JOINT INDUSTRY
UNDERWATER WELDING
DEVELOPMENT PROGRAM

DECEMBER 1995

FINAL REPORT

PHASE I - VOLUME 1

GLOBAL DIVERS & CONTRACTORS INC.

COLORADO SCHOOL OF MINES

JOINT INDUSTRY
UNDERWATER WELDING DEVELOPMENT PROGRAM
PHASE I - FINAL REPORT
December, 1995

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JOINT INDUSTRY
UNDERWATER WELDING DEVELOPMENT PROGRAM
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EXECUTIVE SUMMARY

BACKGROUND

The Joint Industry Underwater Welding Development Program was initiated by Global Divers & Contractors, Inc. and Colorado School of Mines Center for Welding and Joining Research in early 1993 with five participants and a budget of $175,000. As work progressed, the number of participants increased to nine with a budget of $305,000.

OBJECTIVES

Objectives of the program are to improve the properties of wet welds to the highest practical levels, and to determine what those properties are so they may be used as fundamental engineering design principals for solutions to underwater repair/construction problems, where wet welding vs. dry hyperbaric welding, usually results in significant savings in time and costs.

Areas of expected improvements include increased ductility and toughness of weldments, reduced hardness and susceptibility to hydrogen cracking in heat affected zones of base metals, reduced weld metal porosity and increased depths at which sound welds can be made.

HOW THE PROGRAM WORKS

Program work is guided by the Technical Activities Committee (TAC) which is made up of one member from each of the participating organizations, Global Divers and Colorado School of Mines. The participants are: Amoco Research Center, Chevron Research & Technology Company, Shell Offshore Engineering Research Department, Marathon Oil Company, Mobil Research & Development Corporation, Exxon Production Research Company, the U.S. Navy, U.S. Offshore Minerals Management Service and the U.K. Health and Safety Executive-Offshore Safety Division.

Global Divers provides management, welding engineering, technicians, welder/divers, hyperbaric facilities, welding/diving equipment and materials. Colorado

School of Mines provides scientists, a graduate research engineer dedicated to the program, welding electrode formulations, analytical equipment, technical reports on their research tasks, plus calibration in the preparation of other program reports.

Test Matrix and Base Metal

The test Matrix for this phase of the program includes the following tasks. The procedure for, and the results of, each task is discussed separately in this summary.

- Refinement of the multiple temper bead (MTB) wet welding technique used for the prevention of hydrogen cracking and reduction of hardness in the heat affected zones of crack susceptible (carbon equivalent ≥ .40 wt. pct.) base metal.
- Selection of optimum welding power source and auxiliary equipment for underwater wet welding.
- Development of improved electrodes through reformulations of flux coatings and selection of core wires. The program electrode (Ex 7) was chosen as the base electrode for improvement.
- Qualify welding procedures for all position wet fillet and groove welds at 3 ft and 33 ft. and make all-weld-metal tensile and impact welds at 3, 33, 66, 95 and 165 ft with the improved electrode (CSM LC-2).

ASTM A537 Class 1, 3/4" steel plate was selected as the program base metal because of its proven propensity for hydrogen induced cracking, and excessive hardness, in the heat affected zone (HAZ) when welded with conventional wet welding procedures. Carbon equivalent of the A537 material was .462 including .20 carbon. Yield and ultimate design strength were 50 ksi and 70 ksi respectively.

Program welds were made on the A537 material with Ex 7 electrodes in the vertical position at -33 ft unless noted otherwise.

MULTIPLE TEMPER BEAD WET WELDING (PHASE I PART 1)

This unique wet welding technique involves three essential variables which were methodically investigated. Procedures and results are included in the following three section report.

Toe-to-Toe Distance

Microscopic (≥ 100x) examinations of the heat affected zones of a series of wet weldments demonstrated that to prevent hydrogen induced cracking in the HAZ of crack susceptible base metals, the distance between the toes of primary weld beads that tie into the base metal, and toes of temper beads, could vary from 1/16" to 3/16" with equal effectiveness. (Groove welds were made with toe-to-toe distances of 1/16", 3/32", 1/8" and 3/16".) No cracks were detected in the HAZ of any of the sixteen (4 from each weld) specimens examined. However, until temper bead input was substantially increased during welding done later, there was no significant reduction in HAZ hardness.

The fact that the toe-to-toe distance can vary so much, indicates that the MTB technique can be used under less than ideal underwater work conditions and by less than highly skilled welder/divers.

Time Intervals

For the prevention of HAZ hydrogen, it is essential that we know how long it takes for HAZ hydrogen cracks to develop, i.e., what is the maximum allowable time between deposition of primary weld beads and temper beads. Prior to, and during the program work, welders using electrodes other than the Ex 7 electrodes, saw HAZ cracks develop as welds were being made. Based on five experiences, it was concluded that the cracks developed within three to ten minutes.

To determine the maximum acceptable time between deposition of primary and temper beads, welds were made with the Ex 7 electrodes with the time intervals reported below. Results are based on microscopic (100 x) examination of heat affected zones.

Time Intervals	***Results***
Four minutes to ten minutes with ≤ 30 second intervals.	No cracks
Ten minutes to sixty minutes with ten minute intervals.	No cracks
One hour to two hours with thirty minute intervals.	No cracks
Two and one-half hours to four hours with thirty minute intervals.	All specimens had typical HAZ hydrogen induced cracks.

Supplemental Welds

For validation of the highly desirable but unexpected results (2 hours with no cracks), Ex 7 electrodes were used to make an untempered 3/4" x 12" groove weld on ASTM A516 Gr. 70 (CE .44) material which, when welded with commercial wet welded electrodes, developed HAZ cracks within ≤ 10 minutes (welder saw HAZ cracks while welding). During welding with Ex 7 electrodes the welder saw no cracks and none were detected later with magnetic particle examination. And, one of four cross sections showed no cracks when examined at 100x.

A second weld was made on the same material with the Ex 7 electrodes plus temper beading. For this MTB weld, HAZ hydrogen cracking was eliminated.

Knowing the maximum time interval between deposition of primary weld beads and temper beads is essential to the selection of the most efficient sequence for deposition of weld beads/layers.

Temper Bead Heat Input

Throughout the many MTB welding experiments, prevention of HAZ hydrogen cracking was consistently accomplished without any deliberate increase in temper bead heat input. For the same welds, maximum Vickers 10kg 325, as specified by AWS D3.6 for Class A (dry) welds, was maintained in the HAZ and weld metal, except in a very small area (≤ 1/8" x 3/16") in the HAZ beneath the toes of cap passes. To meet the maximum hardness specified by AWS D3.6 for dry welds, a series of welds were made using four levels of increased heat input at the toes of cap passes, plus a fifth unique "half-bead" wet welding procedure. i.e., the thickness of outermost cap passes that overlapped the excessively hard base metal HAZ was reduced approximately 50% (by grinding) and then retempered. For the weld with the fourth level of heat input, (370 kJin), average hardness in the critical area was 324 with two locations registering 332 and 355. While these harnesses are acceptable for most applications, the half-bead technique was next used for further reduction in maximum HAZ hardness. Results were; average hardness in critical area 282 with 300 maximum. (See Summary of Table 1).

MTB Conclusions

Wet welds made with the Ex 7 electrodes at -33' on material that is subject to HAZ hydrogen cracking (CE .462) and excessive hardness (C.20), met AWS D3.6 Class A (dry) weld requirements as specified for lack of cracks and maximum hardness.

Supplemental Information

Wet welds have long been maligned for lack of toughness as determined by Charpy V-notch impact tests made at minimum design service temperature (28-32° F). Wet welds made during the Program exceed the AWS D3.6 requirements for Class A (dry) welds down to -25° F. See accompanying Energy Absorption Temperature Transition Curve. Also, note HAZ notch toughness of 51 ft lb at 28° F.

SUMMARY OF VICKERS 10 KG HARDNESS TEST RESULTS IN HAZ OF WET FILLET WELDMENTS (See Table 1 for Details)

WELDING VARIABLES	AVERAGE HAZ HARDNESS TOE	OTHER	TOE HARDNESS COMMENTS
No Temper Beads	463	291	5 of 6 ≥ 435
Multiple Temper Beads Heat Input 25.5 kJ/in	431	286	2 of 6 ≥ 435
Multiple Temper Beads Heat Input 32.2 kJ/in	410	274	3 of 8 ≥ 435
Multiple Temper Beads Heat Input 34.6 kJ/in	439	270	3 of 8 ≥ 435
Multiple Temper Beads Heat Input 37.0 kJ/in	324	259	2 of 3 ≥ *325
Multiple Temper Beads Plus Half-Bead Technique Heat Input 29.3 kJ/in	282	277	300 max.

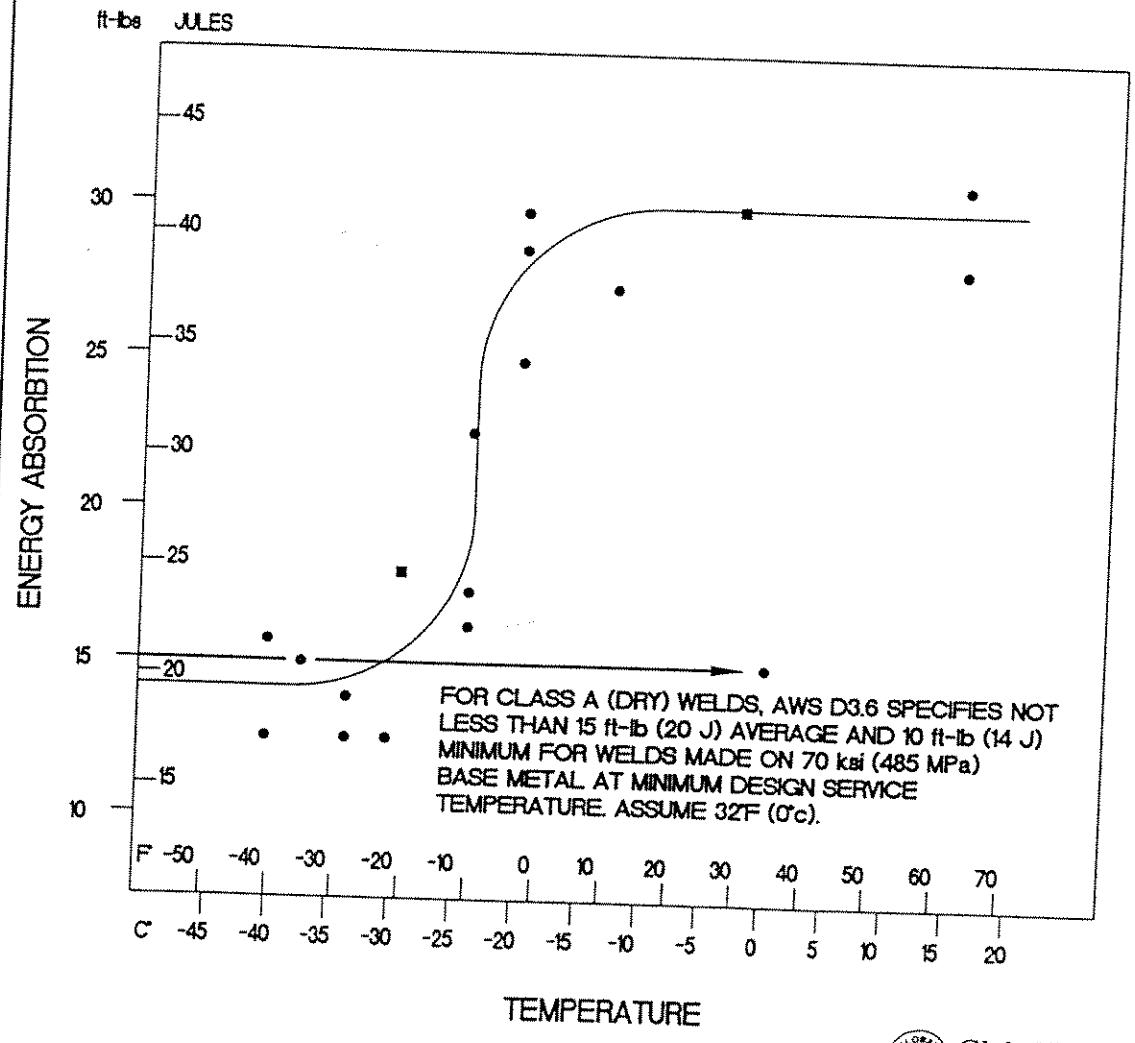
*AWS D3.6 specifies Vickers 10 kg 325 maximum for Class A (dry) welds.

NOTE: Heat inputs are expressed in welding arc output in energy units (kJ) per linear inch at weld joint.

$$\frac{\text{Amps} \times \text{Volts} \times 60}{\text{per minute}} = \text{Jules per inch in.}$$

• HAZ 51 ft-lbs • 28°F
69 JULES • -2°C

ENERGY ABSORPTION TEMPERATURE TRANSITION CURVE FOR WELD METAL - WET WELD MADE AT -33' (10m) WITH JIP Ex 7 ELECTRODES



■ DUPLICATE READINGS

Global Divers & Contractors, Inc.

WELDING POWER SOURCES AND AUXILIARY EQUIPMENT (Phase I Part 2)

For in-air welding, previous Global Divers experience indicated that, depending on base metal, filler metal and welding conditions, a variable pulse welding current output improved arc stability, molten metal droplet transfer and weld metal geometry. Objective of this part of the program was to determine the best power source with or without auxiliary equipment, for wet welding.

Test Matrix

Multiple pass vertical fillet welds were made at -33' on both straight and reverse polarity with the Program Ex 7 electrode and a commercially available wet welding electrode with each of the five power sources that were evaluated. Then , the two best performing power sources were used for more difficult welds, i.e. overhead at -3'.

Equipment Tested

The following equipment was tested in this experimental program:

At -33'	Pow Con 300SS Inverter with and without pulsed arc.
	Thermal Dynamics Arc 300 GMS Inverter with and without pulsing.
	Miller XMT CC/CU Inverter
	Miller 251 D Diesel Driven Generator
	Miller Gold Star Transformer/Rectifier
At -3'	Pow Con Inverter with Pulse Ac
	Miller 251 D Generator

Examinations/Evaluations

Examinations of each weldment included visual, two macros and a fillet weld break test. Weldments were graded on weld bead geometry, amount of porosity, degree of root penetration, and lack of undercut. In addition to weld quality, the performance of the different combinations of power sources and auxiliary equipment were evaluated according to their general weldability, power output, response time, ease of arc initiation and maintenance, arc stability, welder control, and travel speed.

Results

The three inverter power sources, with and without pulsed arc, clearly outperformed the diesel driven generator and transformer/rectifier. Surface appearance of the welds was superior, penetration was increased and there was a reduction in porosity. Additionally, further improvement in weld bead morphology was observed with pulsing.

Supplemental Information

Compared to the second choice, diesel-driven generator, the inverter power sources have additional advantages of not requiring daily fueling and maintenance. The fact that they operate quietly and with no exhaust emissions is highly desirable, especially when work space is limited. The compact construction of the inverter power sources requires minimum space and lifting capacity at the work site. An inverter based power source typically weighs between 70 and 90 pounds, while most diesel-driven generators weigh around 2,000 to 3,000 pounds. However, it should be noted that inverter power sources require a steady AC power input. If the primary power source is often subjected to overload, a separate generator should be provided for the inverter power sources.

WELDING ELECTRODE FORMULATIONS (Phase I Part 3A)

BACKGROUND

Wet welds made with even the best available commercial or proprietary ferritic welding electrodes, fail to meet the radiographic and ductility requirements specified by AWS D3.6 for Class A (dry) welds. Porosity, while fine and evenly distributed, is excessive, and wet weld bend specimens typically fail when tested on radii required for Class A welds. (2T or 3-1/3T depending on design strength of base metal). Initial objective of this part of the program is to, through reformulation of electrode flux coatings and selection of core wires, develop electrodes with less porosity and increased ductility.

The Program Ex 7 electrode was selected as the electrode for modification/improvement because of it's excellent weldability and, when compared to other available electrodes, superior mechanical properties. Qualitative analysis of the base (Ex 7) electrode flux coating, using x-ray defraction techniques was performed with the results shown in Table II.

FORMULATION TEST MATRIX

The Program Report provides a comprehensive explanation of reasons for the initial test matrix for the experimental flux coatings (Table III) which are based on two levels of calcium carbonate additions (10 and 12 wt. pct.), three levels of ferromanganese additions (1.0, 1.5 and 2.0 wt.pct.), and four levels of nickel additions (0.5, 1.0, 1.5 and 2.0 wt. pct). Initially eight coating compositions were produced and tested.

ELECTRODE PERFORMANCE

While depositing weld beads on plate to determine optimal welding parameters, some of the electrodes produced weld beads with good contours with no surface porosity, arc was stable, slag coverage was good, and easily removed. However, with all eight electrodes, weld beads deposited on the previously deposited beads, exhibited excessive porosity. The erratic behavior was attributed to excessive flux coating thickness-to-rod diameter, combined with eccentric core wire. Groove welds planned for the electrodes were not made.

A second set of five batches of electrodes, with smaller coating thickness-to-core-rod diameter ratio, and more concentric core wires, was extruded and tested later. These

electrodes performed better than the previous ones, however multiple pass welding produced poor bead morphology and excessive porosity in overlapping weld passes. The causes of the problems were investigated, and after more detailed analysis of the Ex 7 flux coating, the compositions of new batches (24) of electrode were determined as described in Phase I Part 3B Summary.

WELDING ELECTRODE FORMULATION (Phase I Part 3B)

BACKGROUND

Based on the second and more detailed analysis of the Ex 7 base electrode, and experience with the thirteen previous experimental flux formulations and sometimes eccentric core wires, the Center for Welding and Joining Research of the Colorado School of Mines targeted the screening of multiple flux systems for selection of the optimal electrode. A total of twelve flux coating compositions were designed for testing on two core wires. The fluxes were dry mixed at CSM and extruded by J.M. Minerals, Inc. in Darby, Pennsylvania. Global Divers processed the electrodes for use underwater and made the welds. Weldments were, as a minimum, examined as specified by AWS D3.6 for Class A (dry) welds. Bend tests, hardness surveys, chemical analyses and radiography were performed on all twenty-four experimental welds to screen the electrodes. Four of the welds were selected for further examinations including determination of impact toughness, weld metal tensile properties and microstructural characterization. Based on these results, one combination of flux composition and core wire was identified as producing the best overall results.

EXPERIMENTAL PROCEDURES

Approximately seventy pounds of each of the twenty-four batches of electrodes were produced for making 3/4" vertical groove welds at -33 ft.

Radiography was performed and graded as specified by AWS D3.6 for Class A (dry) and Class B (wet) welds. For characterization of the microstructure of four sets of the welds, transverse cross sections were polished and etched and examined at magnifications of 200 and 500X. Quantitive metallography, using an image analyzer, was used to determine the volume fractions of acicular ferrite, grain boundary ferrite and FS phases. Chemical analysis of all welds were performed using an emission optical

spectrometer, in particular, the carbon, sulphur, oxygen, and nitrogen contents were determined using interstitial analyzers.

Side bend tests and Vickers 1 kg hardness surveys were conducted on all weldments. Welds made with four of the electrodes were examined for HAZ and weld metal Charpy V-notch toughness at 28° F and all-weld-metal properties including yield and ultimate tensile strength, elongation and reduction in area at time of fracture.

RESULTS AND DISCUSSION

As a Summary, this document does not include voluminous amounts of pertinent information that is contained in the Welding Electrode Formulations (Phase I Part 3B) part of the Final Report.. This summary is primarily concerned with the final results of the work that was dedicated to improvement of wet welding electrodes. The success of CSM's program to develop an electrode capable of producing welds with better mechanical properties, and less porosity than the Ex 7 base electrode is demonstrated in the following comparison of averaged test results:

- LC-2 radiographs met the AWS D3.6 requirements for Class A (dry) welds. Ex 7 radiographs met Class B (dry) weld requirements. (Failed Class A due to excessive porosity.
- LC-2 all-weld-metal tensile strength was 83.3 ksi vs. 73.4 ksi for the Ex 7 weld metal.
- LC-2 weld metal elongation averaged 12.3% (10 and 14.6%). Ex 7 elongation averaged 11.5% with 12.5% maximum.
- LC-2 Charpy V-notch weld metal impacts, tested at 28° F, averaged 29.5 ft lbs vs. 29.0 ft lbs for Ex 7 weld metal.
- There was no improvement in side bend test result. Welds made with both electrodes were good for 3-1/3 to 4T bend radii.
- Hardness of weld metal deposited with both electrodes was substantially less than the maximum specified by AWS D3.6 for Class A welds.

WELDS MADE WITH CSM LC-2 ELECTRODES (Phase I Part 4)

BACKGROUND

During Phase I Part 3, Colorado School of Mines (CSM) produced twenty-four experimental welding electrodes with primary targets of reduced porosity and increased ductility. Several of the electrodes produced welds with reduced porosity and improved mechanical properties.

The one designated as LC-2 was selected as best of the twenty-four because, when compared to the excellent Ex 7 program electrode, the welds had less porosity (AWS D3.6 Class A vs. Class B), increased all-weld-metal elongation (average 12.3% vs. 11.5%) and 83.3 ksi ultimate tensile strength vs. 73.4 ksi for the Ex 7 electrodes.

TEST MATRIX

For this part of the program, CSM produced seventy pounds of duplicated LC-2 electrodes for use in making the welds for the examinations shown in Table A. As shown, all position groove and fillet welds were made at -3 and -33 ft. All-weld-metal tensile and impact welds were made at depths of 3, 33, 66, 99, and 165 ft. All of the wet weldments were, as a minimum, examined as specified by AWS D3.6 for Class A (dry) welds.

RESULTS

All position fillet welds met the requirements of AWS D3.6 for Class A welds. All position groove welds met the visual, radiographic, tensile, and Charpy V-notch impact requirements for Class A welds. Sixty-one of sixty-one bend specimens tested at 3-1/3T were satisfactory. (AWS D3.6 specifies 2T for Class A welds). For the all-weld-metal tensile and Charpy V-notch impact welds, yield and ultimate tensile strength decreased rather consistently from -3 to -165 ft, with an ultimate tensile strength of 90.1 ksi at 3 ft and 55.9 ksi at -165 ft. The rate of decrease in the weld metal Charpy V-notch impact values was similarly consistent with 32 ft lbs (28° F) at -3 ft, and 17 ft lbs at -165 ft. Weld metal elongation declined from an inconsistent 7.5% at -3 ft (8.9% at 66' and 99') to 3.7% at -165 ft. (See Table 1). Radiographs of the welds made at depths of 3, 33 and 66 ft met the requirements of AWS D3.6 for Class A (dry) welds, the 99 ft weld was Class B and the 165 ft weld was unsatisfactory due to excessive porosity.

The reheated weld metal microstructure near the root of the weldments showed a very good percentage of desirable acicular ferrite which declined steadily from 61% at -3 ft to 49% at -165 ft. At -3 ft, polygonal ferrite was 36% and side plate ferrite was 3%. At -165 ft polygonal ferrite was 37% and side plate ferrite increased to 14%. (See solid lines on Table 2-A).

Chemical analysis of the weld metal showed and unexpected (based on reports by others) increase in manganese from .62 (wt. pct.) at -3 ft to .91 at -165 ft. Silicon ranged from .41 at -3 ft to .33 at 165 ft. Carbon increased from .12 at -3 ft to .19 at -165 ft. (See solid lines on Table 3-A). Values for the elements are expressed in weight percent.

Microscopic cracks detected in the weld metal had no adverse affect on results of the 3-1/3T bend test. (AWS D3.6 specifies 6T radius for Class B (wet) welds). However, cracks detected at any magnification are undesirable, and plans to eliminate them include reduction in weld metal manganese.

