writer
James F. Lincoln Arc Welding Foundation
Cleveland, Ohio

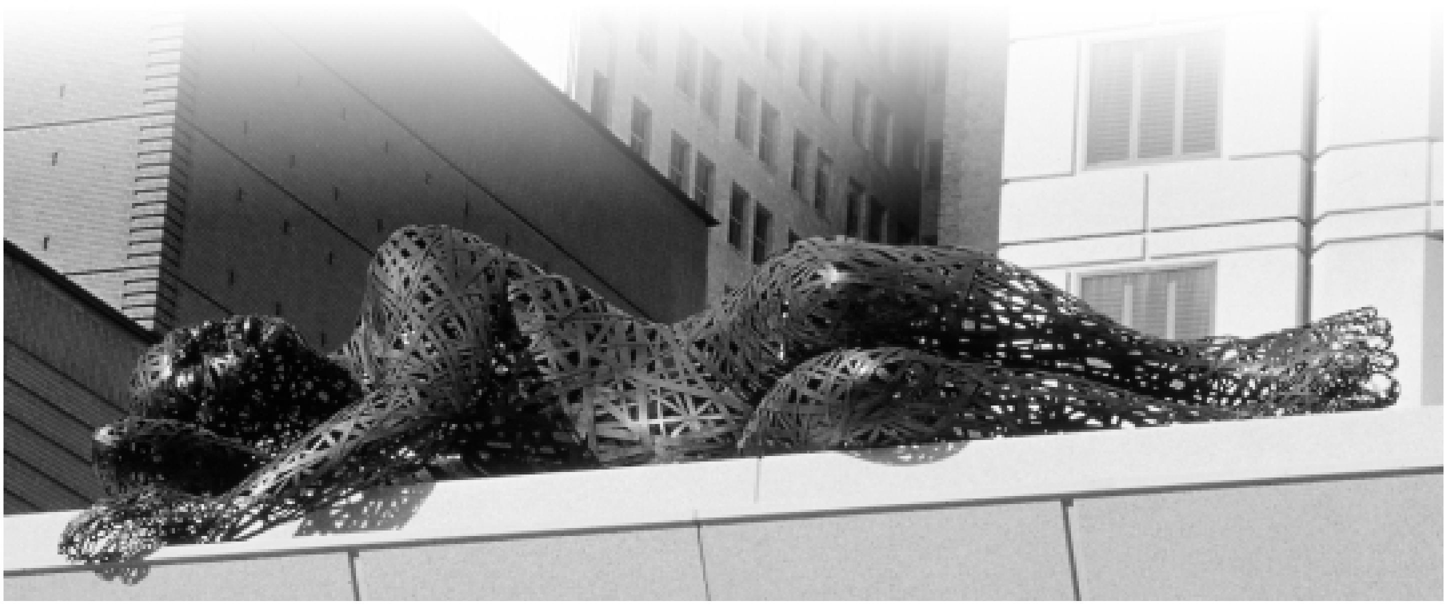

Figure 1. Pneumatic Dreamer settles into its permanent resting place.

A welded bronze sculpture depicting a slumbering human body has been installed over the entrance to the W San Francisco Hotel. Sculptor Michael Stutz, who likes to say that the figure is "made of bronze and air," aptly named it Pneumatic Dreamer. The piece (Figure 1) was fabricated of annealed bronze strips intricately woven and then welded together at Matt Gil's Studio, which specializes in doing fabrication work for San Francisco area artists.

A Public/Private Partnership

The $400,000 project was funded by Starwood Hotels & Resorts Worldwide (manager of the W San Francisco) in accordance with the San Francisco Redevelopment Agency One Percent for Art Program. The program stipulates that for major private developments in the Yerba Buena Center Redevelopment project area, where W San Francisco was built, one percent of the construction costs be set aside for the creation of permanent, public art.

The piece is a woven shell, in which the inside is outside, and the outside is inside

Stutz received the commission by unanimous vote of a panel that included representatives from the San Francisco Museum of Modern Art, which is located in the Yerba Buena neighborhood.

An Artist's Growth

Stutz, who hails from Tennesee, moved to San Francisco in 1987, and supported himself early in his career by creating merchandise displays for Macy's. His commitment to public art grew out of work he did in New Orleans, designing and building large-scale papier mache figures for the city's Mardi Gras parades. Later, he began using recycled materials to create sculptures that have been shown in exhibitions throughout the Bay Area. Pneumatic Dreamer is Stutz's first work in bronze, and initially, he considered having the piece cast. He consulted a foundry but learned the cost would be "astronomical."

The sculpture was specifically designed for installation on the fourth floor terrace of the neoclassical hotel building, overlooking the street below (Figure 2). Stutz points out that the figure, the gender of which is intentionally ambiguous, "could be going into a dream state, or arising from it" and that it illustrates "a very private moment in a very public space." In keeping with that idea, the piece is literally a woven shell, in which, Stutz says, "the inside is outside, and the outside is inside."

Pneumatic Dreamer is lit from both the inside and the front, emphasizing the woven lattice aspect of the design. Its bronze patina will weather to a greenish-blue shade in about a decade.

The Fabrication Process

The 30 ft (9,144 mm) long, 7 ft (2,134 mm) high sculpture was too large to be fabricated inside the shop at Matt Gil's Studio. Thanks to the temperate climate of the Bay Area, it was possible to weld it in the yard outdoors. Gil notes that "We had hoped to plug weld it from the outside, but that was going to be too time-consuming and would have left the surface blemished. So we had to weld it from the inside." The work was accomplished by a team of three welders, three assistants, and the artist, working together for 3-1/2 months. Michael Stutz, while not a welder himself, put the 0.083 in. (21 mm) thick bronze strips in place and served as the "eyes" during fabrication.