Conclusions and Discussion

It has long been recognized that no single wet welding electrode would have equally good mechanical properties, and weldability, at all water depths. It is thought that to make satisfactory wet welds down to 400-500 ft, four different types of electrodes, each with it's own depth range, might be required.

Based on test results of all position fillet and groove welds made at -3' and -33 ft, and vertical groove welds made at those depths plus 66', 99', and 165', the LC-2 electrode is an excellent shallow water (3' to 66') wet welding electrode. Welds made from -3' to -66' met all AWS D3.6 requirements for Class B (wet) welds plus Class A (dry) weld requirements for radiography, tensile strength and Charpy V-notch impacts at -10° F.

Further modification to flux formulations need to be made for deeper depth ranges. Also, the molten slag produced by consumption of the LC-2 electrode is excessively fluid at all depths. This problem can be mitigated by modification of the flux formulation or application of a proprietary overcoat by Global Divers.

The high percentage of desirable acicular ferrite (61% at -3 ft and 57% at -66 ft.)

is a welcome result of welds made with the LC-2 electrodes. However, when compared to the 10.0%, and 14.6% (both at -33 ft) elongation of weld metal deposited with the first batch of LC-2 electrodes, the 7.5% at -3 ft and 8.9% at 33 and 66 ft produced by this second batch of LC-2 electrodes was disappointing. However, it is anticipated that the cause of the problem will be identified and eliminated early in Phase II.

Major break-throughs during Phase I were:

I. Development of wet welding procedures that when used on base metals that were highly susceptible (CE .462 with carbon .20) to HAZ hydrogen induced cracking, and excessive hardness (VH 10 kg 480), produced the following results:

   a. HAZ cracking was eliminated.

   b. Maximum hardness met the requirements of AWS D3.6 for Class A (dry) welds.

   c. Weld metal and HAZ Charpy V-notch test results significantly exceeded AWS D3.6 requirements for Class A welds.

II. Time for development of HAZ hydrogen cracking was extended from $\leq$ 10 minutes to > 1.5 hours.

III. Through the elimination of porosity, radiographs met the requirements of AWS D3.6 for Class A welds.

Challenges for Phase II include, through the reformulation of flux coatings and selection of core wires, compensation for pressure induced changes in weld metal chemistry and micro-structure plus reduced porosity.

UNDERWATER WELDING DEVELOPMENT PROGRAM
PHASE I PART 4 TESTING MATRIX - TABLE A

Water Depth (Feet)	Test Weld Joint Type	Position	Visual	Radiography	Reduced Section Tension	Fillet Weld Shear	All Weld Metal Tension	Side Bends (6t to 2t - Progressive & Fixed Bend Radii)	Macroeth Test	Chemistry and Micro Structure Exam (% PF, AF & FS)	Vickers Hardness (10 kg)	Charpy Impact WM/HAZ @ +28F	Fillet Weld Break
3	Groove	1G	X	X				4 + 4					
3	Groove	2G	X	X				4 + 4					
3	Groove	3G*	X	X	2			4 + 4	1		1	5 HAZ	
3	Groove	4G	X	X				4 + 4					
3	Groove	3G	X	X			1		1	1		6 WM**	
3	Fillet	1F	X						2		1		1
3	Fillet	2F	X						2		1		1
3	Fillet	3F	X						2		1		1
3	Fillet	4F	X						2		1		1
3	Fillet	3F	X			1							
33	Groove	1G	X	X				4 + 4					
33	Groove	2G	X	X				4 + 4					
33	Groove	3G*	X	X	2			4 + 4	1		1	5 HAZ	
33	Groove	4G	X	X				4 + 4					
33	Groove	3G	X	X			1		1	1		6 WM**	
33	Fillet	1F	X						2		1		1
33	Fillet	2F	X						2		1		1
33	Fillet	3F	X						2		1		1
33	Fillet	4F	X						2		1		1
33	Fillet	3F	X			1							
66	Groove	3G	X	X			1		1	1		6 WM**	
99	Groove	3G	X	X			1		1	1		6 WM**	
165	Groove	3G	X	X			1		1	1		6 WM**	

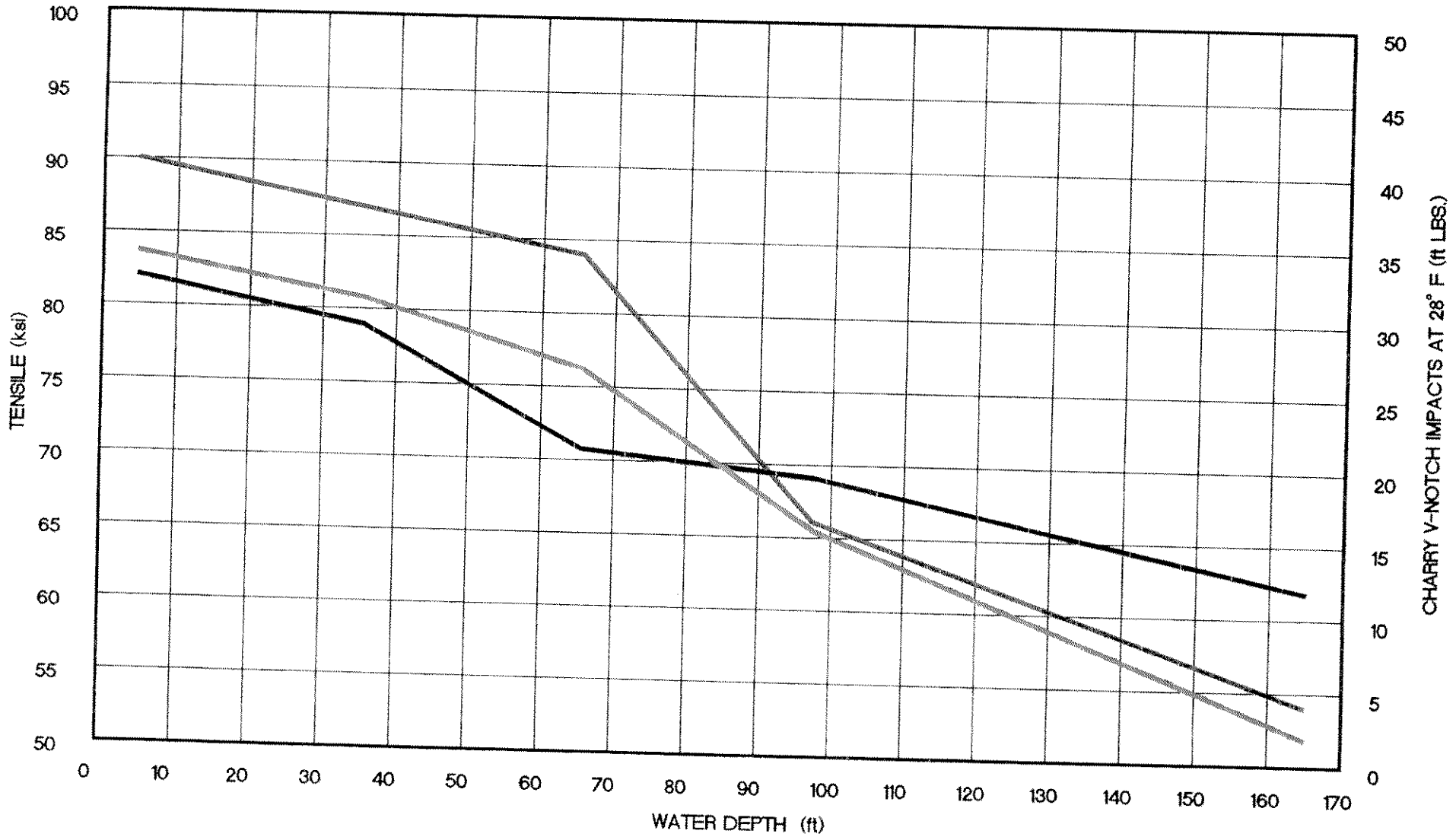
* First Position

PF = Primary Ferrite AF = Acicular Ferrite FS = Ferrite with Aligned & Non-aligned Second Phases

** 5 WM Charpy's will be tested per AWS D3.6 at 28° F. Results of these tests will determine the test temperature for one other specimen.

WELDS MADE WITH CSM LC-2 ELECTRODES

ALL-WELD-METAL YIELD/ULTIMATE TENSILE VALUES AND CHARPY V-NOTCH IMPACTS



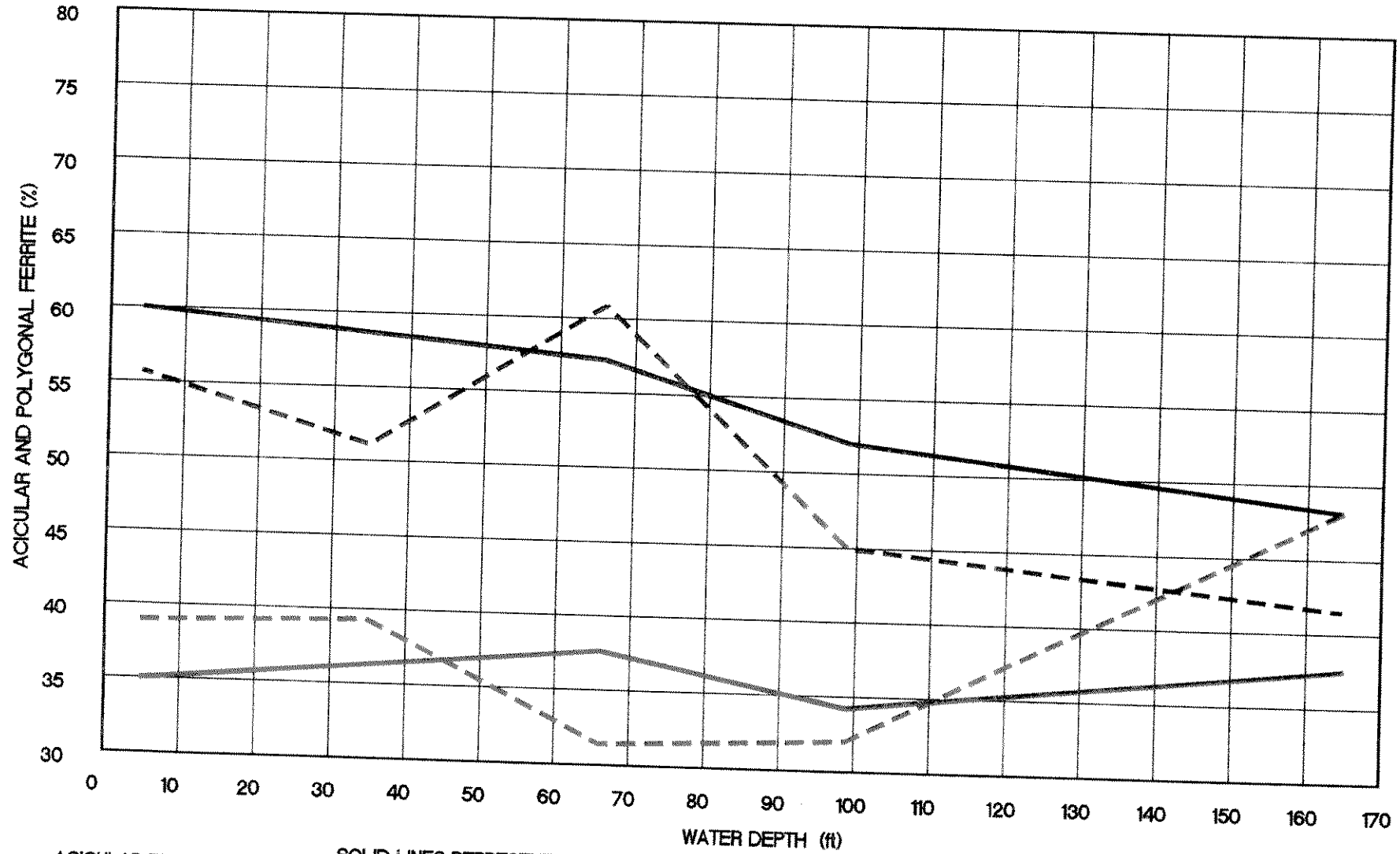
WELD METAL ELONGATION: 3 ft -7.5 %, 33 ft -8.9 %, 66 ft -8.9 %, 99 ft -5.6 %, AND 165 ft -3.7 %

RADIOGRAPHIC RESULTS, AWSD3.6: 3, 33 AND 66 ft WELDS CLASS A, 99 ft CLASS B, 165 ft UNSATISFACTORY DUE TO EXESSIVE POROSITY.

ULTIMATE
CHARPYS
YIELD

TABLE 1

WELDS MADE WITH CSM LC-2 ELECTRODES
CHARACTERIZATION OF WELD METAL MICROSTRUCTURE (3 TO 165 ft)



SOLID LINES REPRESENT TYPE AND PERCENT OF FERRITE OF ROOT PASS NEAR THE FUSION LINE.
BROKEN LINES REPRESENT TYPE AND PERCENT OF FERRITE OF REHEATED WELD METAL BELOW CAP PASSES.
SIDE PLATE FERRITE INCREASED WITH DEPTH FROM 3% AT 3 ft TO 14% AT 165 ft (ROOT PASS)
SIDE PLATE FERRITE INCREASED WITH DEPTH FROM 6% AT 3 ft TO 10% AT 165 ft (BELOW CAP PASS)

TABLE 2-A

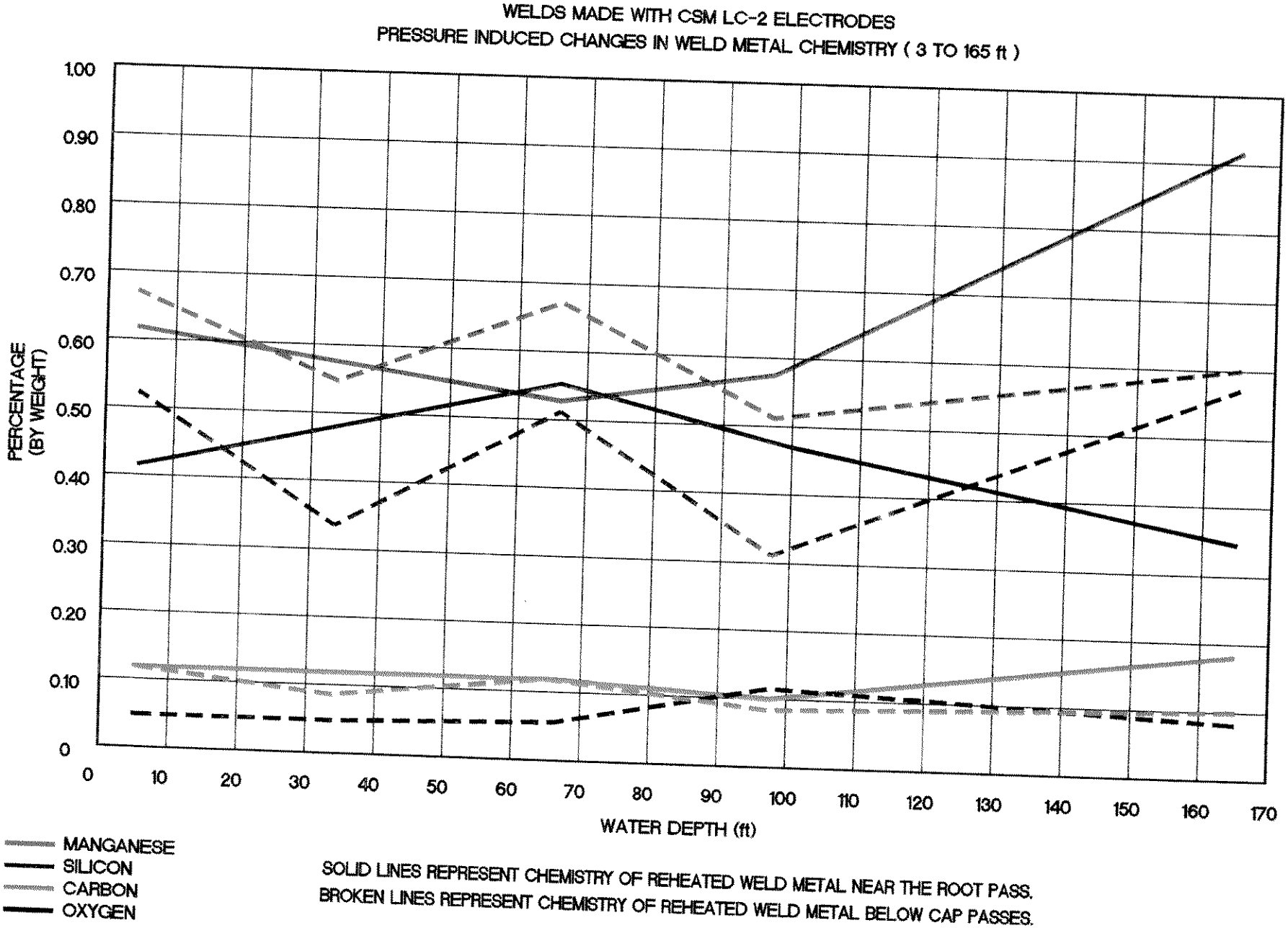

WELDS MADE WITH CSM LC-2 ELECTRODES
PRESSURE INDUCED CHANGES IN WELD METAL CHEMISTRY (3 TO 165 ft)
PERCENTAGE (BY WEIGHT)
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
WATER DEPTH (ft)
MANGANESE
SILICON
CARBON
OXYGEN
SOLID LINES REPRESENT CHEMISTRY OF REHEATED WELD METAL NEAR THE ROOT PASS.
BROKEN LINES REPRESENT CHEMISTRY OF REHEATED WELD METAL BELOW CAP PASSES.

TABLE 3-A

JOINT INDUSTRY
UNDERWATER WELDING DEVELOPMENT PROGRAM
PHASE I - FINAL REPORT
December, 1995

BACKGROUND

The objectives of the Joint Industry Underwater Welding Development Program are to improve the properties of wet welds to the highest levels practical, and to determine what those properties are, so that technical information is available for determining solutions to underwater repair and construction problems. Compared with dry hyperbaric welding, wet welding usually results in significant savings in time and costs.

With the development of this program, areas of expected improvements of wet welds include: 1) increased ductility and toughness, 2) reduced heat affected zone hardness and susceptibility to hydrogen cracking, 3) reduced weld metal porosity, and 4) increased depth at which sound welds can be made.

For execution of the various developmental tasks, Global Divers & Contractors, Inc. (Global Divers) provides program management, welding engineering, technicians, welder/divers, hyperbaric facilities, welding/diving equipment, and material. To provide fundamental interpretation of the experimental results and understanding of underwater wet welding consumables, the Center for Welding and Joining Research of the Colorado School of Mines (CSM) provides scientists, a graduate research engineer, welding electrode manufacturing facilities, and analytical equipment. CSM will also provide technical reports on their research tasks.

From the selection of specific R&D tasks to the monitoring of work execution, this program is conducted under the direction of a steering committee, the Technical Activities Committee (TAC), with one representative from each participating firm, Global Divers and CSM. The representative from Global Divers serves as the chairman of the TAC. There are currently nine participants in the program, including six major petroleum companies (Amoco, Chevron, Marathon, Mobil, Shell and Exxon), the U.S. Navy, and two government regulating agencies (U.S. Minerals Management Service and U.K. Health and Safety Executive). Names and addresses of the TAC members are shown in Appendix I of this report.

This report covers work performed as defined in the January 1993 Test Matrix (Appendix I-A) plus supplemental work specified by the TAC. The original Test Matrix was based on a budget of $175,000. and five participants. With the addition of four more participants, funds available to the program increased to $305,000. Specific tasks include:

Part 1 - Development of the Multiple Temper Bead Wet Welding Technique (MTB) to prevent hydrogen induced cracking, and to reduce hardness, in the heat affected zones (HAZ) of crack-susceptible base metal (CE>.40).

Part 2 - Evaluation of welding power sources and auxiliary equipment and determination of that most suitable for underwater wet welding.

Part 3 - Formulation of welding electrodes to increase ductility and reduce porosity in wet welds.

Part 4 - Use reformulated electrodes to qualify all position fillet and groove welds at -3' and 33' and determine all-weld-metal tensile and impact properties of wet welds made at depths of 3, 33, 66, 99 and 165 ft.

Welds were made on highly crack susceptible ASTM A537, Class 1 (CE .462 wt. pct with .20C) base metal selected by the TAC and examined, as a minimum, in accordance with the requirements of AWS D3.6-93 Specifications for Underwater Welding for Class A (Dry) Welds.

EXPERIMENTAL PROGRAM AND TEST MATRIX

Base Metal Selection

Part I of the Test Matrix is aimed at mitigating the problems associated with wet welding with ferritic welding electrodes on base metals that are sensitive to hydrogen-induced underbead cracking. Prior test results of 122 welds made on 22 different types of steels demonstrated that base metals with carbon equivalents greater than 0.40 wt. pct. were subject to heat affected zone hydrogen cracking.

Carbon equivalent, as defined by the equation below, describes the hardenability of the alloy being welded and its susceptibility to cracking. Particularly in high cooling rate conditions, carbon equivalent is of great importance in specifying preheat and post heat to avoid HAZ cracking in welds made in air.

$$CE_{IIW} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Cu + Ni}{15}$$

To effectively test the multiple temper bead technique, the TAC members specified that the program material have a carbon equivalent greater than 0.45 wt. pct. Additionally, material shall have a minimum of 0.20 wt. pct. carbon. The minimum yield and tensile strengths must be 50 and 70 ksi, respectively. The chemical composition of the 3/4" thick ASTM A537 Class 1 steel plate selected for this program is reported in the following Table I.

Table I. Chemical Composition of the ASTM A537 Class 1 steel selected for the Experimental Program.

C	Mn	P	S	Si	Ni	Cr	Cu	CE_{IIW}
0.20	1.50	0.014	0.019	0.38	0.03	0.02	0.03	0.462

The certificate of analysis of the base metal selected is shown in Appendix II. The yield and tensile strengths of this steel are 55.3 and 82.2 ksi, respectively. Impact toughness measured at -62°C (-90°F) ranged between 26 and 32 ft-lbs. As expected of a hot rolled material, the plate exhibited elongated inclusions, mainly manganese sulfide and silicates. The ASTM A537 Class 1 material chosen met the TAC requirements.

However, with the exception of North Sea structures, the majority of existing offshore platforms are fabricated using ASTM A36 grade materials for which there is no control of chemical composition, except for carbon and manganese. As a result, these materials may present an erratic behavior with respect to hydrogen-induced HAZ cracking and hardness distribution in the heat affected zone. For these reasons, two other base metals with carbon contents of 0.14 and 0.24 wt. pct. were also used in the multiple temper bead program. The carbon equivalent of the two materials were 0.26 and 0.415 wt. pct., respectively. An ASTM A588-88A Grade B material with carbon equivalent 0.449 wt. pct. was also used in the multiple temper bead experiments.

The large differences in carbon content and carbon equivalent observed in the four steels allow for better verification of the effectiveness of the multiple temper bead technique.

Multiple Temper Bead Wet Welding Technique

Wet groove and/or fillet welds were made with and without multiple temper beads (MTB) on the highly crack susceptible A537 Cl.1 (CE .462 with C .20) base metal plus four other materials; A36 (CE .38), A36 (CE .415 with .24 C), A516 Gr. 70 (CE .44) and A-588-88A (CE .449).

Time between deposition of primary weld beads that tied in to crack susceptible base metal and deposition of temper beads was varied from thirty seconds to four hours. Distance from toes of primary weld beads to toes of temper beads were 1/32", 1/8", 3/32" and 3/16". Heat input was gradually increased from less than 25.5 to 37.0 kJ/in, plus a half-bead technique was used with 29.3 kJ/in heat input. All groove welds were severely restrained, fillet welds were made with varying degrees of restraint.

Power Sources and Auxiliary Equipment

Three different inverter type (with and without pulsing), one diesel-driven generator and one transformer/rectifier type welding power sources were used in Part 2 of the test matrix with welds being made a t -3 and -33 ft.

Flux Formulation and Electrode Extrusion

Based on chemical and x-ray analyses, the main ingredients of the program electrode, Ex 7, were determined as: TiO_2, SiO_2, $K_2O.Al_2O_3.6SiO_2$, and $CaCO_3$. Potassium silicate ($K_2O.SiO_2$) was the binder. To increase the amount of acicular ferrite in the weld metal, which has a positive effect on increasing toughness and counteracting the effects of porosity, additions of manganese and nickel to the electrode flux coating were proposed. These metals, in powder form, were mixed with the flux ingredients for extrusion. The manganese content varied from 1.0 to 2.0 wt. pct., and nickel varied from 0.5 to 2.0 wt. pct. Industrial grade chemicals were used for the extrusion of the electrodes. Low carbon steel rods were used as the core rod for extrusion. The chemical composition of the core rod is shown in Table II.

Table II. Chemical Composition of the Low Carbon Steel Core Rod used in Extrusion.

C	Mn	P	S	Si	Ni	Cr	Cu
0.069	0.63	0.008	0.016	0.08	0.03	0.02	0.03

Welding Parameters and Joint Design

As a result of the large number of welds performed for diverse purposes in the multiple experiments, different welding parameters were used throughout this program. The individual welding data will be provided in the specific sections of this report. Welds were made at -33' unless noted otherwise.

Light Metallography

To ensure the detection of underbead cracking and hydrogen fissures in the HAZ and weld metal, cross sections of the wet weldments were examined at ≥100X magnification, instead of the 5X as specified by the AWS D3.6 "Specification for Underwater Welding" for Class A (dry) welds.

Cracking Susceptibility of the ASTM A537 Class 1 steel

A large number of welds were made on an ASTM A537 Class 1 steel plate with 0.462 wt. pct. carbon equivalent and 0.20 wt. pct. carbon. A 3/4" thick plate was used for the all- position confirmation weldments. For welds that required thinner sections (for example, 5/8"), the plate was milled to thickness.

A 5/8" groove weld (without temper bead deposition) was initially produced to confirm the cracking susceptibility of the material. A detailed Global Divers welding report with the welding parameters, joint design and bend test results is included in the text of the report. As expected from a steel with high carbon equivalent, cracking occurred in the heat affected zone of both bead-on-plate welds and fillet welds, as shown in Figure 1, initiating at the toe region and propagating inward. The face-bend specimens in Figure 2 also show that failure occurred in the heat affected zone of the welds. All specimens failed at less than 20° bend angle. Additionally, two 2 T bend specimens of a dry bead-on-plate weldment also failed due to cracks at the toe of the weld which further confirmed the extreme crack sensitivity of the selected base metal. The SRC Engineers, Inc. report on the bend test results is included as Appendix III.

Micrographic examinations were also performed on these welds to determine the nature of the cracks in the heat affected zone. Cracks were reported to be visible at 50X magnification and caused by hydrogen. A test certificate from SRC Engineers, Inc. on the

micrographic analysis is included in the following page. The remaining three test certificates of these tests can be found in Appendix IV of the report.

SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch on weld sample (No T.B.)
P.O. #GD406244 Weld Sample- 3/4" x 8"(#1) 3G

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 5X, 50X, & 100X Magnification. Evidence of Hydrogen Cracking were found near the cap of the weld. Cracks were visible at 50X.

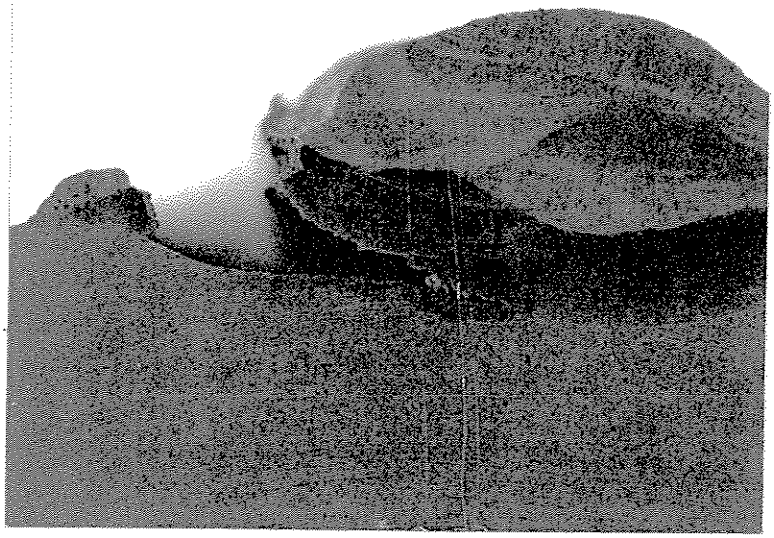
EQUIPMENT UTILIZED FOR TEST
Type: Metallograph
Manufacturer: Olympus
Serial No.: 502796
Last Servicing: December, 1992

SRC Job No. 92-352

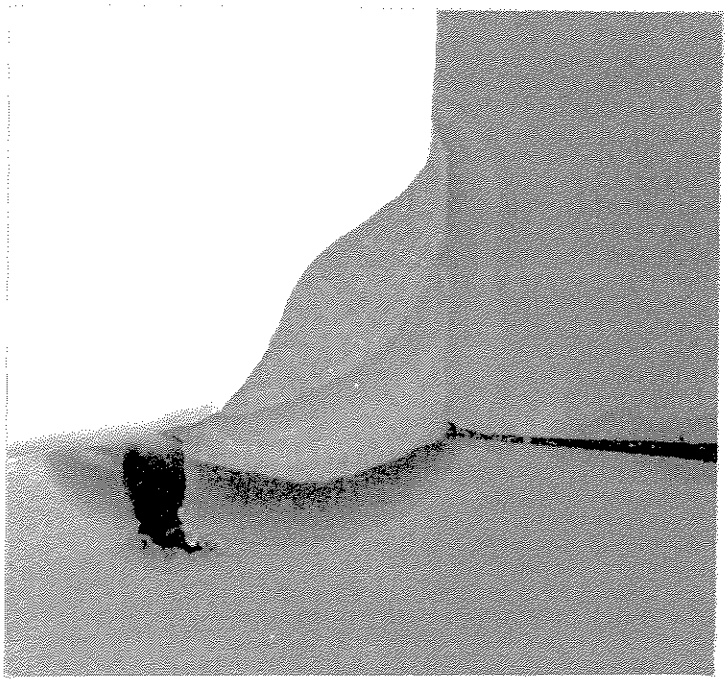
Certified By: [signature] Date: 7-1-93

Reviewed By: [signature] Date: 07-01-93

GLOBAL5.MAC



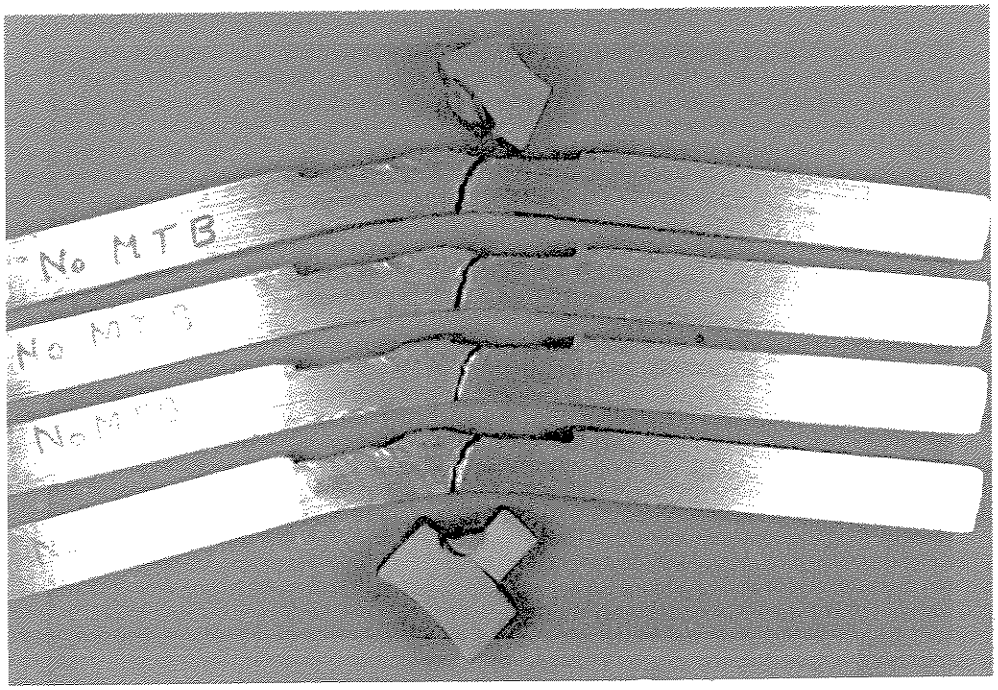
Weld Beads on Plate



Fillet Weld

Fig. 1

Examples of HAZ Crack Sensitivity of A537 Cl.1 (CE .462) Plate



20° Bridge Bend Failures

Fig. 2

BACKGROUND

Appendices

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NOTE: Weldments and testing reported in Appendices III and IV were made to confirm crack susceptibility of the ASTM A537 Class 1 base metal (CE .462 wt pct including .20 carbon)

APPENDIX 1

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JOINT INDUSTRY
UNDERWATER WELDING DEVELOPMENT PROGRAM

TEST MATRIX

Phase I
for the Development of
Underwater Wet Welding

January - 1993

GLOBAL DIVERS & CONTRACTORS, INC.
Technical Services Division

COLORADO SCHOOL OF MINES
Center for Welding & Joining Research

TEST MATRIX

PHASE I

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PHASE I - PART 1

MULTIPLE TEMPER BEAD WET WELDING TECHNIQUE

BACKGROUND

The multiple temper bead (MTB) wet welding technique was developed to prevent hydrogen induced under-bead cracking in the hardened heat affected zones (HAZ) of crack susceptible ($\geq$ .40 CE) high strength steels. It has been qualified and used to repair offshore structures with demonstrated crack susceptible materials with carbon equivalents ranging from .416 To .455, and has been effective on normalized steel with a carbon equivalent of .47.

One set of test results showed that the MTB technique is also capable of significantly reducing HAZ hardness. (Vickers 450 reduced to 320) and improving charpy-v-notch impacts (22 ft lbs increased to 36 ft. lbs. at -10° C).

During the qualifications of MTB welding procedures for specific underwater repairs, not enough controlled experimental work was done to establish the following essential parameters:

* Maximum allowable time between start of the primary weld beads and the start of the temper beads. (Each primary bead that ties into crack susceptible base metal is tempered before another primary bead is deposited.) Lengths of primary beads do not exceed that which can be deposited with one electrode).
* Maximum acceptable distance between the toes of temper beads and primary beads.
* Optimum temper bead heat input.

TEST PROGRAM

During establishment of the aforementioned parameters, test welds will be made at -33' on carbon steel plate that has been test welded to insure it's crack susceptibility. (ASTM A537 Cl .1, C .20, CE .462).

For determining the maximum allowable time between start of the primary bead and start of the temper bead, the matrix for each test specimen will be:

* Deposit a 2" long primary bead-on-plate across a 5/8" x 2" x 12" crack susceptible steel plate.

* Deposit a temper bead over the primary bead. For the first weldment, the time interval between the start of the primary bead and start of the temper bead will be thirty seconds. For each of six weldments, the interval between primary beads and temper beads will be increased in thirty second increments, up to 180 seconds.
* Each specimen will be examined in accordance with the AWS D3.6 procedure for bridge bend tests except that bends will be 4T instead of 20°. If the bead on plate face bends do not reveal cracking, specimens will be polished, etched, and examined at 100X magnification. (An additional weld will be made with no temper bead).

For determining the maximum acceptable distance from the toe of temper beads to the toe of primary beads, previously determined acceptable time interval will be used to make 5/8" groove welds on crack susceptible plate at -33'. Four welds will be made with toe-to-toe distances being 1/16", 3/32", 1/8" and 3/16". Testing of each weldment will include four macros examined at 100X, four hardness surveys and five charpy V-notch HAZ impact tests.

After determining the maximum time interval and toe-to-toe distance, 5/8" groove welds will be made to evaluate the effectiveness of the MTB wet welding technique in reducing hardness and increasing notch toughness in the heat affected zone. Two welds will be made at -33' on material that, while not susceptible to HAZ cracking (<.40 CE), will be subject to unacceptable HAZ hardness and notch toughness at 28°F.

One weld will be made using the MTB technique and the other will be made using conventional wet welding procedures. Examination of the welds will include four macros with hardness surveys and five charpy V-notch HAZ tests.

If the use of proper time intervals and toe-to-toe distances does not result in hardness and impact properties that are comparable to above water welds, additional welds will be made to determine optimum heat input. Three 5/8" groove welds will be made on crack susceptible material at -33'. Temper bead heat input will be progressively increased through changes in welding current, rate of travel and pulse arc parameters. Testing of each weldment will include four macros with hardness surveys and five charpy v-notch HAZ impacts at 28° F.

CONFIRMATION WELDS

To complete this part of the wet welding developmental program, and to provide a base for work at deeper depths, all position 3/4" groove welds will be made on crack susceptible material at -33' and examined in accordance with the requirements of AWS[1] D3.6 for type A (dry) welds with the added requirement that weldments shall be aged ≥ 72 hours at ambient temperature before examination. Ageing at 200°-220° F. as permitted by AWS D3.6 will not be done on any Phase I weldments. Five welds will be made; one each in the flat, horizontal and overhead positions and two in the vertical position. Orientation of the groove in the heat affected zone impact specimens from one of the vertical weldments will be as shown in AWS D3.6. Impact specimens from the other vertical weldment will be prepared for testing with the groove parallel to the heat affected zone.

[1]AWS D3.6-89 Specification of Underwater Welding defines Type B welds as wet welds and Type A (also Type O) as dry welds. In the pending edition of AWS D3.6-93, underwater welds are categorized by Class rather than Type and are not defined as wet or dry. The requirements for qualifying A welds and B welds are unchanged, see Exhibit A for comparison of test requirements.

PHASE I - PART 1

MULTIPLE TEMPER BEAD WET WELDING TECHNIQUE

TEST MATRICES

MATRIX NUMBER	WELD TYPE	TEMPER BEAD INTERVAL (SECONDS)	TOE TO TOE DISTANCE (INCHES)	HEAT INPUT (KJ/mm)	4T BENDS OR MACRO ETCH @ 100X	HARDNESS SURVEY HV 10	CHARPY V-NOTCH @ 28°F
1	BEAD ON PLATE	NO TB			X		
1	BEAD ON PLATE	30	1/16	LEVEL 1	X		
1	BEAD ON PLATE	60	1/16	LEVEL 1	X		
1	BEAD ON PLATE	90	1/16	LEVEL 1	X		
1	BEAD ON PLATE	120	1/16	LEVEL 1	X		
1	BEAD ON PLATE	150	1/16	LEVEL 1	X		
1	BEAD ON PLATE	180	1/16	LEVEL 1	X		
2	GROOVE	(1)	1/16	LEVEL 1	MACRO ETCH	X	X
2	GROOVE	(1)	3/32	LEVEL 1	MACRO ETCH	X	X
2	GROOVE	(1)	1/8	LEVEL 1	MACRO ETCH	X	X
2	GROOVE	(1)	3/16	LEVEL 1	MACRO ETCH	X	X
3	(2) GROOVES	(4)	(4)	LEVEL 1	MACRO ETCH	X	X
3	(3) GROOVES			LEVEL 1	MACRO ETCH	X	X
4	(2) GROOVES	(4)	(4)	LEVEL 2	MACRO ETCH	X	X
4	(2) GROOVES	(4)	(4)	LEVEL 3	MACRO ETCH	X	X
4	(2) GROOVES	(4)	(4)	LEVEL 4	MACRO ETCH	X	X
5	(5) GROOVES	(6)	(6)	(6)	AWS D3.6A	X	X

(1) Optimum time interval as determined by Matrix 1.

(2) Groove weld with MTB.

(3) Groove weld without MTB.

(4) Optimum time interval and distance as determined by Matrices 1 and 2.

(5) Confirmation welds.

(6) Optimum MTB welding techniques.

PHASE I - PART 1

MULTIPLE TEMPER BEAD WET WELDING TECHNIQUE

MATRIX SUMMARY - PART 1

WELDMENTS

MATRIX NO.	WELDMENTS	TOTAL
MATRIX 1	7	7
MATRIX 2	4	4
MATRIX 3	2	2
MATRIX 4	3	3
MATRIX 5	5	5
TOTAL	**21**	**21**

PHASE I PART 2

POWER SOURCES AND AUXILIARY EQUIPMENT

BACKGROUND

Significant improvements have been made since the last comprehensive study was made of welding power sources and auxiliary equipment for use in underwater wet welding. During developmental work for specific projects, Global Divers has found that for the welding of stainless steel for underwater repairs at nuclear power plants, a variable pulse current output improves arc stability, weld metal transfer and weld bead geometry. And, during the welding of high strength steels with nickel electrodes, an inverter coupled with the pulse current device, provides the increased heat input that is required for this type of welding. These and other combinations of power sources and auxiliary equipment can be expected to produce improved results when used for wet welding with ferritic welding electrodes.

TEST PROGRAM

Combinations of power sources including diesel powered rotary generators, transformer/ rectifiers and sold-state inverters will be used with and without manually controlled variable pulsed current equipment and high frequency arc starter/stabilizers. A square wave variable/intermittent polarity power source will also be used. Experimental fillet welds (≥ 3/8") will be made at depths of 3' and 33'. Welds will include start/stops at mid-length of each weldment.

Examination of weldments will include visual, two macros and a fillet weld break. Weldments will be graded on weld bead geometry, amount of porosity, degree of root penetration and lack of undercut. In addition to the examinations of the weldments, the performance of the different combinations of power sources and auxiliary equipment will be judged on:

* General weldability and fitness for purpose.
* Ease of arc initiation and maintenance.
* Arc stability.
* Welders control of weld bead configuration and rate of travel.

PHASE I - PART 2

POWER SOURCES AND AUXILIARY EQUIPMENT
VERTICAL FILLET WELDS AT MINUS THIRTY-THREE FEET

TEST MATRIX 1

POWER SOURCES	AUXILIARY EQUIPMENT	[1]ELECTRODE	POLARITY
GENERATOR	NONE	E 6013	STRAIGHT
GENERATOR	NONE	E 6013	REVERSE
GENERATOR	NONE	E 7014	STRAIGHT
GENERATOR	NONE	E 7014	REVERSE
TRANSFORMER/RECTIFIER	NONE	E 6013	STRAIGHT
TRANSFORMER/RECTIFIER	NONE	E 6013	REVERSE
TRANSFORMER/RECTIFIER	NONE	E 7014	STRAIGHT
TRANSFORMER/RECTIFIER	NONE	E 7014	REVERSE
TRANSFORMER/RECTIFIER	ARC PULSE (2 LEVEL)	E 6013	STRAIGHT
TRANSFORMER/RECTIFIER	ARC PULSE (2 LEVEL)	E 6013	REVERSE
TRANSFORMER/RECTIFIER	ARC PULSE (2 LEVEL)	E 7014	STRAIGHT
TRANSFORMER/RECTIFIER	ARC PULSE (2 LEVEL)	E 7014	REVERSE
INVERTER	NONE	E 6013	STRAIGHT
INVERTER	NONE	E 6013	REVERSE
INVERTER	NONE	E 7014	STRAIGHT
INVERTER	NONE	E 7014	REVERSE
INVERTER	ARC PULSE (2 LEVELS)	E 6013	STRAIGHT
INVERTER	ARC PULSE (2 LEVELS)	E 6013	REVERSE
INVERTER	ARC PULSE (2 LEVELS)	E 7014	STRAIGHT
INVERTER	ARC PULSE (2 LEVELS)	E 7014	REVERSE
INTERMITTENT POLARITY	NONE	E 6013	---
INTERMITTENT POLARITY	NONE	E 7014	---

[1] The E 6013 electrode will be the one selected by global divers as the base electrode CSM will modify for use during PART 3. THE E 7014 electrode is a commercially available wet welding electrode.

PHASE I - PART 2

POWER SOURCES AND AUXILIARY EQUIPMENT OVERHEAD FILLET WELDS AT MINUS THREE FEET

TEST MATRIX 2

BACKGROUND

BECAUSE OF THE 'DIFFICULTY IN MAKING WET WELDS IN THE OVERHEAD POSITION IN SHALLOW WATER (< 10'), THE TWO COMBINATIONS OF POWER SOURCES AND AUXILIARY EQUIPMENT THAT DELIVERS THE BEST RESULTS AT -33' WILL BE USED TO MAKE OVERHEAD FILLET WELDS AT -3'.

POWER SOURCES	AUXILIARY EQUIPMENT	ELECTRODE	POLARITY
NO. 1	NO. 1	E 6013	STRAIGHT
NO. 1	NO. 1	E 6013	REVERSE
NO. 1	NO. 1	E 7014	STRAIGHT
NO. 1	NO. 1	E 7014	REVERSE
NO. 2	NO. 2	E 6013	STRAIGHT
NO. 2	NO. 2	E 6013	REVERSE
NO. 2	NO. 2	E 7014	STRAIGHT
NO. 2	NO. 2	E 7014	REVERSE

[1] THIS WET WELDING PHENOMENA IS ATTRIBUTED AN EXCESSIVE VOLUME OF GAS DUE TO REDUCED AMBIENT PRESSURE.

PHASE I - PART 2

POWER SOURCES AND AUXILIARY EQUIPMENT

TEST MATRIX SUMMARY

SERIES	TOTAL
MATRIX 1	30
MATRIX 2	8
TOTAL	**38**

PHASE I - PART 3
ELECTRODE FORMULATIONS

BACKGROUND

Welding with shielded metal arc electrodes in underwater environment often presents problems related to water depth and to the arc environment. Loss of alloying elements in the weld pool, as well as weld properties deterioration, are observed with increasing depth. Welding electrodes that are adequately formulated must be used to adjust the final weld pool chemical composition. The high moisture environment also poses a significant problem because of hydrogen pickup from the surrounding water vapor which results in severe weld metal porosity and cracking. Both requirements, a balanced weld metal composition and controlled amounts of weld defects, demand more in-depth knowledge of electrode formulation for improved performance in underwater wet welding.

E6013 grade electrodes, common in structural welding of steels, are also used in underwater welding of low carbon medium strength steels. However, these electrodes are lean in alloying elements, thus incapable of producing weld metals of high strength and toughness. The elevated hydrogen content of the weldments produced by these electrodes is another concern. Improvements in electrode coating must be made to maximize weld strength and toughness, and to minimize weld metal hydrogen pickup. Non-hygroscopic flux ingredients and higher temperature baking schedules are some of the methods that will reduce the amount of moisture in the electrode coating. However, an optimal amount of moisture should be retained in the electrode coating to promote adequate penetration and shielding.

Underwater wet welds also experience considerably higher cooling rate than surface welds prepared using equivalent welding parameters. As a result, underwater welds generally contain large amounts of bainite and martensite, which are hard and brittle. Methods to increase the toughness of underwater wet welds with increased amounts of acicular ferrite must be developed. Multiple temper bead and plasma arc post- weld heat treatment are some of the techniques being investigated. However, development of

improved electrode formulations appears to be a more economical solution, and will be less dependent on welder skill. Tailoring the type and amount of alloying elements and flux ingredients added to the electrode coating will promote the formation of acicular ferrite and minimize hydrogen pickup in the weld metal.