Figure 2. The artist, Michael Stutz, in front of the entrance to San Francisco's W Hotel.

We were literally working on top of each other...the tediousness was a little unexpected

Asked to describe the welding process itself, Matt Gil responds, "We used MIG and standard heliarc TIG welding with a serium electrode. I weld bronze using AC and continuous high frequency as I would do for aluminum, but the use of the serium electrode was unique." All of the smallest parts (the fingers, toes, and face) had to be TIG welded because that was the only tool that could be manipulated in such small spaces. The four mild steel structural columns that support the sculpture were shop-fabricated using Lincoln 7018 electrode.

Stutz and Gil agree that the most difficult aspect of fabricating the piece was the challenge posed by working in such tight quarters. Gil says "We were literally working on top of each other. The welding was like stitching on the inside of the piece, while simultaneously there were guys on the outside doing the weaving. The tediousness was a little unexpected."

Although the soft and tactile appearance of Pneumatic Dreamer fittingly echoes that of a sleeping human body, both Gil and Stutz were surprised at the strength and rigidity of the finished sculpture. When it was completed, Sheedy Crane & Rigging hoisted it out of the fabrication yard and it was trucked to the Third Street location of W San Francisco. Delighted pedestrians gawked as the sculpture was lifted into the air and set onto its supports on the fourth floor terrace above. Like a contented hotel guest, the slumbering figure never stirred, but nestled comfortably into place, dreaming all the while.

Further information about Michael Stutz and his artwork is available on his website at:

www.mdstutz.com

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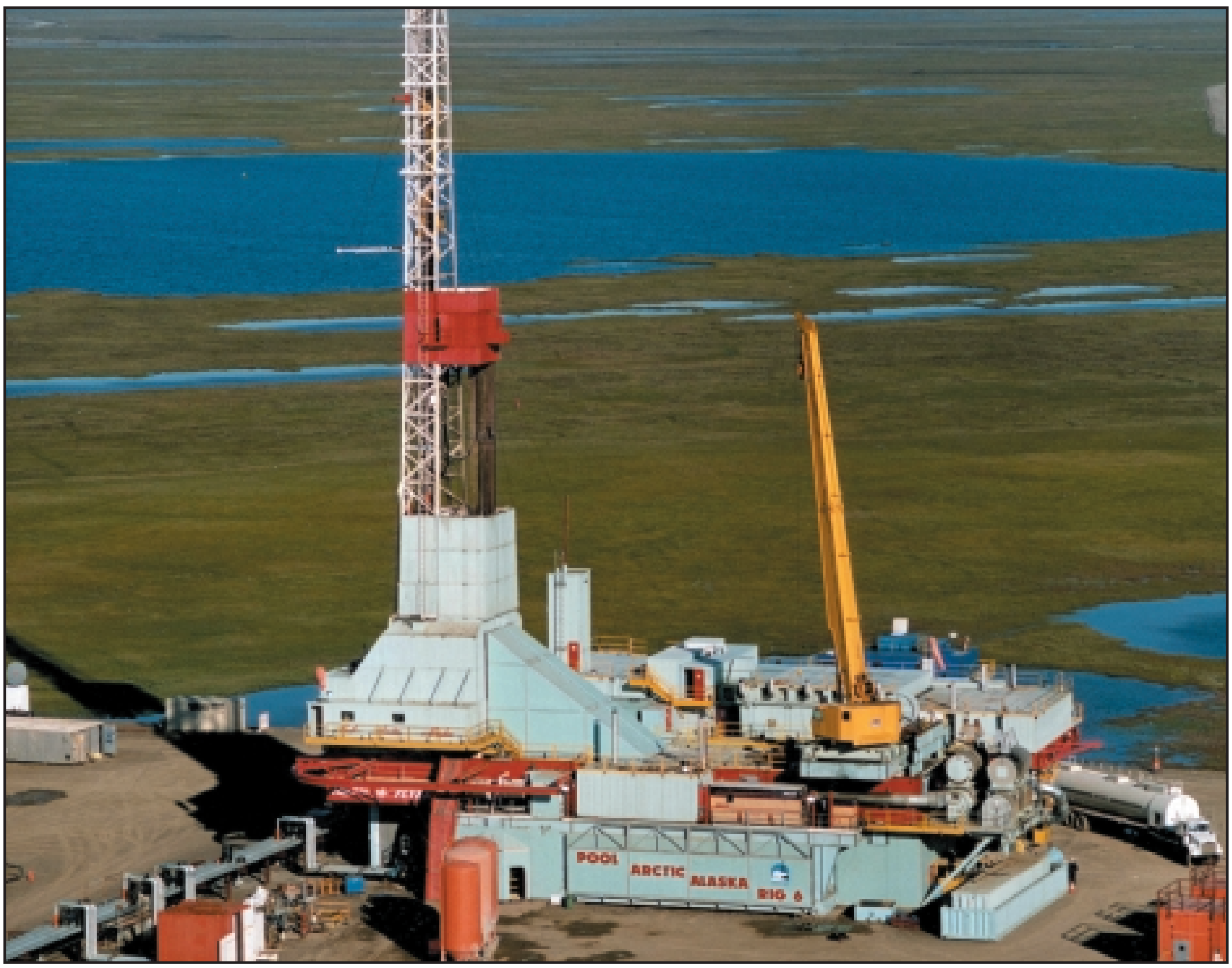

This drill rig designed for Alaska's north slope received the Foundation's Best of Program Award. See page 2, and page 11.

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