OBJECTIVE

The objective of the proposed research program is to investigate the effects of several alloying elements and flux ingredients on electrode weldability, microstructure and properties of underwater wet welds. Experimental E6013 grade electrodes will be designed and manufactured at CSM. Underwater wet welds will be performed by Global Divers. Data on arc stability, chemical elements transfer, weld bead morphology, weld metal microstructure and mechanical properties will be gathered and evaluated. The results of this research will provide sound engineering and scientific basis for the design of shielded metal arc electrodes for underwater wet welding at various water depths.

PROGRAM

The proposed program consists of first identifying a commercial E6013 grade electrode as the base electrode for modification. (Global Divers will identify and provide the base electrode to CSM.) The major flux ingredients of the coating of this commercial electrode will be used as the primary composition of the experimental rods. The alloying elements currently under consideration are manganese (1.0, 1.5 and 2.0 weight percent) and nickel (.5, 1.0, 1.5 and 2.0 weight percent), known to improve significantly the strength and toughness of low carbon steel weldments. Titanium and boron will also be added. The optimal range of titanium and boron for acicular ferrite formation, determined previously as 200 ppm and 20 ppm, respectively, will be used in the coating composition in the experimental electrodes. In terms of flux ingredients, the major ones under consideration are $CaCO_3$ and Li_2SiO_3. It is the intent of this program to determine an optimal addition of $CaCO_3$ for weld pool shielding, low hydrogen pickup in the weld metal, and smooth bead surface. Two levels of calcium carbonate will be tested. The amount of lithium silicate that will provide a non-hygroscopic and extrudable coating will also be investigated in this program.

A total of 24 batches of experimental E6013 grade electrodes will be formulated and manufactured at CSM. A minimum of 40 electrodes from each batch will be delivered to Global Divers for further processing and underwater wet welding. Multiple-pass bead-in groove welds will be required. Each weld coupon must be large enough for the extraction of all weld metal mechanical testing specimens. Hardness and side bend tests will be performed on representative weldments of all experimental electrodes. Based on the results of the two tests, tensile and Charpy-V-notch tests will be done on selected specimens. Quantitative metallography of the weldments will be performed using light microscopy. The results will be used to relate porosity and microstructure to mechanical properties. Complete chemical composition of the welds including interstitial analysis will be determined to evaluate the effectiveness of the slag systems in weld pool protection and alloying element recovery.

WORK STATEMENT

1. Identify one commercial electrode as the base composition for electrode formulation.
2. Formulate and manufacture 24 batches of experimental electrodes; forty electrodes minimum from each batch. (8 batches delivered during 2nd , 6th and 10th month of program.
3. Characterize the macrostructure (bead morphology, surface condition, and internal defects) of the 24 sets of underwater wet welds produced.
4. Perform hardness tests on all 24 sets of underwater wet welds produced.
5. Perform side bend test on all 24 sets of underwater wet welds produced.
6. Perform all-weld-metal tensile and Charpy-V-notch tests on selected specimens; no less than four of the 24 sets will be tested.
7. Characterize quantitatively the microstructure of the underwater wet welds that have undergone mechanical testing.
8. Determine the chemical composition of all 24 sets of underwater wet welds produced.
9. Develop a knowledge base of the effects of flux ingredients on electrode weldability and weld metal properties for future design of underwater wet welding electrode coatings.

10. Prepare semi-annual summary reports of project research activities.

11. Prepare yearly progress report of project research activities, and propose research plans phase II.

12. Formulate and manufacture welding electrodes for Part 4 welding procedures.

PHASE I - PART 3

ELECTRODE FORMULATIONS

TEST MATRICES

BASE ELECTRODE WELDMENTS

Based on results of previous developmental work by Global Divers, the number of potential base electrodes for modifications by CSM has been reduced to three. Final evaluation of these electrodes will include, for each electrode, a straight and a reverse polarity fillet weld to determine best polarity (least porosity) and a vertical groove weld. Eight side bend specimen from each weldment will be tested to compare ductility of the three weldments. The best of the three electrodes will be used to make an all-weld-metal tensile and weld metal charpy impact weldment for comparison to weldments made in Part 4.

ELECTRODE FORMULATION WELDMENTS

Twenty-four groove welds will be made. Weldments will be long enough for CSM to perform the examination described in the Part 3 Work Statement.

TEST MATRIX SUMMARY

Six fillet welds, one all-weld-metal tensile and impact weldment and twenty-seven groove welds will be made at -33.

PHASE I - PART 3
ELECTRODE FORMULATIONS

Matrix 1 - Identify base electrode (10 weldments)

Matrix 2, 3 & 4 - Make twenty-four 3/4" x 14-1/2" groove welds for CSM evaluation.

TEST MATRIX SUMMARY

SERIES	TOTAL
MATRIX 1	10
MATRIX 2	8
MATRIX 3	8
MATRIX 4	8
TOTAL	**34**

PHASE I - PART 4
WELDING PROCEDURES

BACKGROUND

Objective of the final part of Phase I will be to determine to what degree the state of the art of underwater wet welding has been advanced by the developmental program. This will be done by making welds with the best combination of experimental electrode, optimum multiple temper bead technique and power source/auxiliary equipment.

WELDING PROCEDURES

All position groove and fillet welds will be made at -3' and -33' and examined in accordance with the requirements of AWS D3.6 for Type A (Dry welds).

For qualification of all position Type A fillet welding procedures, AWS D3.6 requires a fillet weld in each position, one fillet weld shear/tension weldment and one all-weld-metal tensile/impact weldment. (Six weldments) examinations specified for the fillet welds are visual, two macros, one hardness survey and a fillet weld break. The all-weld-metal tension/impact weldments, and examination requirements are included with information reference the welds that will be made from -3' to -165'.

For qualification of all position Type A groove welding procedures, AWS D3.6 requires a groove weld in each position and one all-weld-metal tension/impact weldment. Examinations of the groove weldments will include visual, radiographic, two macros with hardness surveys, two reduced section tensiles, four 2T side bends and five HAZ and five WM Charpy impact tests at 28° F. The all-weld-metal tensile/impact weldment is included in the following group of weldments.

All-weld-metal tensile and impact weldments will be made at depths of 3', 33', 66', 99', and 165'. AWS D3.6 Type A examinations will include one all-weld-metal tensile test and, five weld metal charpy V-notch impact tests at 28° F.

Base metal for all weldments will be test-proven crack susceptible carbon steel. (ASTM A537 Cl .1, C .20, CE .462).

Welding procedure specifications will include, as developed during Parts 1, 2, and 3, the optimum multiple temper bead wet welding procedure, the preferred combination of welding power source/ auxiliary equipment and the best welding electrode from CSM

PHASE I - PART 4

TEST MATRIX

Matrix 1 - Qualification of all position fillet welds at -3' and -33' ([1] 10 weldments).

Matrix 2 - Qualification of all position groove welds at -3' and -33' ([1] 8 weldments).

Matrix 3 - Make all-weld-metal tensil and charpy v-notch impact weldments at depths of 3', 33', 66', 99' and 165'.

MATRIX SUMMARY - PART 4

MATRIX NO.	WELDMENTS
MATRIX 1	10
MATRIX 2	8
MATRIX 3	5
TOTAL	23

[1] All weld-metal tensile/impact weldments for Matrices 1 and 2 are included in Matrix 3.

UNDERWATER WELDING DEVELOPMENT PROGRAM
PHASE I PART 4 TESTING MATRIX

Water Depth (Feet)	Test Weld Joint Type	Position	Visual	Radiography	Reduced Section Tension	Fillet Weld Shear	All Weld Metal Tension	Side Bends (6t to 2t - Progressive & Fixed Bend Radii)	Macroeth Test	Chemistry and Micro Structure Exam (% PF, AF & FS)	Vickers Hardness (10 kg)	Charpy Impact WM/HAZ @ +28F	Fillet Weld Break
3	Groove	1G	X	X				4 + 4					
3	Groove	2G	X	X				4 + 4					
3	Groove	3G*	X	X	2			4 + 4	1		1	5 HAZ	
3	Groove	4G	X	X				4 + 4					
3	Groove	3G					1			1		6 WM**	
3	Fillet	1F	X						2		1		1
3	Fillet	2F	X						2		1		1
3	Fillet	3F	X						2		1		1
3	Fillet	4F	X						2		1		1
3	Fillet	3F				1							
33	Groove	1G	X	X				4 + 4					
33	Groove	2G	X	X				4 + 4					
33	Groove	3G*	X	X	2			4 + 4	1		1	5 HAZ	
33	Groove	4G	X	X				4 + 4					
33	Groove	3G					1			1		6 WM**	
33	Fillet	1F	X						2		1		1
33	Fillet	2F	X						2		1		1
33	Fillet	3F	X						2		1		1
33	Fillet	4F	X						2		1		1
33	Fillet	3F				1							
66	Groove	3G	X	X			1		1	1	1	6 WM**	
99	Groove	3G	X	X			1		1	1	1	6 WM**	
165	Groove	3G	X	X			1		1	1	1	6 WM**	

* First Position

PF = Primary Ferrite AF = Acicular Ferrite FS = Ferrite with Aligned & Non-aligned Second Phases

** 3 WM Charpy's will be tested at 28° F. Results of these tests will determine the test temperature for the other 3.

Appendix II

SWL SOUTHWESTERN LABORATORIES

193012

222 Cavalcade Street P.O. Box 8768 Houston, Texas 77249 (713) 692-9151

Attention: *Pat Hays*
American Alloy Steel
Post Office Box 40469
Houston, Texas 77040

Report No: 30916
File No: 12-0432-00
Date: 02/12/93
P.O. No: 21398

Project: Chemical Analysis of Steel Alloy

PROJECT INFORMATION

Material:	Two - Plate coupons		
Identification:	See Below		
Date Received:	February 10, 1993	*Technician:*	H. Bui, G. Klein
Specifications:	N/A	*Date of Test:*	February 10 to February 12, 1993
Test Equipment:	Siemens SRS-200, Leco IR-212 Carbon	*Procedure:*	ASTM E322, E1019

CHEMICAL COMPOSITION (WT. %)

Specimen Identification	C	Mn	P	S	Si	Ni	Cr	Mo	Cu	V	Cb	CE
~~Plate 5018115 Heat R2954 Size 3/8" x 1" x 2" Slab 19 Mfg: YUC~~	~~0.04~~	~~1.00~~	~~0.014~~	~~0.010~~	~~0.04~~	~~0.17~~	~~0.18~~	~~0.06~~	~~0.10~~	~~0.04~~	~~0.04~~	
Plate A46677 Heat 79006 Size 3/4" x 1" x 2" Slab 12 Mfg: RAUTA	0.20	1.50	0.014	0.019	0.38	0.03	0.02	<0.01	0.03	<0.01	<0.01	.462

Note: The submitted material will be discarded after a period of thirty (30) days unless otherwise directed.

SOUTHWESTERN LABORATORIES

R. France
Reviewed By

Gary A. Klein

ns

RAUTARUUKKI OY
RAAHEN TERÄSTEHDAS
SF-92100 RAAHE
Puh. (982) 301 Telephone 358 82 301

AINESTODISTUS TEST REPORT
WERKSZEUGNIS RELEVE DE CONTROLE

A 3/4
10315 -09

ASME SA-20/ASTM A-20

Purchaser	Consignee	Date
STEMCOR USA INC. EMPIRE STATE BUILDING	HOUSTON	18.08.1991

Order No	Shipping mark	Mark of the Manufacturer
NYI496	17780	

Quality	Product	Process
ASME SA-537 CL1/ASTM A 537 CL1	ASME SA-20	Oxygen steel, continuous casting

PRESSURE VESSEL STEEL ACC. TO ASME SA-20 1989 SECTION II

Pos.	Thickness	Cast No	Ceq	C	SI	MN	P	S	AL	NB	V	CU	CR	NI	MO
001	9.53	79006	.45	.19	.39	1.49	.016	.016	.035	.002	.005	.042	0.04	0.04	.002
002	12.70	78357	.43	.17	.41	1.50	.015	.009	.033	.002	.007	.012	0.02	0.03	.000
002	12.70	78922	.42	.17	.45	1.45	.021	.013	.035	.002	.007	.015	0.03	0.03	.001
003	12.70	79006	.45	.19	.39	1.49	.016	.016	.035	.002	.005	.042	0.04	0.04	.002
004	15.88	78922	.42	.17	.45	1.45	.021	.013	.035	.002	.007	.015	0.03	0.03	.001
005	19.05	79006	.45	.19	.39	1.49	.016	.016	.035	.002	.005	.042	0.04	0.04	.002
~~006~~	~~22.23~~	~~78370~~	~~.43~~	~~.18~~	~~.40~~	~~1.52~~	~~.019~~	~~.017~~	~~.038~~	~~.002~~	~~.012~~	~~.220~~	~~0.03~~	~~0.04~~	~~.001~~
007	25.40	78922	.42	.17	.45	1.45	.021	.013	.035	.002	.007	.015	0.03	0.03	.001
008	25.40	79006	.45	.19	.39	1.49	.016	.016	.035	.002	.005	.042	0.04	0.04	.002
009	28.58	79006	.45	.19	.39	1.49	.016	.016	.035	.002	.005	.042	0.04	0.04	.002
010	31.75	78516	.45	.19	.41	1.52	.016	.006	.032	.001	.009	.008	0.02	0.03	.000
011	31.75	79057	.44	.18	.39	1.53	.019	.012	.038	.001	.009	.010	0.02	0.03	.000

N 920C,T=1.1(MIN)XTHICKN(MM)
CEKV=C+MN/6+(CR+MO)/5+(NI+CU)/15

Pos.	Cast, test No	Cond	K2	REH N/mm²	Rm N/mm²	A% 50	K3	C	1	2	3	Average	Special tests
001	79006 31	N	11	408	572	34	111	-62	047	052	049	049	
002	78357 53	N	11	388	561	42	111	-62	042	028	019	030	
002	78922 42	N	11	373	542	43	111	-62	046	044	109	066	T.S. = 82,200
003	79006 22	N	11	385	566	39	111	-62	028	056	052	045	Y.S. = 55,300
004	78922 43	N	11	355	535	41	111	-62	043	075	035	051	
004	78922 59	N	11	360	533	44	111	-62	055	044	050	050	
005	79006 12	N	11	381	567	40	111	-62	035	043	040	039	Charpy Test
~~006~~	~~78370 23~~	~~N~~	~~11~~	~~384~~	~~527~~	~~45~~	~~111~~	~~-62~~	~~062~~	~~059~~	~~050~~	~~057~~	1. 26 Ft/Lbs.
007	78922 41	N	11	369	529	48	111	-62	107	066	052	075	
008	79006 21	N	11	378	554	48	111	-62	059	059	041	053	2. 32 Ft/Lbs.
009	79006 11	N	11	386	556	47	111	-60	067	044	059	057	3. 30 Ft/Lbs.
010	78516 23	N	11	383	557	52	111	-60	133	033	125	114	
011	79057 21	N	11	349	536	56	111	-60	041	041	045	042	Avg. = 29 Ft/Lbs

K2: 11=TOP,TRANSV.
K3: 111=CH-V/ISO-V(J),10X10,TOP,LONGIT.

TEST REPORT APPROVED DATE 10-8-91
AMERICAN ALLOY STEEL BY [signature]
QUALITY ASSURANCE DEPT.

This certificate is recorded by computer system and is valid without signature. Alteration or use for other products is prohibited and will be subject to criminal jurisdiction.

We hereby certify, that the material described above has been tested and complies with the terms of the order contract.

23.09.91 MR

RAUTARUUKKI OY
Raahe Steel Works Quality Control
PENTTI KASKENTOLA
Authorized Inspector
Telephone 358 82 301

N = normalized

Certified a true copy of the original, retained in our file.
AMERICAN ALLOY STEEL, INC.

ORIGINAL FILE COPY
DO NOT REMOVE

AMERICAN ALLOY
PLATE # B4667Z

RAUTARUUKKI OY
RAAHEN TERÄSTEHDAS
SF-92100 RAAHE
Puh. (968) 301 Telephone 358 82 301

VASTAANOTTOTODISTUS INSPECTION CERTIFICATE
ABNAHMEPRÜFZEUGNIS CERTIFICAT DE RECEPTION

ASME SA-20/ASTM A-20

A 1 4
10315 -09

STEMCOR USA INC.
NEW YORK, NY 10118 USA

HOUSTON
USA

18.08.91

NY1496
17780
10315
STAR SKOGANGER
TOTAL DELIVERY
381

SA 537 CL.1 MT 1.TV

HEAVY PLATES
ASME SA-537 CL1/ASTM A 537 CL1
PRESSURE VESSEL STEEL ACC. TO ASME SA-20 1989 SECTION II

Tolerances ASME SA-20

IMPACT TEST CHARPY-V LONG PER ASME SA 20.
NORMALIZED STEEL PLATES

STEMCOR USA INC./FINLAND							
001	9.53 X 3048 X 12192	3/8X120X480 17780	2	5560	79006- 31	31	
STEMCOR USA INC./FINLAND							
002	12.70 X 2438 X 12192	1/2X96X480 17780	1	2964	78357- 53	53	
002	12.70 X 2438 X 12192		1	2964	78922- 42	42	
STEMCOR USA INC./FINLAND							
003	12.70 X 3048 X 12192	1/2X120X480 17780	2	7410	79006- 22	22	
STEMCOR USA INC./FINLAND							
004	15.88 X 3048 X 12192	5/8X120X480 17780	1	4632	78922- 43	43	
004	15.88 X 3048 X 12192		1	4632	78922- 59	59	
STEMCOR USA INC./FINLAND							
005	19.05 X 2438 X 12192	3/4X96X480 17780	2	8892	79006- 12	12	
STEMCOR USA INC./FINLAND							
006	22.23 X 3048 X 12192	7/8X120X480 17780	1	6485	78370- 23	23	
STEMCOR USA INC./FINLAND							
007	25.40 X 2438 X 12192	1X96X480 17780	1	5928	78922- 41	41	
STEMCOR USA INC./FINLAND							
008	25.40 X 3048 X 12192	1X120X480 17780	1	7410	79006- 21	21	
STEMCOR USA INC./FINLAND							
009	28.58 X 3048 X 12192	1-1/8X120X480 17780	1	8337	79006- 11	11	
STEMCOR USA INC./FINLAND							
010	31.75 X 2438 X 12192	1-1/4X96X480 17780	1	7410	78516- 23	23	
STEMCOR USA INC./FINLAND							
011	31.75 X 3048 X 12192	1-1/4X120X480 17780	1	9262	79057- 21	21	
STEMCOR USA INC./FINLAND							
012	38.10 X 2438 X 12192	1-1/2X96X480 17780	1	8891	79057- 22	22	
STEMCOR USA INC./FINLAND							
013	44.45 X 3048 X 6401	1-3/4X120X252 17780	1	6808	78981- 49	49	

21.09.91

RAUTARUUKKI OY
PENTTI KASKENTOLA

Certified a true copy of the original, retained in our file.
AMERICAN ALLOY STEEL, INC.

TEST REPORT APPROVED DATE 10-8-91
AMERICAN ALLOY STEEL BY
QUALITY ASSURANCE DEPT.

ORIGINAL FILE COPY
DO NOT REMOVE
AMERICAN ALLOY
PLATE #A46677

CUSTOMER Global Quest
CUST. P. O. # GQ405507
A.A.S. S/O # 94557
DATE MAILED 3/2/93
DESCRIPTION 18 2(1) 3/4" x 72" x 96"
Mark D.D.R

SRC ENGINEERS, INC.
P.O. BOX 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710
(318) 837-3810, 837-3819 STEPHEN R. CALLEGARI, P.E.

CERTIFICATE OF ANALYSIS

Date: 6-28-93 P.O. No. GD406244

Company: Global Divers & Contractors, Inc.

Test: AWS D3.6-93 Bridge Bend Test for Class C Welds

Test Performed on: Weld Sample 3/4" X 8"Lg. (No T.B.)

Welders Name: Darryl Phillips

20° BRIDGE BEND TEST	
SAMPLE TYPE & NUMBER	RESULTS
F1	Failed in HAZ
F2	Failed in HAZ
F3	Failed in HAZ
F4	Failed in HAZ

EQUIPMENT UTILIZED FOR TEST
Type: Guided Bend Tester
Manufacturer: CRC

Certified By: Tim Broussard Date: 6-28-93
Tim J. Broussard
SRC Engineers, Inc.

Reviewed By: Stephen R. Callegari Date: 06-28-93

GLOBAL5.BND

Global Divers
& Contractors, Inc.

Sheet 1 of 2
W/O No. ED-011-93

MATERIALS JOINING WORK REPORT
Part 1 Confirm A537 Cl.1 Crack Sensitivity

Location GLOBAL DIVERS - PORT OF IBERIA Contract No. 91-M-4346

Mat'l (1) A 537 Grade Cl 1
Ht./Slab No. 79006-12
Thick 5/8" 3/4 in. Dia. _____ in.

Mat'l (2) _____ Grade _____
Ht./Slab No. _____
Thick _____ in. Dia. _____ in.

Electrode (AWS) E 6013 A5.1 TN Program Ex 7 Mfr. Proprietary Ctry _____

Process SMAW Current/Polarity CC/DCEP/PULSE Joint Type V-GROOVE Position 3G

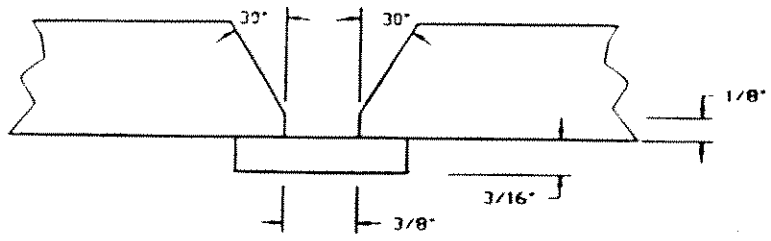
Water Depth 33' Dry _____ Wet X

Welding Variables:

R F & C	PASS	DIA.	AMPS	VOLTS	I.P.M.	REMARKS
ROOT	1 & 2	1/8"	155 - 160	33 - 34	5.8	PPS - 125
FILL	3 - 35	1/8"	155 - 160	33 - 34	6.4	PW - 50%
CAP	36 - 41	1/8"	155 - 160	33 - 34	9.1	Background - 30%
						Weld Time - 55 Min.
						No Temper Beads Were Used.

Welder: Darryl R. Phillips Date: 6-25-93

Welding Joint Sketch:



Welding Techniques:

Stringer Beads with all passes downhill.

Global Divers
& Contractors, Inc.

Sheet 2 of 2
W/O No. ED-011-93

Tension Tests: (Reduced Section/All-Weld-Metal) N/A

SPECIMEN	ORIENT	ULTIMATE S.	YIELD S.	ELONGATION	FAILURE
1					
2					

Bends: AWS D3.6 20° Bridge Bend Test for Class C Welds

SPECIMEN	ROOT	FACE	SIDE	RADIUS	RESULTS
1		X			FAILED IN HAZ
2		X			FAILED IN HAZ
3		X			FAILED IN HAZ
4		X			FAILED IN HAZ

Chemistry: A537 Cl.1

	CE	C	Mn	P	S	Si	Ni	Cr	Mo	Cu	V	Cb	Nb	Al
CTR														
LAB	.462	.20	1.50	.014	.019	.38	.03	.02	.01	.03	.01	.01	---	---

Hardness (Vickers/Rockwell): N/A

LOCATION	LEFT SIDE	RIGHT SIDE
BASE METAL (AVG.)		
HAZ (MAX)		
HAZ (AVG)		
WM (MAX)		

Purpose of Test: Confirm crack susceptibility of A537 Cl.1 (C.20, CE.462) Program material.

Remarks & Evaluation: Four of four bridge bend specimens failed in HAZ at approx. 10°.
Four of four macros had HAZ cracks when examined at 50X magnification.

By: C.E. Grubbs Date: 6-25-93 Rev: ---

APPENDIX IV

SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch on weld sample (No T.B.)
P.O. #GD406244 Weld Sample- 3/4" x 8"(#2) 3G

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 5X, 50X, & 100X Magnification. Evidence of Hydrogen Cracking were found near the cap of the weld. Cracks were visible at 50X.

EQUIPMENT UTILIZED FOR TEST
Type: Metallograph
Manufacturer: Olympus
Serial No.: 502796
Last Servicing: December, 1992

SRC Job No. 92-352

Certified By: Tim Bryant Date: 7-1-93

Reviewed By: Dwight A. Dabbs Date: 07-01-93

SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch on weld sample (No T.B.)
P.O. #GD406244 Weld Sample- 3/4" x 8"(#3) 3G

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 5X, 50X, & 100X Magnification. Evidence of Hydrogen Cracking were found near the cap of the weld. Cracks were visible at 50X.

EQUIPMENT UTILIZED FOR TEST
Type: Metallograph
Manufacturer: Olympus
Serial No.: 502796
Last Servicing: December, 1992

SRC Job No. 92-352

Certified By: Tim Bennett Date: 7-1-93

Reviewed By: Date: 07-01-93

SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch on weld sample (No T.B.)
P.O. #GD406244 Weld Sample- 3/4" x 8"(#4) 3G

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 5X, 50X, & 100X Magnification. Evidence of Hydrogen Cracking were found near the cap of the weld. Cracks were visible at 50X.

EQUIPMENT UTILIZED FOR TEST
Type: Metallograph
Manufacturer: Olympus
Serial No.: 502796
Last Servicing: December, 1992

SRC Job No. 92-352

Certified By: Tim Brown Date: 7-1-93

Reviewed By: Date: 07-01-93

MULTIPLE TEMPER BEAD WET WELDING TECHNIQUE (PHASE I - PART 1)

The multiple temper bead (MTB) wet welding technique was developed to prevent hydrogen-induced underbead cracking in the hardened heat affected zones of crack-susceptible high strength steels. The carbon equivalent of these steels generally exceeds 0.40 wt. pct. The procedure has been qualified and used to repair ship hulls and offshore structures of materials that have demonstrated crack susceptibility (typically with carbon equivalents ranging from 0.416 to 0.455 wt. pct.). Also with adequate temper bead heat input, the technique is capable of significantly reducing HAZ hardness and improving Charpy V-notch impact properties.

To further strengthen the position of multiple temper bead technique as a viable engineering solution to welding high carbon equivalent steels in an underwater environment, several essential process parameters must be better determined and demonstrated in controlled experimental conditions. Global Divers identified the following three parameters as the most critical ones that must be examined in Phase I Part 1 of the experimental program:

1. Maximum allowable time between start of the primary weld beads that tie-in to the base metal and start of the temper beads.
2. Maximum acceptable distance between the toes of temper beads and primary beads.
3. Optimum temper bead heat input.

Maximum Allowable Time Between Primary and Temper Beads ($t_{p/t}$)

The maximum acceptable time interval between the deposition of primary weld beads on crack susceptible base metal, and the deposition of temper beads, is related to the time for hydrogen-induced cracks to develop in wet weldments. Since the development of cracks can also be related to microstructure, the maximum time allowable between the deposition of the primary and temper beads must also be related to the kinetics of austenite decomposition to form martensite. It is desirable to have a long time interval between deposition of primary and temper beads because of better options for sequence and timing of weld bead deposition.

Initial efforts to determine the maximum acceptable time between the deposition of the primary weld beads on the A537 base metal, and deposition of temper beads over the primary beads consisted of laying down single primary beads-on-plate followed by single temper beads deposited at different time intervals. This approach was, however, unsuccessful and the welds

exhibited gross HAZ cracking. After a 4T bend, the entire weld metal "slug" separated from the base metal as shown in Figure 3. The negative result can be attributed to the difficulty in travel speed control while attempting to maintain an adequate toe-to-toe distance between the two beads.

Weld deposition scheme

The welder's control over travel speed and heat input was restored by the following procedure:

a) On each of the time interval test plates, an 8" long weld bead was first deposited above water.

b) With test plates at -33', the wet primary weld bead was deposited parallel to, and slightly overlapping the dry weld bead.

c) With the wider area of weld metal, the welder had complete control over travel speed, bead morphology (size and geometry) and heat input as he deposited the temper beads over the wet primary beads.

With the small degree of overlapping, the dry welds did not appear to affect either the deposition behavior of the underwater primary and temper beads, or the performance of the temper beads. The presence of these prewelds did not alter the significance of the time interval determined. However, the dilution of the wet primary bead had changed as a result of the weld bead deposited above water. Figure 4 shows the cross section of a weld specimen, illustrating the overlapping weld deposition sequence according to the scheme described.

For time intervals, $t_{p/t}$, ranging between 30 and 210 seconds, two 10" long plates were laid out and welded as shown in Figure 5. A photograph of experimental welds to determine the $t_{p/t}$ is shown in Figure 6. The combination of different weld sequences (directions of welding) with start delays allowed for the preparation of specimens that experienced different times between the primary and temper bead. A total of eleven time intervals were obtained from the two sets of welds. Eleven cross sections (at 15 to 30 second intervals) corresponding to the eleven time intervals described above were removed from the two weldments and examined for hydrogen induced underbead cracking in the HAZ.

Instead of the 5X magnification specified by AWS D3.6, 100X magnification was used to evaluate the eleven specimens for underbead cracking. The higher magnification was to ensure

a more rigorous testing procedure than that called for in the AWS D3.6 specification. Six specimens were found to be crack free. These welds correspond to the ones on which temper beads were deposited at 30, 45, 105, 120, 135, and 195 second intervals. The Material Joining Work Report for the 30 to 210 second welds, and the test results of the 30 seconds $\Delta t_{p/t}$ weld are shown on the following pages. The test reports of the other sound welds are included in Appendix V.

The remaining five specimens (corresponding to $t_{p/t}$ of 60, 90, 150, 180, and 210 seconds) exhibited some fine cracking which required more detailed examination. The test report of the 60 seconds $t_{p/t}$ weld is shown in the following pages. The test reports of the other four weld specimens with cracks are included in Appendix VI. Descriptions of cracks observed in these welds are given in Table III.

Upon recommendation of SRC Engineers, Inc., CSM was requested to examine these five weld specimens. Microscopic examination using magnifications as high as 1000X was performed to observe the cracks. Some of the lower magnification (100X) micrographs, Figures 7 to 11, are included in this report. Figure 7 shows several cracks observed in the specimen of 60 seconds $t_{p/t}$. The interconnected cracks are oriented along the rolling direction, which indicates a relationship to base metal inclusions. Some inclusions are known to act as hydrogen traps. However, the jagged appearance of the crack also reminds of hydrogen cracking.

Figure 8-A shows a photograph of the cross sections of the specimen of 90 seconds $t_{p/t}$, indicating the presence of hydrogen cracks. The cracks, located in the coarse grained heat affected zone of this weld, are clearly visible in Figure 9. However, the crack appears to have occurred because of the location of the crater. With the extinction of the arc, the lower arc energy and the collapse of the shielding gas column contribute to a large influx of hydrogen. This explanation seems to be reasonable since the opposite side of the sample did not show any evidence of cracking, Figure 8-B.

Global Divers
& Contractors, Inc.

MATERIALS JOINING WORK REPORT
Part 1 MTB Time Intervals, 30 thru 210 Sec's

Location GLOBAL DIVERS - PORT OF IBERIA Contract No. 91-M-4346

Mat'l (1) A 537 Grade Cl 1
Ht./Slab No. 76006-12
Thick 5/8" in. Dia. _____ in.

Mat'l (2) _____ Grade _____
Ht./Slab No. _____
Thick _____ in. Dia. _____ in.

Electrode (AWS) E 6013 A5.1/E 7018 A5.1 TN Program Ex 7/LH-718-Mo Mfr. Proprietary/Hobart Ctry _____

Process SMAW Current/Polarity CC/DCEP/PULSE Joint Type BEAD-ON-PLATE Position 3G

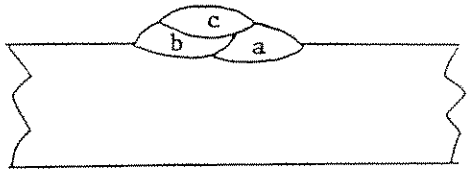
Water Depth 33' Dry _____ Wet X

Welding Variables:

R F & C	PASS	DIA.	AMPS	VOLTS	I.P.M.	REMARKS
BOP	1	1/8"	155	30	8.0	Dry weld (E 7018)
BOP	2	1/8"	155	30	7.8	Wet Primary Bead (E 6013)
Temper	3	1/8"	155 - 160	28 - 30	6.5	Wet Temper Bead (E 6013)

Welder: Darryl R. Phillips Date: 6-21-93

Welding Joint Sketch:



a - Dry Weld Bead b - Wet Primary Bead
c - Wet Temper Bead

Welding Techniques:

Bead-on-plate downhill. Times between start of primary bead and start of temper beads varied from 30 sec's to 210 sec's in approximately 30 sec intervals. (See sketch of plate layouts).

Global Divers
& Contractors, Inc.

Sheet 2 of 2
W/O No. ED-007X-93

Tension Tests: (Reduced Section/All-Weld-Metal) N/A

SPECIMEN	ORIENT	ULTIMATE S.	YIELD S.	ELONGATION	FAILURE
1					
2					

Bends: N/A

SPECIMEN	ROOT	FACE	SIDE	RADIUS	RESULTS
1					
2					
3					
4					

Chemistry: A-537 Cl.1

	CE	C	Mn	P	S	Si	Ni	Cr	Mo	Cu	V	Cb	Nb	Al
CTR														
LAB	.462	.20	1.50	.014	.019	.38	.03	.02	.01	.03	.01	.01	—	—

Hardness (Vickers/Rockwell): N/A

LOCATION	LEFT SIDE	RIGHT SIDE
BASE METAL (AVG.)		
HAZ (MAX)		
HAZ (AVG)		
WM (MAX)		

Purpose of Test: Determine maximum acceptable time between start of primary weld beads and start of temper beads. (How long does it take for hydrogen induced underbead cracking to occur in the HAZ of wet welds)?

Remarks & Evaluation: At ≤ 100X, no cracks were detected when temper beads were deposited at 30, 45, 105, 120, 135, and 195 sec's intervals. See attached report reference anomalies detected in the 60, 90, 150, 180 and 210 second specimens.

By: C.E. Grubbs Date: 6-21-93 Rev: —

SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch on weld sample
P.O. #GD106064 Underwater Weld Sample-30 sec.

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 5X, 50X, & 100X Magnification.

No evidence of any Hydrogen Cracking were found.

EQUIPMENT UTILIZED FOR TEST
Type: Metallograph
Manufacturer: Olympus
Serial No.: 502796
Last Servicing: December, 1992

SRC Job No. 92-352

Certified By: _____ Date: 6-24-93

Reviewed By: _____ Date: 6-24-93

GLOBAL.MAC

SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch on weld sample
P.O. #GD106064 Underwater Weld Sample-60 sec.

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 5X, 50X, & 100X Magnification.

Indications of Unidentified Cracks were found.

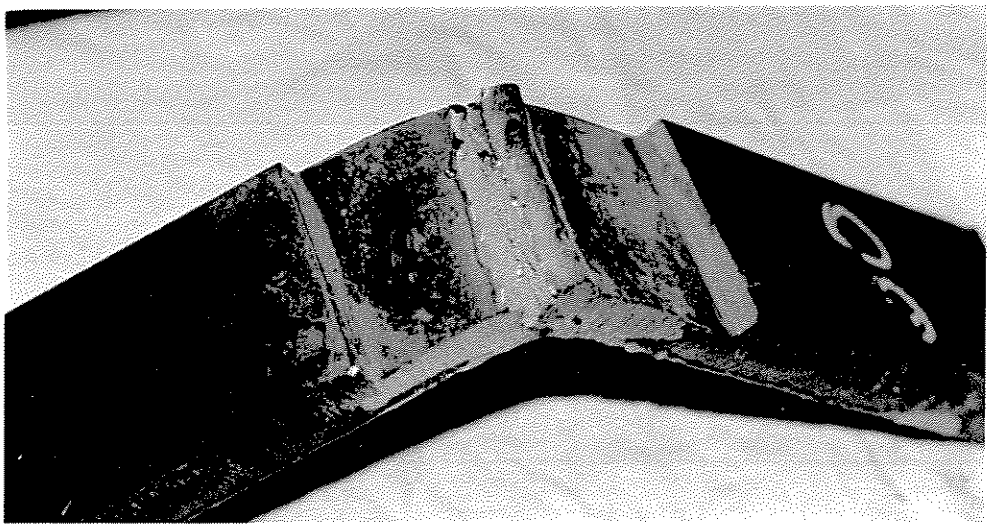
Further study of these cracks by the Colorado School of Mines is advised.

EQUIPMENT UTILIZED FOR TEST
Type: Metallograph
Manufacturer: Olympus
Serial No.: 502796
Last Servicing: December, 1992

SRC Job No. 92-352

Certified By: Tim Rousseau Date: 6-24-93

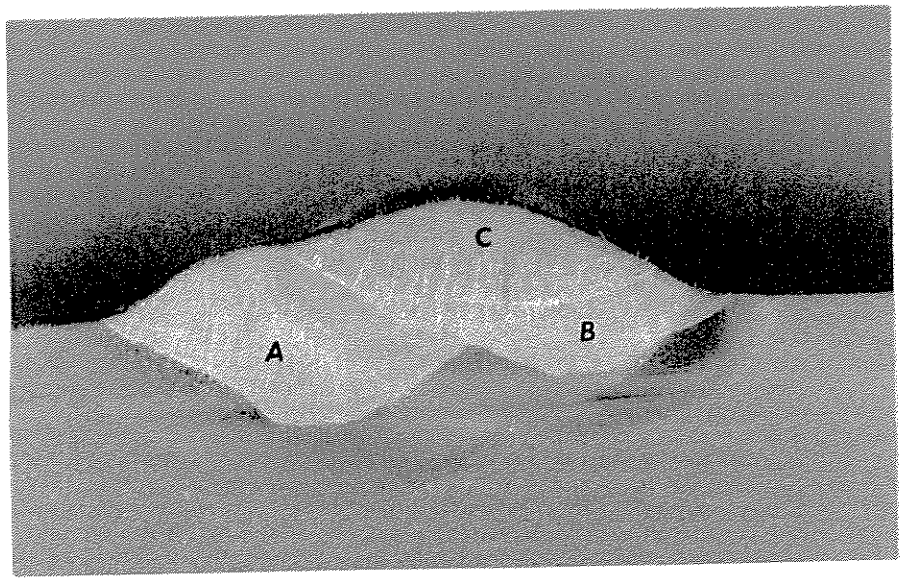
Reviewed By: Scott A Dilley Date: 6-24-93



HAZ Crack in Bend Specimen Due to Lack of Temper Bead Heat Input in Primary Bead on A537 Cl.1 (CE .462) Plate

Fig. 3

Cross Section of Weld Beads on Plate



A - Weld Bead Deposited Above Water
B - Wet Primary Weld Bead C-Wet Temper Bead

Fig. 4

LATE LAYOUTS FOR TIME INTERVALS BETWEEN PRIMARY BEADS AND TEMPER BEADS (BASED ON 8" LONG WELD BEAD PER MINUTE)

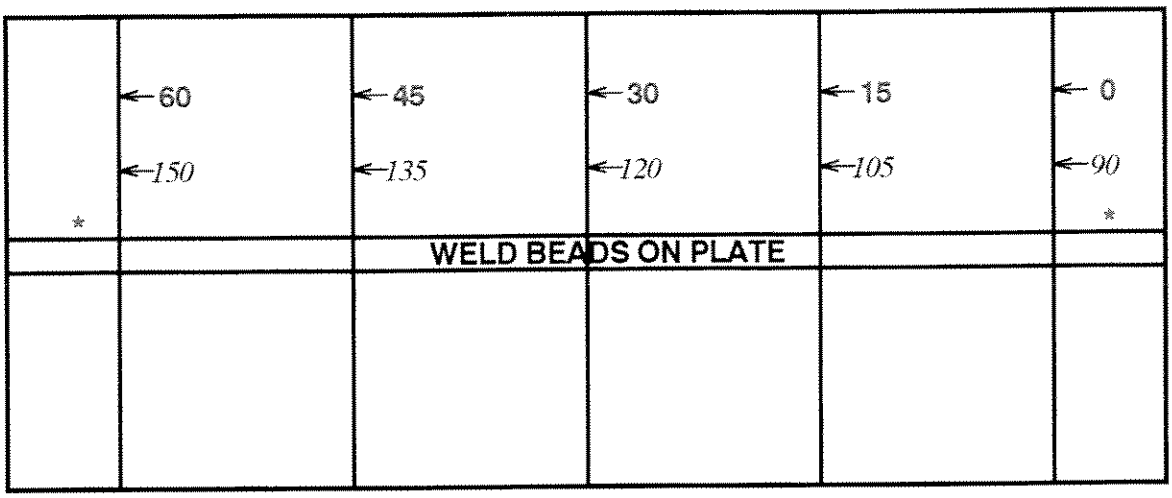


PLATE #1

Primary Bead Right to Left

Temper Bead Right to Left

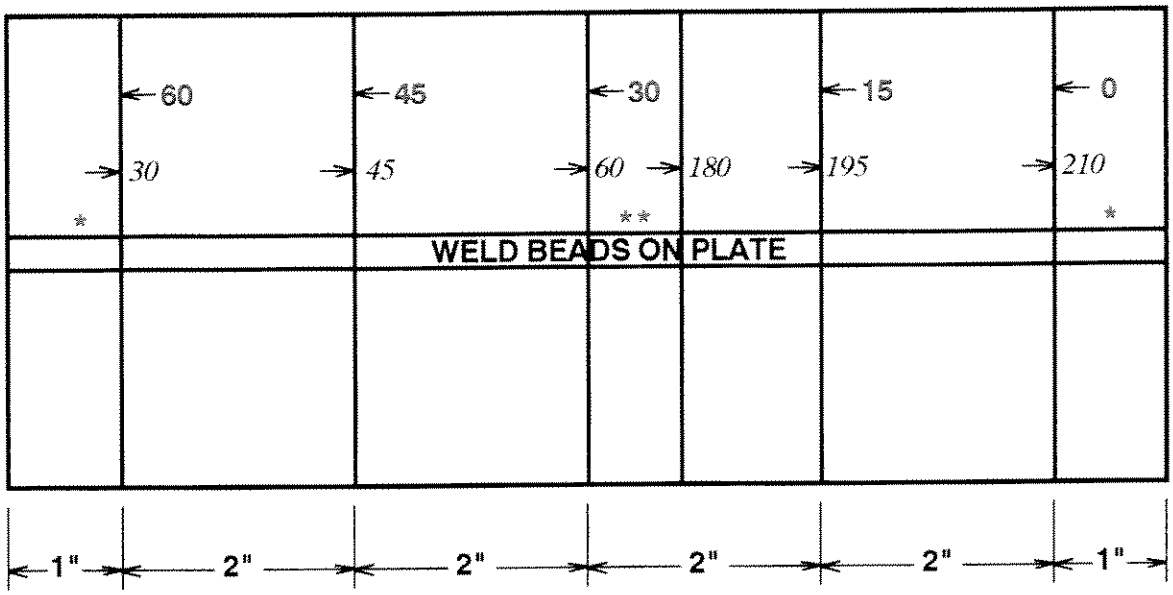


PLATE #2

Primary Bead Right to Left

Temper Bead Left to Right

Primary Bead - Number of Seconds.

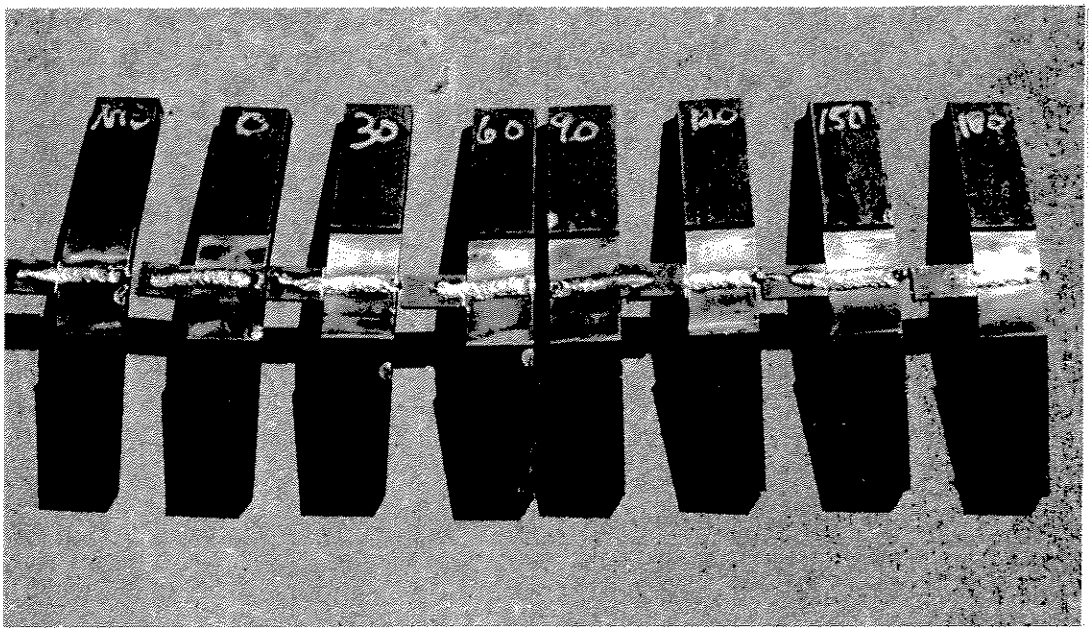
Temper Bead - Number of Seconds, After 30 Seconds Start Delay.

* - Start/Stop Beads.

** - 120 Second Delay.

Figure 5

First Experimental Weldments to Determine Maximum Acceptable Time Interval Between Start of Primary Weld Bed and Temper Bead



AWS 2" x 12" Bridge Bend Specimen

Fig. 6

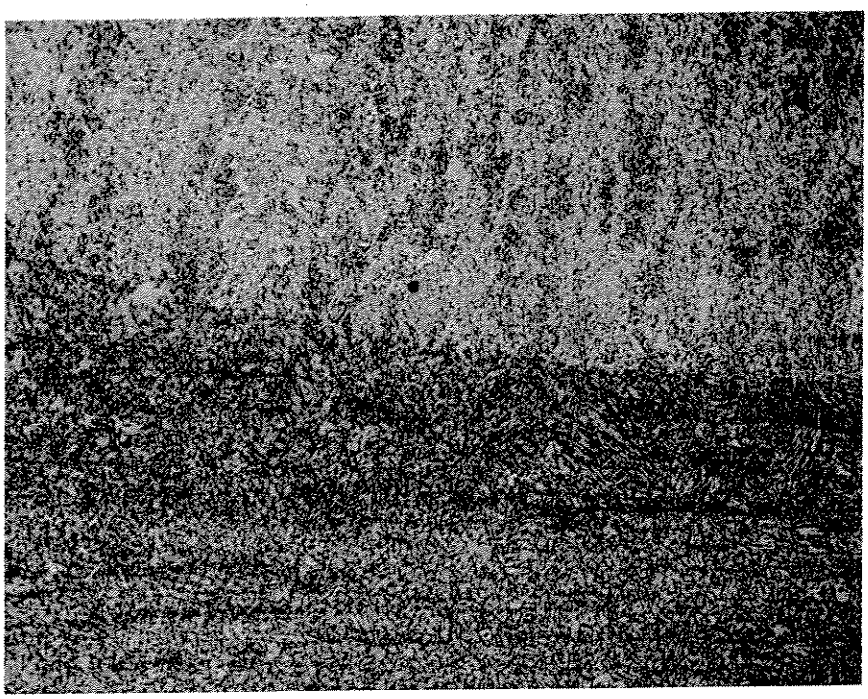
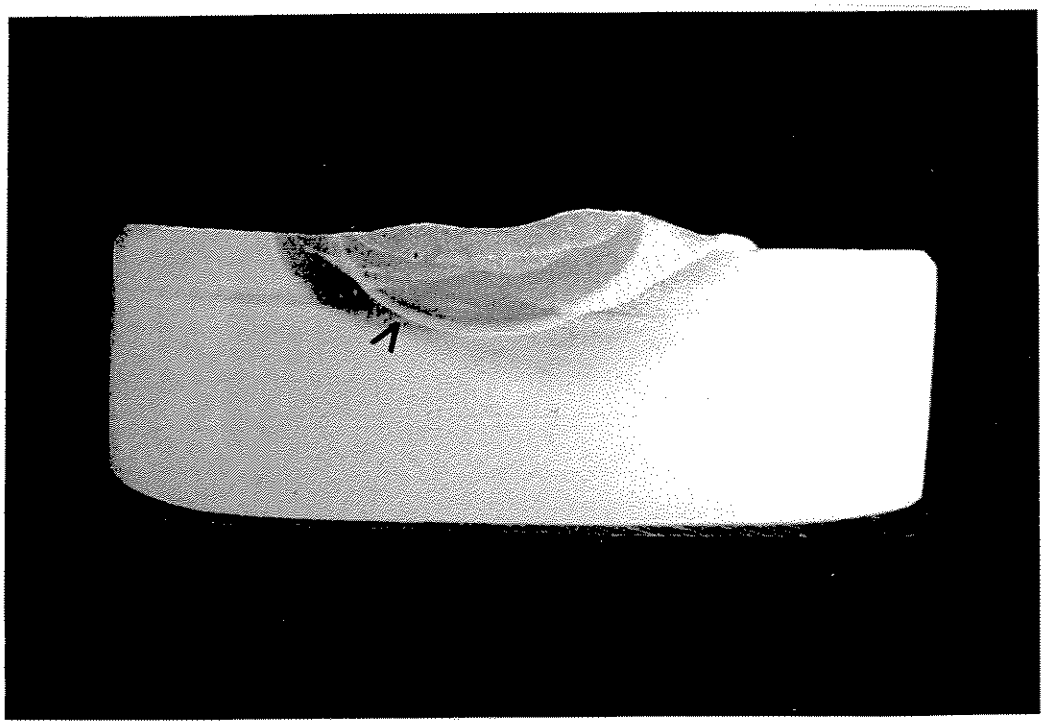


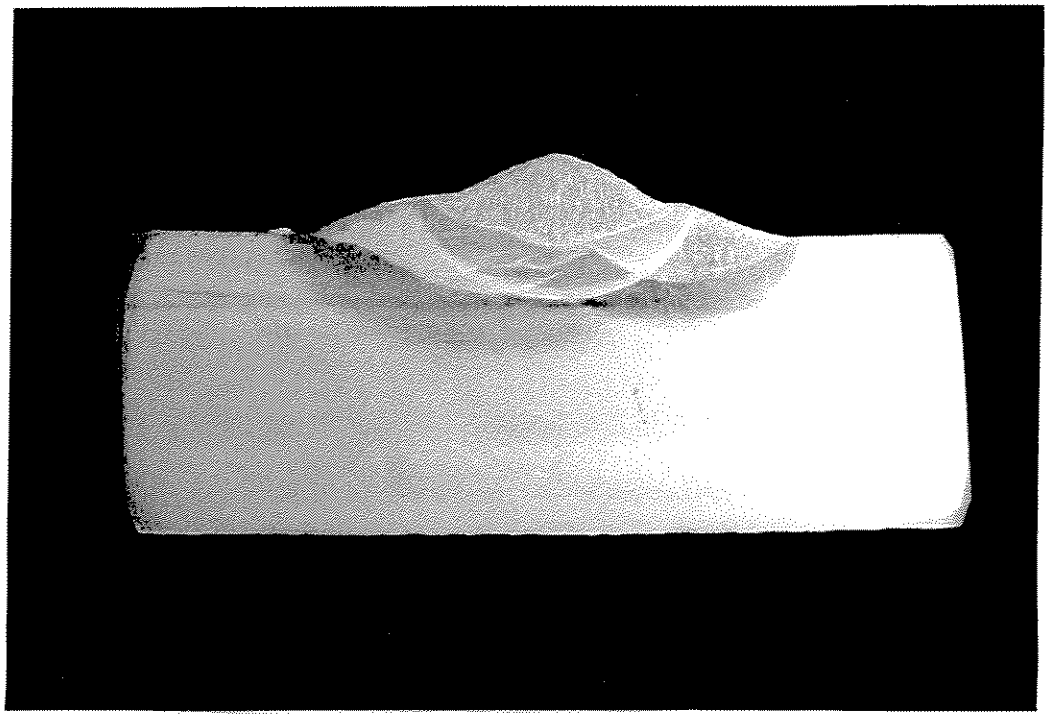
Figure 2. A photomicrograph of the cracks noted in left weld pass HAZ of macro-section 60. (100X, Nital Etch)

Cross Section of 90 Second Time Interval Weldment



Hydrogen Crack in HAZ of Primary Weld Bead
Due to Concave Temper Bead (Lack of Heat Input)

Fig. 8 **A**



Reverse Side of 3/8" Cross Section Had
Full Temper Bead and No Cracks

Fig. 8 **B**

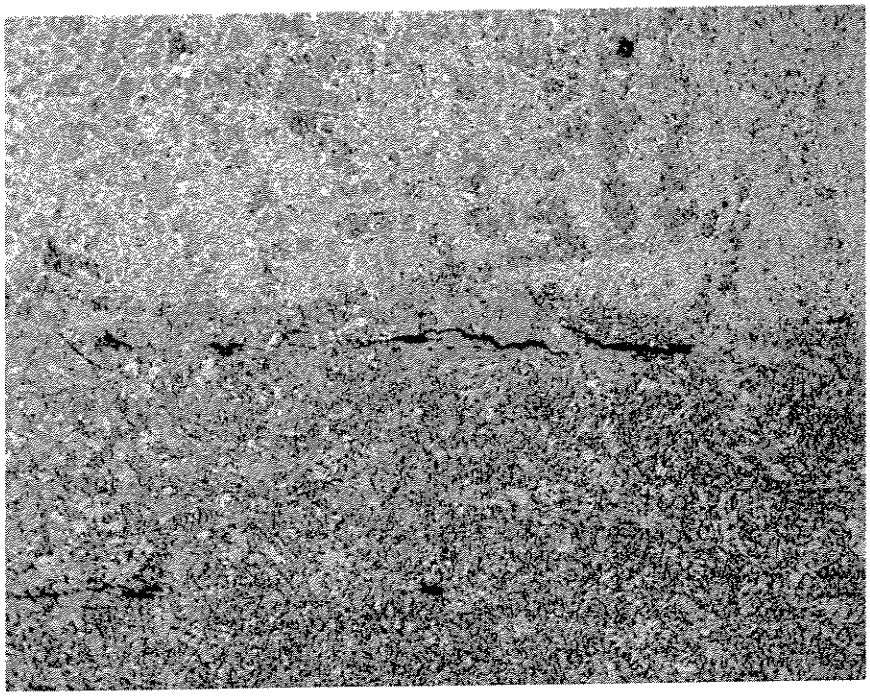


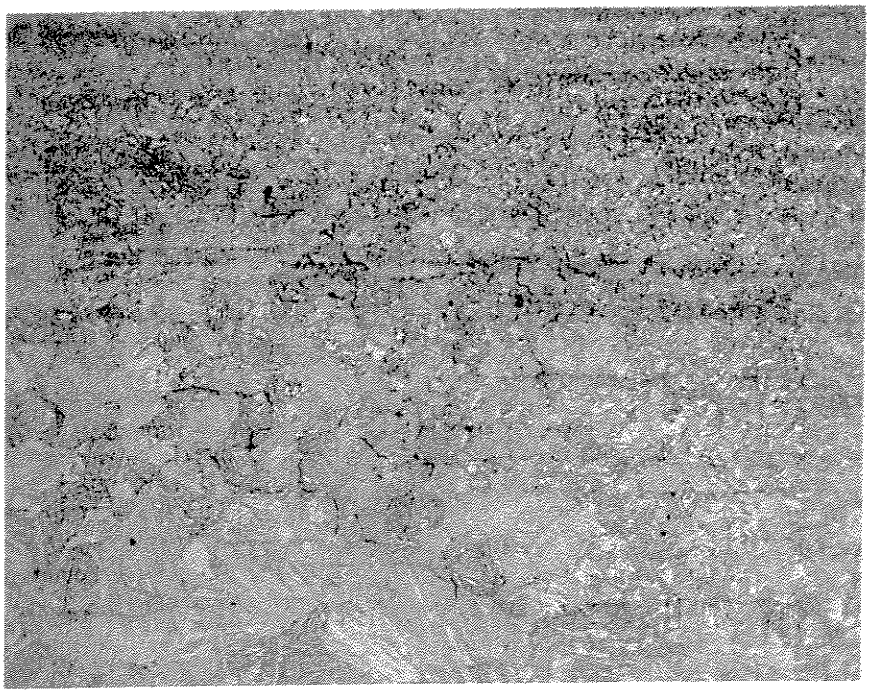
Figure 3. A photomicrograph of the cracks noted in left weld pass HAZ of macro-section 90. (100X, Nital Etch)

Table III. Description of the Cracks observed in the Multiple Temper Bead Weldments

Time between Primary and Temper beads ($t_{p/t}$)	Description of Crack (Interpretation by Scientific Testing Laboratories, Inc.)
60 seconds	Several small cracks in the HAZ of the left weld pass (wet primary weld bead). Identification of the type of cracking was not possible at 100X magnification. The cracks are aligned with elongated MnS inclusions. Such type of inclusions are known as excellent sites for hydrogen entrapment.
90 seconds	Micro-examination (100X magnification) showed typical hydrogen induced cracking in the HAZ of the left weld pass (wet primary pass). [Later visual examination of the specimen revealed excessive concavity in the temper bead (weld crater) which resulted in inadequate heat input where the cracking occurred. Reverse side of 3/8" thick specimen was examined at 100X magnification and found to be without anomalies.]
150 seconds	Fine cracks in the HAZ of the right weld pass (Dry E7018 weld bead). Identification of type of cracks was not possible at 100X magnification.
180 seconds	A maze of small cracks in the HAZ of the right weld pass (Dry E7018 weld bead).
210 seconds	Dr. S. Ibarra (Amoco Research) examined this specimen and detected no hydrogen induced cracking in the HAZ.

Figures 10 and 11 show multiple fine cracks located in the heat affected zones of the weld specimens of $t_{p/t}$ of 150 and 180 second. These cracks are intergranular, typical of hydrogen cracking. However, since these welds were deposited dry, these cracks are not related to the multiple temper bead procedure.

Based on examinations by SRC Engineers, CSM, and reexaminations by Scientific Testing Laboratories of the vertical groove welds made with the Program EX 7 electrodes on the ASTM A537 Class 1 steel plate, none of the typical hydrogen induced underbead cracking were



Photomicrograph of Cracks Noted in the Right (Dry) Weld Pass HAZ of Macro-section 150 Seconds Weldment. (100X, Nital Etch).

Fig. 10

Photomicrograph of Cracks Noted in the Right (Dry) Weld Pass HAZ of Macro-section 180 Seconds Weldment. (100X, Nital Etch).

Fig. 11

detected in the HAZ of the eleven weldments. With this information established for welds made with time between deposition of primary weld beads and start of temper beads ranging from 30 to 210 seconds (3.5 minutes), welds were made with the time between beads extending from four minutes to four hours with the following results when examined at 100X:

Results

* Four minutes to ten minutes with thirty second intervals. No HAZ cracks.
* Ten minutes to sixty minutes with ten minute intervals. No HAZ cracks.
* One hour to two hours with thirty minute intervals. No HAZ cracks.
* Two and one-half hours to four hours with thirty minute intervals. All specimens had typical HAZ hydrogen induced cracking.

Results of examinations of welds made with time between deposition of primary weld beads and temper beads varying from four minutes to four hours are reported in Appendix VII.

Supplemental Information (Two Reports)

1. Subsequent to the completion of the scheduled program welds that were made to determine the maximum acceptable time between deposition of the primary weld beads and temper beads, the following supplemental welds were made possible by the assistance of Mr. Tom West.

At the time Mr. West was overseeing an underwater wet welding research project for the U.S. Navy which involved using nickel electrodes to weld crack susceptible ASTM A516 Grade 70 (CE .44 wt. pct.) normalized 3/4" steel plate. While making a weld with commercial ferritic electrodes to confirm the crack susceptibility of the material, the underwater welder saw typical hydrogen cracking in the HAZ of the base metal. Because this had not occurred when making any of the many welds Global Divers made on the A537 Class 1 (CE .462) material with the Program Ex 7 electrodes, Mr. West provided enough of the A516 Grade 70 plate for Global to make two vertical 3/4" groove welds with the Ex 7 electrodes. Both welds were made at -33 ft, one was made using the multiple temper bead wet welding technique and the other was made with no intentional use of temper beads. (The welds that developed cracks during welding and the two welds made by Global were made in south Louisiana in August, so water temperature was not a factor). While making the weld with no temper beads, the welder looked for, but did

not see any cracks in the HAZ and no cracks were detected in the HAZ when the completed weld was subjected to magnetic particle examination. Four cross sections from each of the two welds were later examined by SRC Engineers at 100X and 400X magnification. Hydrogen cracks were detected in three of the four specimens taken from the weld made with no deliberate effort to use temper beads. (Some weld beads that tie-in to the base metal may be tempered regardless of the welding technique). The SRC test results are shown on one of the following pages.

2. Listed below are examples of materials that, when being welded with other than Ex 7 electrodes, developed HAZ hydrogen cracks before the welds were completed. (All weldments were restrained):

   * ASTM A516, Grade 70 (CE .44) - "welder saw cracks as weld was being made".
   * ASTM A516, Grade 70 (CE.37) - "before capping the weld, welder saw cracking in the heat affected zone".
   * DH 36 (CE .43) - "HAZ cracks seen by welder after, or during, laying down third layer of weld beads".
   * BS 4360 Grade 50 D (CE .416) - "welder saw HAZ cracks while making a severely restrained 3/4" fillet weld".
   * BS 4360 Grade 50 D (CE .416) - "rusty cracks in HAZ of fractured surfaces of bend specimens indicated that cracks developed while the weldment was still underwater".

The importance of the test results of welds made with the Ex 7 electrodes on the A516 Grade 70 (CE .44) material, and the experiences of using other electrodes to weld the five other crack susceptible base metals, is discussed in the MTB Conclusions section of this report.

Maximum Acceptable Distance Between the Toes of Primary and Temper Beads

The effectiveness of the multiple temper bead technique is intimately related to the thermal profile that the temper bead imposes on the primary bead. Thus, the location of the temper bead with respect to the primary bead is a critical factor in this procedure. It is desirable to determine the significance of requiring an "exact" toe-to-toe distance between the primary and temper beads. If an exact toe-to-toe distance is not required, what is the maximum distance between the primary and temper beads without the risk of HAZ hydrogen cracking and

mechanical properties deterioration in a crack susceptible base metal?

Four 5/8" groove welds were made on A537 Cl.1 steel plates in the vertical position. The toe- to-toe distances were 1/16", 3/32", 1/8", and 3/16". The time between start of primary weld beads and temper beads ranged from 90 to 120 seconds. Weld examinations included microscopic, four weld cross sections from each weldment were examined at 100X magnification, four hardness profiles from each weldment at Vickers 10 kg load, and five Charpy V-notch impact tests at 28° F. For statistical significance, the highest and lowest impact energy were discarded and the remaining three averaged for reporting as specified by AWS D3.6 for Class A welds. A Global Divers work report on the 1/16" toe-to-toe distance welds is included in the following pages. The other reports (for $d_{p/t}$ of 3/32", 1/8" and 3/16") are compiled in Appendix VIII.

Microscopic Examination

Microscopic inspection of the weld specimens did not detect any cracking, which demonstrates that even with a toe-to-toe distance of 3/16", there was enough temper bead heat input to prevent HAZ hydrogen cracking.

Vickers hardness measurements

Vickers 10 kg hardness surveys were made on four cross sections from each of the weldments. A schematic drawing of the cross section #1 of weld 1/16" $d_{p/t}$, has been included as Figure 12 to show the locations of the hardness readings. In general, a total of twenty eight hardness readings were made on each weld specimen: twelve in the weld metal, twelve in the heat affected zone, and four in the base metal. The average hardness readings are summarized in Table IV.

Global Divers
& Contractors, Inc.

Sheet 1 of 2
W/O No. ED-007-93

MATERIALS JOINING WORK REPORT
Part 1 MTB Toe-to-Toe Distance 1/16"

Location GLOBAL DIVERS - PORT OF IBERIA Contract No. 91-M-4346

Mat'l (1) A 537 Grade Cl 1
Ht./Slab No. 79006-12
Thick 5/8" in. Dia. _____ in.

Mat'l (2) _____ Grade _____
Ht./Slab No. _____
Thick _____ in. Dia. _____ in.

Electrode (AWS) E 6013 A5.1 TN Program Ex 7 Mfr. Proprietary Ctry _____

Process SMAW Current/Polarity CC/DCEP/PULSE Joint Type V-GROOVE (8") Position 3G

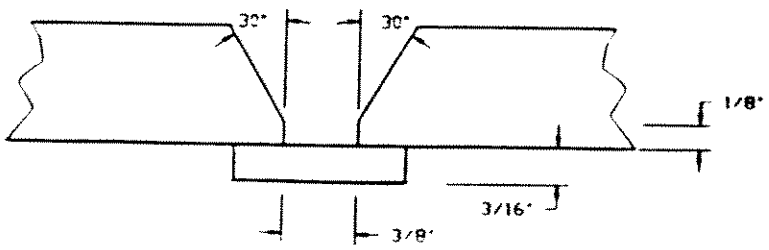
Water Depth 33' Dry _____ Wet X

Welding Variables:

R F & C	PASS	DIA.	AMPS	VOLTS	I.P.M.	REMARKS
ROOT	1	1/8"	150 - 160	28 - 30	5.6	Temper beads were deposited on all
ROOT	2	1/8"	150 - 160	28 - 30	6.3	beads that tied into the base metal.
[illegible]	AVG	1/8"	155	30	9.4	Toe-to-toe distances were 1/16".
FILL	AVG	1/8"	155	30	8.6	Number of passes -33. Electrodes
CAP	AVG	1/8"	155	30	9.2	consumed -37. Welding time 54
						minutes.

Welder: Darryl R. Phillips Date: 6-1-93

Welding Joint Sketch:



Welding Techniques:

Stringer Beads with all passes downhill.

Global Divers
& Contractors, Inc.

Tension Tests: (Reduced Section/All-Weld-Metal) N/A

SPECIMEN	ORIENT	ULTIMATE S.	YIELD S.	ELONGATION	FAILURE
1					
2					

Bends: N/A

SPECIMEN	ROOT	FACE	SIDE	RADIUS	RESULTS
1					
2					
3					
4					

Chemistry:

	CE	C	Mn	P	S	Si	Ni	Cr	Mo	Cu	V	Cb	Nb	Al
CTR														
LAB	.462	.20	1.50	.014	.019	.38	.03	.02	.01	.03	.01	.01	---	---

Hardness (Vickers/Rockwell): Vickers 10 kg, combined test results on four macros.

LOCATION	LEFT SIDE	RIGHT SIDE
BASE METAL (AVG.)	187	189
HAZ (MAX)	395	434
HAZ (AVG)	259	256
WM (MAX)	240	210

Purpose of Test: Determine maximum acceptable distance between toes of primary beads and toes of temper beads.

Remarks & Evaluation: See HAZ hardness tests, 6 each side on .5mm center, under toe of cap where maximum hardness can be expected. Charpy v-notch HAZ impacts at 28° F. averaged 72 ft. lbs. with 70% shear. Base metal charpys averaged 86.7 ft. lbs. with 100% shear. No HAZ cracks at 100X.

By: C.E. Grubbs Date: 6-1-93 Rev: ---

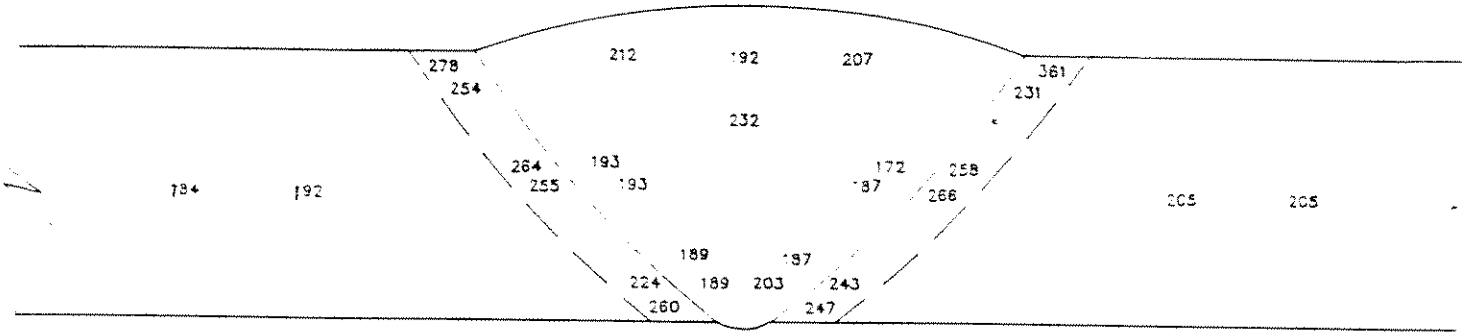
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers 10kg load hardness test on weld sample
P.O. #GD106306 Underwater Weld Sample #1(1/16")
3G - With T.B.

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



Note: HAZ Examined at 5X, 40X, & 100X Magnification

EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 18, 1993

SRC Job No. 92-352

Certified By: _____ Date: 6-14-93

Reviewed By: _____ Date: 06-14-93

VICKERS.WLD

FIGURE 12

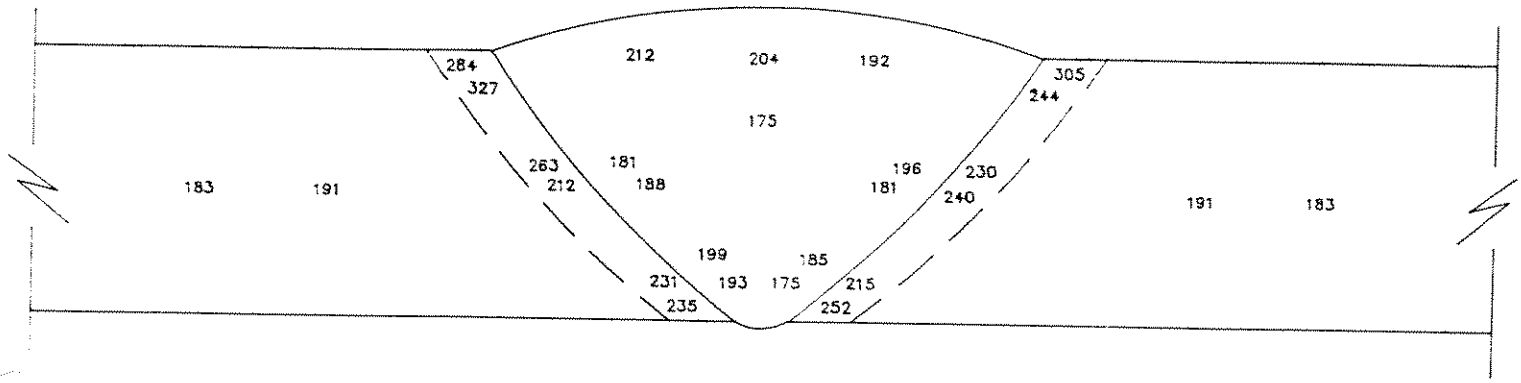
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers 10kg load hardness test on weld sample
P.O. #GD106306 Underwater Weld Sample #2(1/16")
3G - With T.B.

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



Note: HAZ Examined at 5X, 40X, & 100X Magnification

EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 18, 1993

SRC Job No. 92-352

Certified By: Tim Pursel Date: 6-14-93

Reviewed By: Stephen L. Collins Date: 06-14-93

VICKERS.WLD

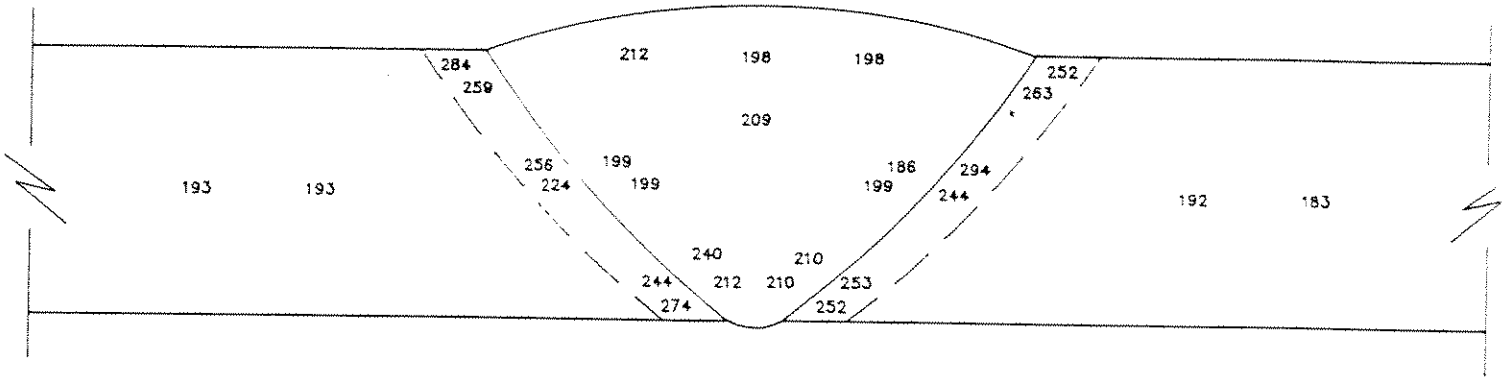
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers 10kg load hardness test on weld sample
P.O. #GD106306 Underwater Weld Sample #3(1/16")
3G - With T.B.

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



Note: HAZ Examined at 5X, 40X, & 100X Magnification

EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 18, 1993

SRC Job No. 92-352

Certified By: _____ Date: 6-14-93

Reviewed By: _____ Date: 06-14-93

VICKERS.WLD

Table IV. Hardness Data of the Experimental Welds in the $d_{p/t}$ Determination.

Toe-to-toe Distance $d_{p/t}$	Average Base Metal Hardness (HV_{10k})	Average Weld Metal Hardness (HV_{10k})	Average HAZ Hardness (HV_{10k})	Hardness Readings Greater than 325 (HV_{10k}) (1) (2)
1/16"	188	240	257	327, 344, 356 361, 395, 434
3/32"	178	260	244	369, 345
1/8"	174	212	266	340, 361
3/16"	169	286	258	332

(1) AWS D3.6 specifies a maximum hardness of 325 HV_{10k} for Class A (dry) weldments.

(2) Includes sixteen test sites (2 on each side of 4 specimens) per weldment at 0.5 mm centers under toe of cap pass on each side of weldments [Typically the hardest areas except one 1/16" weld (Fig 13)].

All base metal hardness readings were reasonably consistent throughout the specimens and averaged 178 HV_{10k}. Weld metal hardness averaged 250 HV_{10k} with a maximum reading of 260 HV_{10k}. HAZ hardness averaged 256 HV_{10k} with five of the initial 96 readings exceeding the 325 HV_{10k} maximum specified by AWS D3.6 for Class A (dry) welds. However, four of the five readings (340, 344, 361 and 434 HV_{10k}) could be identified with welds that experienced irregular processing, whether inadequate heat input or misplacement of the temper bead (overlapping the base metal). The schematic drawing of the cross section #4 of weld 1/16" $d_{p/t}$, with all the hardness data is shown in Figure 13. As a result of the hardness fluctuations observed, more hardness readings were made in this weld. The hard spots were all located in the heat affected zone at the toe of the weld. This observation indicates the need for more heat input from the temper bead at the toe of the weld to eliminate the hard spots. The individual hardness readings are compiled in Appendix XIII.

Charpy V-notch impact toughness measurements

Charpy impact tests were carried out at 28°F to determine the impact toughness

of the HAZ of four welds. The shear fracture and lateral expansion of each of the fractured specimens were also measured. The experimental data obtained are listed in Table V.

Table V. HAZ Charpy V-notch Impact Testing Results of the $t_{p/t}$ Weld Specimens at 28°F.

Toe-to-Toe Distance, $t_{p/t}$	Absorbed Energy (ft-lb)	Shear Fracture (percent)	Lateral Expansion (mils)
1/16"	72	70	60
3/32"	47	75	43
1/8"	49	85	52
3/16"	50	80	55
Base Metal	86	100	77

The heat affected zones of all four "toe-to-toe distance" wet weldments exceeded the Charpy V-notch impact requirements for AWS D3.6 Class A (dry) welds. For the 1/16" $d_{p/t}$ weldment, the Charpy V-notch impact tests resulted in an average absorbed energy of 72.3 ft-lb and 70 percent shear on the fracture surface. These impact properties compared favorably with those of the base metal, 86.6 ft-lbs and 100 percent shear. For the 3/32", 1/8" and 3/16" "toe-to-toe distance" weldments, the Charpy test results ranged from 47 ft lbs with 75 percent shear to 50 ft lbs with 80 percent shear. Even though these results were not as impressive as the 1/16" $d_{p/t}$ welds, they all exceeded the requirements of AWS D3.6 for Class A (dry) welds. (10 ft lb minimum and ≥ 15 ft lb average). It is interesting to note that while the HAZ notch toughness of the 1/16" weldment was significantly greater than that of the other weldments, its HAZ hardness was also higher.

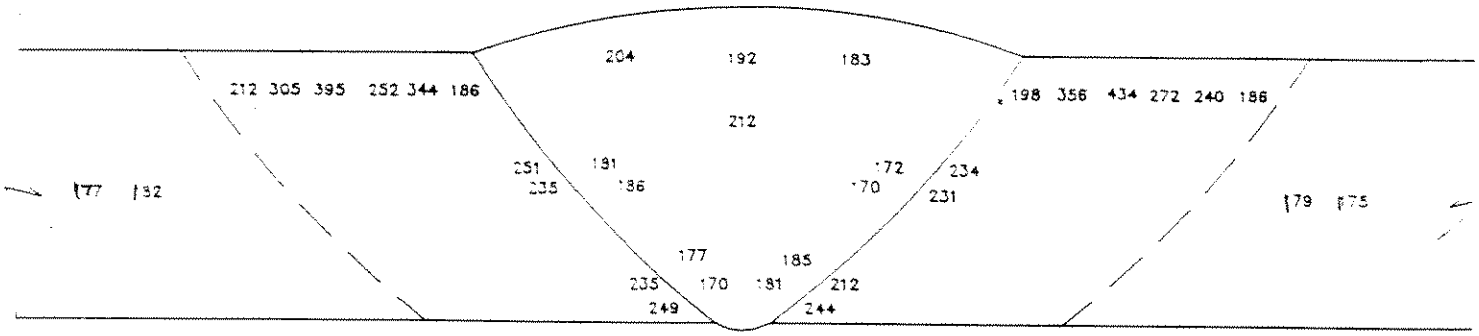
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers 10kg load hardness test on weld sample
P.O. #GD106306 Underwater Weld Sample #4(1/16")
3G - With T.B.

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



Note: HAZ Examined at 5X, 40X, & 100X Magnification

EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 18, 1993

SRC Job No. 92-352

Certified By: _____ Date: 6-14-93

Reviewed By: _____ Date: 06-14-93

VICKERS.WLD

FIGURE 13

Temper Bead Heat Input

As a result of the excellent Charpy impact results of the weldments with 1/16", 3/32" and 3/16" toe-to-toe distance, the welding processing parameters and heat input selected were close to the optimal. However, it was obvious that more heat input would be required in cap passes at the toes of the welds to lower the hardness in the HAZ under those weld beads to the 325 maximum specified by AWS D3.6 for Class A (dry) welds. TAC members proposed that fillet welds, which are most often used for underwater repairs, be used for additional heat input efforts. The following supplemental report covers those successful efforts.

PHASE I SUPPLEMENTAL REPORT

WET FILLET WELDS WITH AND WITHOUT TEMPERING, WITH VARYING DEGREES OF RESTRAINT AND FIVE LEVELS OF HEAT INPUT

Background

Members of the Technical Activities Committee proposed a further investigation of the effectiveness of the multiple temper bead (MTB) wet welding technique in preventing hydrogen induced underbead cracking, and reduction of hardness, in the HAZ of wet fillet welds.

Objective

Expand previously developed information pertaining to groove welds, and more recent information on fillet welds, to include not only the ability to prevent HAZ hydrogen cracking but also the ability to reduce HAZ hardness to the Vickers 10 kg 325 maximum specified by AWS D3.6 for Class A (Dry) welds.

Justification

This supplemental investigation is especially meaningful because the vast majority of underwater wet welded structural repairs are made with fillet welds.

Test Program

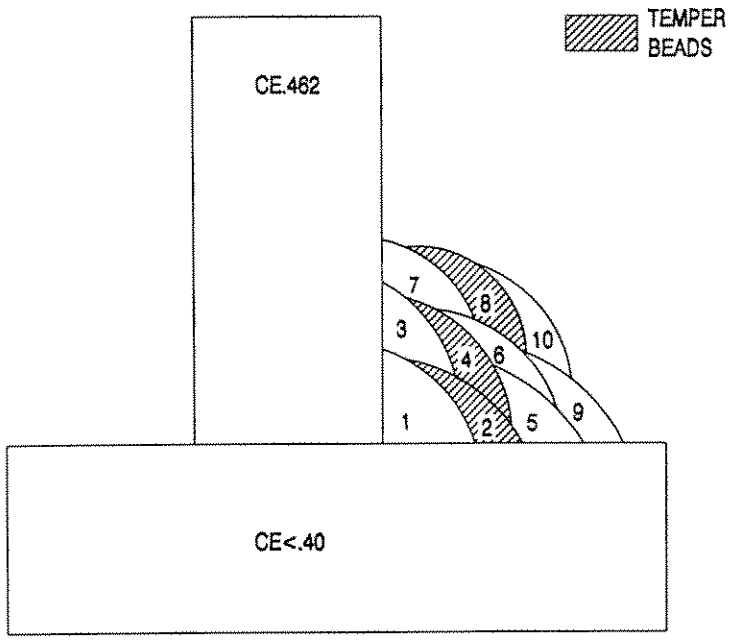
5/8" vertical wet fillet welds were made on 3/4" A537 C1.1 normalized (C.20 and CE.462) steel plate with the Program Ex 7 electrodes at -33'. Cross sections were polished/etched and examined at 100x for HAZ hydrogen cracking. Vickers 10 kg hardness tests were made as required by AWS D3.6 for Class A (Dry) welds. Weldments were restrained by either dry, or wet, opposing fillet welds and by welded or mechanical fixtures. (See Photographs)

The work was done in two parts. During Part 1, (reported in the January 1994 Interim Report) two welds were made without temper beads, one with dry welded restraint and the other with mechanical fixture restraint. Two MTB welds were then made with temper bead heat input at 25.5 kJ/in. and the same two types of restraint.

During Part 2, restrained (see Table 1 for types of restraint) MTB welds were made with heat inputs of 32.2, 34.6, and 37.0 kJ/in. A fourth restrained MTB fillet weld was made on which, after the weld was built up to full size, the thickness of two primary weld beads that tied in to the base metal at the toe of the weld was reduced to approximately one-half by grinding, and then reheated by temper beads deposited with 3/32" Ø welding electrodes. (1/8" Ø electrodes were used for all other welding) Calculated heat input was 29.3 kJ/in. See Fig. 1 for the MTB wet welding technique and Fig. 2 for the MTB/Half-Bead technique including sequence and placement of weld beads/passes.

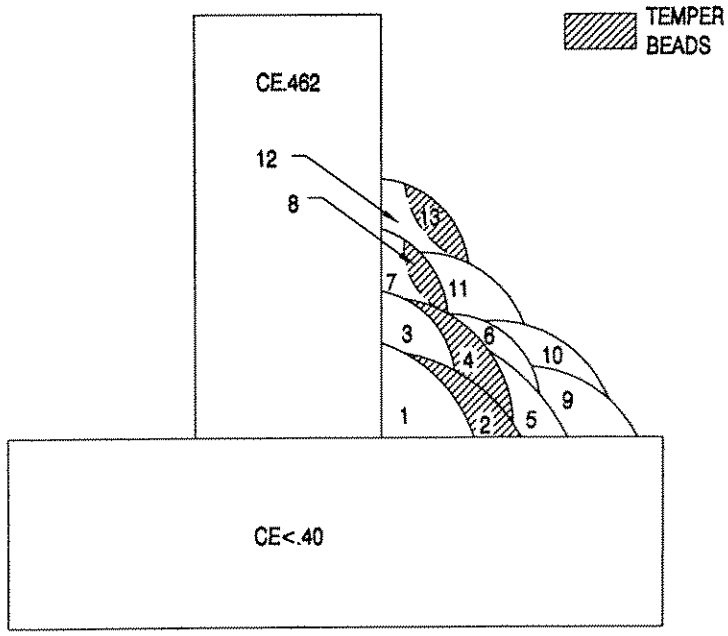
Results-Multiple Temper Bead Weldments

As shown by the Summary of Vickers 10 kg test results and Table 1 that are part of this report, except at the toe of the weld, all areas of the HAZ are sufficiently tempered (HV 10 < 300) by overlaying weld beads, with or without any deliberate effort by the welder/diver. Three levels of temper bead heat input (25.5, 32.2, and 34.6 kJ/in) failed to reduce the HAZ toe hardness to an acceptable level. When the heat input was increased to 37.0 kJ/in., the average HAZ toe hardness was sharply reduced to 324 vs. 463 for the no temper bead weldment. However, two of the three test results (332 and 355) exceeded our target of the 325 maximum. While a hardness of HV 10 355 is acceptable for most applications, the MTB/Half-bead technique was subsequently used for further reduction of HAZ hardness. (See Results-Multiple Temper Bead/Half-bead Weldments).



1/8" DIA. ELECTRODES USED FOR ALL BEADS

FIGURE 1



1/8" DIA. ELECTRODES USED FOR ALL PASSES
EXCEPT 3/32" DIA USED FOR PASSES 8 AND 13.

PASSES 7 AND 12 GROUND DOWN TO "HALF-BREADS"

FIGURE 2

SUMMARY OF VICKERS 10 KG HARDNESS TEST RESULTS IN HAZ OF WET FILLET WELDMENTS (See Table 1 for Details)

WELDING VARIABLES	AVERAGE HAZ HARDNESS TOE	AVERAGE HAZ HARDNESS OTHER	TOE HARDNESS COMMENTS
No Temper Beads	463	291	5 of 6 ≥ 435
Multiple Temper Beads Heat Input 25.5 kJ/in	431	286	2 of 6 ≥ 435
Multiple Temper Beads Heat Input 32.2 kJ/in	410	274	3 of 8 ≥ 435
Multiple Temper Beads Heat Input 34.6 kJ/in	439	270	3 of 8 ≥ 435
Multiple Temper Beads Heat Input 37.0 kJ/in	324	259	2 of 3 ≥ *325
Multiple Temper Beads Plus Half-Bead Technique Heat Input 29.3 kJ/in	282	277	300 max.

*AWS D3.6 specifies Vickers 10 kg 325 maximum for Class A (dry) welds.

NOTE: Heat inputs are expressed in welding arc output in energy units (kj) per linear inch at weld joint by formula shown in the text of this Supplemental Report.

TABLE 1

WET FILLET WELDS WITH AND WITHOUT TEMPERING, WITH VARYING DEGREES OF RESTRAINT AND FIVE LEVELS OF HEAT INPUT

WELDMENT VARIABLES	VICKERS 10 kg HARDNESS TOE	MIDPOINT	ROOT
No Temper Beads Dry Weld Restraint	482 477 442	327 292 306	280 294 275
No Temper Beads Fixture Restraint	479 299* 435	272 282 278	306 283 294
Averages	**463***	**293**	**289**
Multiple Temper Beads* Level 1 Heat Input (25.5 kJ/in) Dry Weld Restraint	421 400 442	279 312 289	283 289 274
Multiple Temper Beads* Level 1 Heat Input (25.5 kJ/in) Fixture Restraint	425 421 477	306 287 294	282 286 263
Averages	**431**	**294**	**279**
Multiple Temper Beads Level 2 Heat Input (32.2 kJ/in) Wet Welded Restraint	435 426 478 410 360 389 461 319	305 260 320 305 252 265 262 282	273 262 262 282 262 255 268 270
Averages	**410**	**281**	**267**

* The inconsistent 299 hardness was not included in the HAZ Toe Hardness average.

Table 1 (Continued)

WELDMENT VARIABLES	HAZ TEST SITES (VICKERS 10 KG) TOE	MIDPOINT	ROOT
Multiple Temper Beads	428	272	282
Level 3 Heat Input (34.6 kJ/in)	426	272	293
Wet Welded Restraint	426	262	272
	425	252	299
	455	292	272
	478	262	260
	412	265	252
	460	261	261
Averages	**439**	**267**	**274**
Multiple Temper Beads	355	252	235
Level 4 Heat Input (37.0 kJ/in)	332	267	267
Dry Welded Bar Restraint	284	282	252
Averages	**324**	**267**	**251**
Multiple Temper Beads	252	268	277
Plus Half-Bead Technique	293	297	278
At toes of Weld. Level 5	300	272	272
Heat Input (29.3 kJ/in) Dry Welded Bar Restraint	———	———	———
Averages	**282**	**279**	**275**

* Material Joining Work Reports and test results are provided in Appendix IX.

NOTES:

- All weld beads were deposited with 1/8" ø electrodes except 3/32" ø electrodes were used for capping and tempering the toes of the Level 5 heat input MTB/half-bead weldment.

- Welds were made on A537 Cl.1 (C.20 and CE.462) 5/8" plate in the vertical position at -33'.

- Formula used for heat input was $\frac{\text{Amps x Volts x 60}}{\text{per minute}}$ = Jules per inch in.

Results-Multiple Temper Bead/Half-Bead Weldments

Results of the MTB/Half-Bead weldments were extraordinarily good. HAZ toe hardness averaged 282 with a maximum of 300 (252, 293, and 300).

Supplemental Results and Information

- Of the twenty-eight MTB fillet weld cross sections examined to date at 100x, none showed any evidence of cracks in the HAZ.
- The type of restraint, whether an opposing fillet weld or a mechanical fixture, appeared to have no affect on the propensity for HAZ cracking.
- In November 1992, Gene Mitchell (U. S. Navy) suggested that the half bead temper bead technique be considered for use during the program. At that time, we were of the opinion that the acceptable time interval (before HAZ cracks could develop) between deposition of primary weld beads and temper beads was too short to use any of the time for grinding to reduce the primary weld bead thickness. However, results from timing welds made in October 1993 showed that when for the A537 C1.1 material was welded with Ex 7 electrodes it took up to two hours for the cracks to develop. With that new information, Mr. Mitchell's suggestion was resurrected with the excellent results reported herein.
- The heat input formula used in this report,

$$H \text{ (joules per inch)} = \frac{E \text{ (volts)} \times I \text{ (amperes)} \times 60}{S \text{ (speed in inches per minute)}}$$

is commonly used to express the welding arc output in energy units per linear inch at weld joint. While the formula may be useful in comparing the heat inputs to the HAZ by wet weld temper beads, other essential variables include: thickness of the primary weld bead that is being tempered, distance between the toe of the primary weld bead and the toe of the temper bead, diameter of the tempering electrode, angle of the electrode in relation to the plane of the primary weld bead and welding polarity (Electrode Negative or Positive).

Further investigation would be required to determine the following variables pertaining to the use of the half-bead technique and the application of increased temper bead heat input without the half-bead technique.

* Is it necessary to reduce the thickness of two primary weld beads at the toe of a weld or would the reduction of the thickness of the outermost bead produce acceptable reduction in the HAZ hardness?

  For wet welds made on the A537 material the area of the HAZ that is susceptible to the excessive hardness is relatively small, i.e. ≤ 1/8" (3.2 mm) thick by ≤1/4" (6.3 mm) wide. It is therefore quite possible that reduction of the thickness of only the outermost primary weld bead is necessary.

* Is there any advantage of using 3/32" ϕ welding electrodes for tempering the half-beads vs. 1/8" ϕ electrodes that are used for the balance of the welding?

* What is an acceptable thickness range (maximum and minimum) for weld beads that are ground down for tempering at a given level of heat input?

* While the MTB/half-bead technique was highly effective, it is more time consuming than the MTB alone. Can the HAZ toe hardness be reduced to comparable levels by simply increasing the temper bead heat input at the toe of the weld beyond 37.0 kJ/in?

* Will it take less heat input to reduce HAZ hardness in materials that have less than the A537 .20 wt. pct. carbon?

* And finally, next efforts to increase heat input to the HAZ beneath the toes of cap passes should include the conventional above water temper bead procedure i.e., build welds up to full size and then deposit oversized high heat input temper beads near the toes of cap passes. (These beads would then be ground down to meet visual inspection requirements). This procedure, if effective on wet welds, would be more efficient than the half-bead technique.

Effectiveness of multiple temper bead welding in all position wet welding

To demonstrate the broad effectiveness of the multiple temper bead techniques all position wet groove welds were made on 3/4" A537 Class 1 steel plates at -33' and

tested in accordance with the requirements of AWS D3.6 for the qualification of Class A (dry) welding procedures. However, to investigate more in detail the performance of these welds, the welds were allowed to age at ambient temperature for over 72 hours before testing. A second vertical weld was made and impact tested with the notch parallel to the heat affected zone. Charpy impact tests were performed on both the heat affected zone and the weld metal.

The Global Divers reports with the joint design and welding parameters for the 1G, 2G, 3G, and 4G welding are included in the following pages. All weldments met the requirements of AWS D3.6 for Class B (wet) welds. Charpy V-notch HAZ and weld metal impacts results exceeded the requirements of AWS D3.6 for Class A welds.

Tensile Testing Results

For qualification in the first position (1G), all-weld-metal tensile tests results were 75.4 ksi yield and 79.7 ksi ultimate with 12% elongation. (Elongation of weld metal of welds made with commercial wet welding electrodes is usually 6 - 9%). Reduced section tensile test results were 76.2 and 78.6. Average of the three tensiles (78.2 ksi) compares favorable with the 65 - 70 ksi of previously considered excellent for wet welds. SRC's test reports are included in Appendix X. No tensile tests were required for the 2G, 3G, and 4G welds.

Impact Testing Results

Charpy V-notch impact testing at 28°F was carried out on samples extracted from the heat affected zone and weld metal of weld 1G. Table VI contains the average impact energy, percent shear fracture and test specimen lateral expansion data. Detailed reports of the individual tests are included in Appendix XI.

Table VI. Average Impact Test Data for Weld 1G at 28°F.

	Absorbed Energy (ft-lb)	Shear Fracture (percent)	Lateral Expansion (mils)
Heat Affected Zone	43	70	51
Weld Metal	32	100	37

Global Divers
& Contractors, Inc.

Sheet 1 of 2
W/O No. ED-012-93

MATERIALS JOINING WORK REPORT
Part 1 Confirmation Weld (1G)

Location GLOBAL DIVERS - PORT OF IBERIA Contract No. 91-M-4346

Mat'l (1) A 537 Grade Cl 1
Ht./Slab No. 79006-12
Thick 3/4" in. Dia. _____ in.

Mat'l (2) _____ Grade _____
Ht./Slab No. _____
Thick _____ in. Dia. _____ in.

Electrode (AWS) E 6013 A5.1 TN Program Ex 7 Mfr. Proprietary Ctry _____

Process SMAW Current/Polarity CC/DCEP/PULSE Joint Type V-GROOVE Position 1G (16")

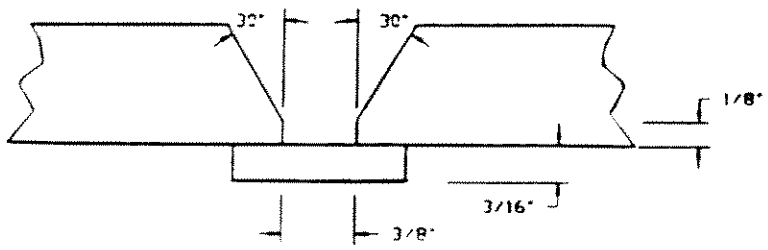
Water Depth 33' Dry _____ Wet X

Welding Variables:

R F & C	PASS	DIA.	AMPS	VOLTS	I.P.M.	REMARKS
ROOT	1	1/8"	155 - 160	32 - 34	8.0	PPS - 125
TEMPER	1	1/8"	155 - 160	32 - 34	6.8	PW - 50%
ROOT	2	1/8"	155 - 160	32 - 34	8.0	Background - 30%
TEMPER	2	1/8"	155 - 160	32 - 34	6.8	Weld Time - 2 Hrs. 48 Min
FILL	3 - 30	1/8"	155 - 160	32 - 34	8.9	Multiple Temper Bead Wet Welding Technique Used.
CAP	31 - 36	1/8"	155 - 160	32 - 34	9.2	

Welder: Darryl R. Phillips Date: 7-1-93

Welding Joint Sketch:



Welding Techniques:

Stringer Beads

Global Divers
& Contractors, Inc.

Sheet 2 of 2
W/O No. ED-012-93

Tension Tests: (Reduced Section/All-Weld-Metal) Reduced Section and All-Weld-Metal

SPECIMEN	ORIENT	ULTIMATE S.	YIELD S.	ELONGATION	FAILURE
1 & 2	Transverse	76.202 & 78.627	N/A	N/A	WM
3	Longitudinal	79.684	75.356	12%	WM

Bends: * Best of twelve specimens. See Attached Report.

SPECIMEN	ROOT	FACE	SIDE	*RADIUS	RESULTS
1			X	4 T	Satisfactory
2			X	4 T	Satisfactory
3			X	6 T	Satisfactory
4			X	6 T	Satisfactory

Chemistry:

	CE	C	Mn	P	S	Si	Ni	Cr	Mo	Cu	V	Cb	Nb	Al
CTR														
LAB	.462	.20	1.50	.014	.019	.38	.03	.02	.01	.03	.01	.01	---	---

Hardness (Vickers/Rockwell): Vickers 10 kg

LOCATION	LEFT SIDE	RIGHT SIDE
BASE METAL (AVG.)	164	171
HAZ (MAX)	401	395
HAZ (AVG)	298	278
WM (MAX)	223	212

Purpose of Test: First position of all-position MTB confirmation Welds

Remarks & Evaluation: Charpy V-notch Impact Results at 28° F (Averages)

Location	Absorbed Energy Foot Pounds	% Shear Fracture	Lateral Expansion (Mils)
HAZ	42.7	70	51
W.M.	32	100	37

No HAZ cracks at 100X.
Radiograph met requirements of AWS D3.6 - Class B

By: C.E. Grubbs Date: 7-1--93 Rev: ---

Global Divers
& Contractors, Inc.

Sheet 1 of 2
W/O No. ED-013-93

MATERIALS JOINING WORK REPORT
Part 1 Confirmation Weld (2G)

Location GLOBAL DIVERS - PORT OF IBERIA Contract No. 91-M-4346

Mat'l (1) A 537 Grade Cl.1
Ht./Slab No. 79006-12
Thick 3/4" in. Dia. _____ in.

Mat'l (2) _____ Grade _____
Ht./Slab No. _____
Thick _____ in. Dia. _____ in.

Electrode (AWS) E 6013 A5.1 TN Program Ex 7 Mfr. Proprietary Ctry _____

Process SMAW Current/Polarity CC/DCEP/PULSE Joint Type V-Groove Position 2G (8")

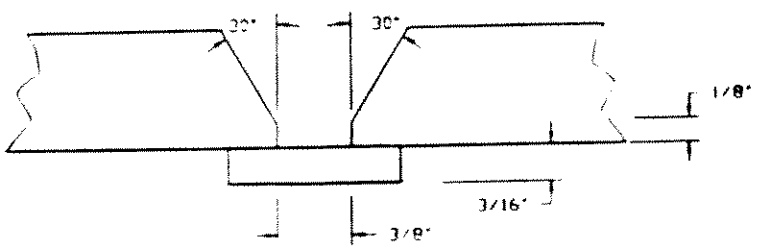
Water Depth 33' Dry _____ Wet X

Welding Variables:

R F & C	PASS	DIA.	AMPS	VOLTS	I.P.M.	REMARKS
ROOT	1	1/8"	135 - 140	32 - 34	7.8	PPS - 125
TEMPER	1	1/8"	135 - 140	32 - 34	7.1	PW - 70%
ROOT	2	1/8"	135 - 140	32 - 34	8.0	Background - 30%
TEMPER	2	1/8"	135 - 140	32 - 34	7.4	Used MTB Wet Welding Technique
FILL	3 - 37	1/8"	135 - 140	32 - 34	8.6	
CAP	38 - 44	1/8"	135 - 140	32 - 34	9.2	

Welder: Darryl R. Phillips Date: 7-1-93

Welding Joint Sketch:



Welding Techniques:

Stringer Beads

Global Divers
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Sheet 2 of 2
W/O No. ED-013-93

Tension Tests: (Reduced Section/All-Weld-Metal) N/A

SPECIMEN	ORIENT	ULTIMATE S.	YIELD S.	ELONGATION	FAILURE
1					
2					

Bends:* Best of twelve specimen. See attached report

SPECIMEN	ROOT	FACE	SIDE	*RADIUS	RESULTS
1			X	3-1/3 T	Satisfactory
2			X	3-1/3 T	Satisfactory
3			X	3-1/3 T	Satisfactory
4			X	3-1/3 T	Satisfactory

Chemistry:

	CE	C	Mn	P	S	Si	Ni	Cr	Mo	Cu	V	Cb	Nb	Al
CTR														
LAB	.462	.20	1.50	.014	.019	.38	.03	.02	.01	.03	.01	.01	---	---

Hardness (Vickers/Rockwell): N/A

LOCATION	LEFT SIDE	RIGHT SIDE
BASE METAL (AVG.)		
HAZ (MAX)		
HAZ (AVG)		
WM (MAX)		

Purpose of Test: Additional position (2G) of all position confirmation welds.

Remarks & Evaluation: Radiograph met requirements of AWS D3.6 for Class B welds.

By: C.E. GRUBBS Date: 7/1/93 Rev: ---

Global Divers
& Contractors, Inc.

Sheet 1 of 2
W/O No. ED-014-93

MATERIALS JOINING WORK REPORT
Part 1 Confirmation Weld (3G)

Location GLOBAL DIVERS - PORT OF IBERIA Contract No. 91-M-4346

Mat'l (1) A 537 Grade Cl.1
Ht./Slab No. 79006-12
Thick 3/4" in. Dia. _____ in.

Mat'l (2) _____ Grade _____
Ht./Slab No. _____
Thick _____ in. Dia. _____ in.

Electrode (AWS) E 6013 A5.1 TN Program Ex 7 Mfr. Proprietary Ctry _____

Process SMAW Current/Polarity CC/DCEP/PULSE Joint Type V-Groove Position 3G (8")

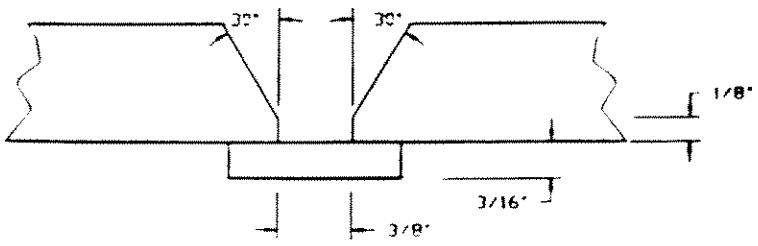
Water Depth 33' Dry _____ Wet X

Welding Variables:

R F & C	PASS	DIA.	AMPS	VOLTS	I.P.M.	REMARKS
ROOT	1	1/8"	155 - 160	33 - 35	8.9	PPS - 125
TEMPER	1	1/8"	155 - 160	33 - 35	8.2	PW - 50%
ROOT	2	1/8"	155 - 160	33 - 35	8.9	Background - 30%
TEMPER	2	1/8"	155 - 160	33 - 35	8.2	Used MTB Wet Welding Technique
FILL	3 - 36	1/8"	155 - 160	33 - 35	8.2	
CAP	37 - 42	1/8"	155 - 160	33 - 35	9.0	

Welder: Darryl R. Phillips Date: 7-1-93

Welding Joint Sketch:



Welding Techniques:

Stringer Beads. All passes downhill

Global Divers
& Contractors, Inc.

W/O No. ED-014-93

Tension Tests: (Reduced Section/All-Weld-Metal) N/A

SPECIMEN	ORIENT	ULTIMATE S.	YIELD S.	ELONGATION	FAILURE
1					
2					

Bends:* Best of twelve specimen. See attached report

SPECIMEN	ROOT	FACE	SIDE	*RADIUS	RESULTS
1			X	2 T	Satisfactory
2			X	3-1/3 T	Satisfactory
3			X	3-1/3 T	Satisfactory
4			X	3-1/3 T	Satisfactory

Chemistry:

	CE	C	Mn	P	S	Si	Ni	Cr	Mo	Cu	V	Cb	Nb	Al
CTR														
LAB	.462	.20	1.50	.014	.019	.38	.03	.02	.01	.03	.01	.01	---	---

Hardness (Vickers/Rockwell): N/A

LOCATION	LEFT SIDE	RIGHT SIDE
BASE METAL (AVG.)		
HAZ (MAX)		
HAZ (AVG)		
WM (MAX)		

Purpose of Test: Additional position (3G) of all position confirmation welds.

Remarks & Evaluation: Radiograph met requirements of AWS D3.6 Class B welds.

By: C.E. GRUBBS Date: 7/1/93 Rev: ---

Global Divers
& Contractors, Inc.

Sheet 1 of 2
W/O No. ED-015-93

MATERIALS JOINING WORK REPORT
Part 1 Confirmation Weld (4G)

Location GLOBAL DIVERS - PORT OF IBERIA Contract No. 91-M-4346

Mat'l (1) A 537 Grade Cl.1
Ht./Slab No. 79006-12
Thick 3/4" in. Dia. _____ in.

Mat'l (2) _____ Grade _____
Ht./Slab No. _____
Thick _____ in. Dia. _____ in.

Electrode (AWS) E 6013 A5.1 TN Program Ex 7 Mfr. Proprietary Ctry _____

Process SMAW Current/Polarity CC/DCEP/PULSE Joint Type V-Groove Position 4G (8")

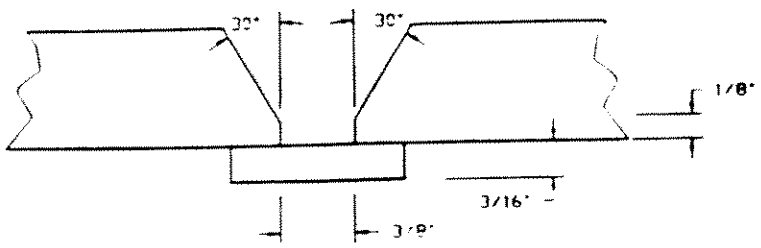
Water Depth 33' Dry _____ Wet X

Welding Variables:

R F & C	PASS	DIA.	AMPS	VOLTS	I.P.M.	REMARKS
ROOT	1	1/8"	145 - 150	32 - 34	8.9	PPS - 150
TEMPER	1	1/8"	145 - 150	32 - 34	8.2	PW - 70%
ROOT	2	1/8"	145 - 150	32 - 34	8.9	Background - 30%
TEMPER	2	1/8"	145 - 150	32 - 34	8.2	Used MTB Wet Welding Technique
FILL	3 - 41	1/8"	145 - 150	32 - 34	8.4	
CAP	42 - 48	1/8"	145 - 150	32 - 34	9.2	

Welder: Darryl R. Phillips Date: 7-1-93

Welding Joint Sketch:



Welding Techniques:

Stringer Beads

Global Divers
& Contractors, Inc.

W/O No. ED-015-93

Tension Tests: (Reduced Section/All-Weld-Metal) N/A

SPECIMEN	ORIENT	ULTIMATE S.	YIELD S.	ELONGATION	FAILURE
1					
2					

Bends:* Best of twelve specimen. See attached report

SPECIMEN	ROOT	FACE	SIDE	*RADIUS	RESULTS
1			X	2 T	Satisfactory
2			X	2 T	Satisfactory
3			X	4 T	Satisfactory
4			X	4 T	Satisfactory

Chemistry:

	CE	C	Mn	P	S	Si	Ni	Cr	Mo	Cu	V	Cb	Nb	Al
CTR														
LAB	.462	.20	1.50	.014	.019	.38	.03	.02	.01	.03	.01	.01	---	---

Hardness (Vickers/Rockwell): N/A

LOCATION	LEFT SIDE	RIGHT SIDE
BASE METAL (AVG.)		
HAZ (MAX)		
HAZ (AVG)		
WM (MAX)		

Purpose of Test: Additional position (4G) of all position confirmation welds.

Remarks & Evaluation: Radiograph met requirements of AWS D3.6 Class B welds.

By: C.E. GRUBBS Date: 7/1/93 Rev: ---

Global Divers
& Contractors, Inc.

Sheet 1 of 2
W/O No. ED-016-93

MATERIALS JOINING WORK REPORT
Part 1 Confirmation Weld - Compare Charpy HAZ Notch Orientations

Location GLOBAL DIVERS - PORT OF IBERIA Contract No. 91-M-4346

Mat'l (1) A 537 Grade Cl.1
Ht./Slab No. 79006-12
Thick 3/4" in. Dia. _____ in.

Mat'l (2) _____ Grade _____
Ht./Slab No. _____
Thick _____ in. Dia. _____ in.

Electrode (AWS) E 6013 A5.1 TN Program Ex 7 Mfr. Proprietary Ctry _____

Process SMAW Current/Polarity CC/DCEP/Pulse Joint Type V-Groove Position 3 G (8")

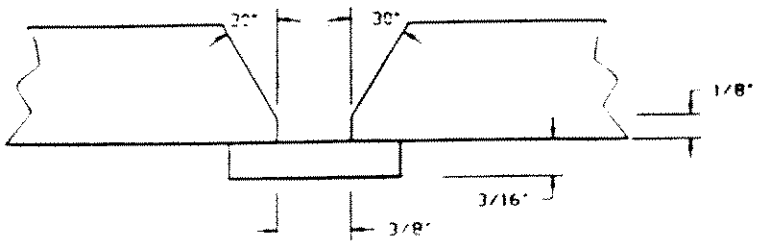
Water Depth 33' Dry _____ Wet X

Welding Variables:

R F & C	PASS	DIA.	AMPS	VOLTS	I.P.M.	REMARKS
Root	1	1/8"	155 - 160	33 - 35	8.0	PPS - 150
Temper	1	1/8"	155 - 160	33 - 35	6.7	PW - 70%
Root	2	1/8"	155 - 160	33 - 35	8.0	Background - 30%
Temper	2	1/8"	155 - 160	33 - 35	6.7	41 Passes
Fill	3 - 35	1/8"	155 - 160	33 - 35	8.0	Weld time - 46 min.
Cap	36 - 41	1/8"	155 - 160	33 - 35	9.2	Used Multiple temper bead technique

Welder: Darryl R. Phillips Date: 7-1-93

Welding Joint Sketch:



Welding Techniques:

Stringer Beads. All passes downhill

Global Divers
& Contractors, Inc.

Sheet 2 of 2
W/O No. ED-016-93

Tension Tests: (Reduced Section/All-Weld-Metal) N/A

SPECIMEN	ORIENT	ULTIMATE S.	YIELD S.	ELONGATION	FAILURE
1					
2					

Bends: N/A

SPECIMEN	ROOT	FACE	SIDE	RADIUS	RESULTS
1					
2					
3					
4					

Chemistry:

	CE	C	Mn	P	S	Si	Ni	Cr	Mo	Cu	V	Cb	Nb	Al
CTR														
LAB	.462	.20	1.50	.014	.019	.38	.03	.02	.01	.03	.01	.01	---	---

Hardness (Vickers/Rockwell): N/A

LOCATION	LEFT SIDE	RIGHT SIDE
BASE METAL (AVG.)		
HAZ (MAX)		
HAZ (AVG)		
WM (MAX)		

Purpose of Test: Compare Charpy V-notch HAZ impact test results with notch oriented per AWS D3.6 Vs parallel to HAZ.

Remarks & Evaluation: For Charpy tests on this weldment, the notch was oriented per AWS D3.6. Average results of tests on four macros were: Absorbed Energy, 44.7 ft. lbs. shear fracture, 85%. Lateral expansion, 49.5 mils.

By: C.E. Grubbs Date: 7-1-93 Rev: ---

Global Divers
& Contractors, Inc.

Sheet 1 of 2
W/O No. ED-017-93

MATERIALS JOINING WORK REPORT
Part 1 Confirmation Weld - Compare Charpy HAZ Notch Orientations

Location GLOBAL DIVERS - PORT OF IBERIA Contract No. 91-M-4346

Mat'l (1) A 537 Grade Cl.1
Ht./Slab No. 79006-12
Thick 3/4" in. Dia. _____ in.

Mat'l (2) _____ Grade _____
Ht./Slab No. _____
Thick _____ in. Dia. _____ in.

Electrode (AWS) E 6013 A5.1 TN Program Ex 7 Mfr. Proprietary Ctry _____

Process SMAW Current/Polarity CC/DCEP/Pulse Joint Type Single bevel Position 3G (8")

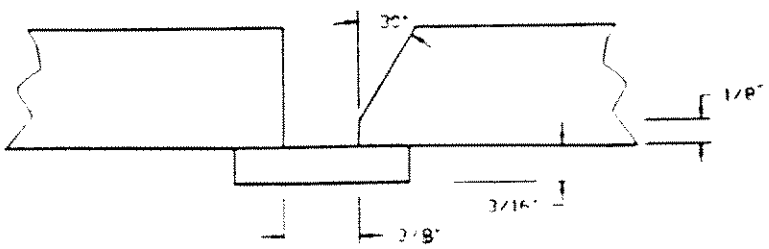
Water Depth 33' Dry _____ Wet X

Welding Variables:

R F & C	PASS	DIA.	AMPS	VOLTS	I.P.M.	REMARKS
Root	1	1/8"	160 - 165	32 - 34	5.7	PPS - 150
Temper	1	1/8"	160 - 165	32 - 34	5.5	PW - 70%
Root	2	1/8"	160 - 165	32 - 34	5.6	Background - 30%
Temper	2	1/8"	160 - 165	32 - 34	5.7	42 Passes
Fill	3 - 36	1/8"	160 - 165	32 - 34	8.6	Weld time 56 min.
Cap	37 - 42	1/8"	160 - 165	32 - 34	9.2	Used Multiple Temper Bead Technique

Welder: Darryl R. Phillips Date: 7-1-93

Welding Joint Sketch:



Welding Techniques:

Stinger beads all passes down hill

Global Divers
& Contractors, Inc.

Sheet 2 of 2
W/O No. ED-017-93

Tension Tests: (Reduced Section/All-Weld-Metal) N/A

SPECIMEN	ORIENT	ULTIMATE S.	YIELD S.	ELONGATION	FAILURE
1					
2					

Bends: N/A

SPECIMEN	ROOT	FACE	SIDE	RADIUS	RESULTS
1					
2					
3					
4					

Chemistry:

	CE	C	Mn	P	S	Si	Ni	Cr	Mo	Cu	V	Cb	Nb	Al
CTR														
LAB	.462	.20	1.50	.014	.019	.38	.03	.02	.01	.03	.01	.01	---	---

Hardness (Vickers/Rockwell): N/A

LOCATION	LEFT SIDE	RIGHT SIDE
BASE METAL (AVG.)		
HAZ (MAX)		
HAZ (AVG)		
WM (MAX)		

Purpose of Test: Compare Charpy V-notch HAZ impact test results with notch parallel to HAZ vs AWS D3.6 orientation.

Remarks & Evaluation: For Charpy impacts on this weldment, the notch was parallel to the HAZ. Average results of tests on four macros were: Absorbed Energy, 29.3 ft. lbs. Shear Fracture, 70%. Lateral Expansion, 31.7 mils.

By: C.E. GRUBBS Date: 7-1-93 Rev: ---

Weld Hardness Results

As illustrated in Figure 14, even though the average hardness reading was only 288 HV_{10k}, two of the twelve readings exceeded substantially the 325 HV_{10k} limit specified by AWS D3.6 for Class A welds. These readings were 401 and 395 HV_{10k}, respectively. These two readings are located in the HAZ at the toe of the weld which verifies the need for more temper bead heat input at the toe of cap passes. The maximum hardness of the weld metal was 223 HV_{10k}.

Because of an inappropriate sequence of events, the all position groove welds were made before the supplemental welds with increased levels of heat input and the half-bead technique welds were made. Without the benefit of the knowledge gained from results of the supplemental increased heat input welds, the MTB procedure was ineffective in reducing HAZ hardness, at toes of cap passes.

Bend Test Results

For Class A welds, AWS D3.6 specification requires bending radii from 2 T to 3-1/3 T, depending on the minimum specified base metal yield strength. For wet welds the specification requires only 6 T bending.

Side bend tests were performed on all welds. For the overhead position weld, only four specimens, as required by AWS D3.6, were tested. For the three other positions, four specimens were initially tested. The results of these tests, in the form of test certificates issued by SRC Engineers, Inc., are included in Appendix XII. These results are also summarized in Table VII. For the flat, horizontal and vertical position welds, additional bend specimens were tested to attempt better results. In total, twelve specimens from each of the three positions were bend tested. All specimens failed at locations near the center of the weld metal.

The bending of each specimen was started on a 6 T mandrel and progressed to 4 T, 31/3 T, and 2 T or failure. While this method may be unorthodox, it provides maximum information without the cost of making additional weldments. One participant maintained that use of the multiple radii procedure increased the ductility of the weld metal and therefore, the possibility of making smaller radius bends. Others were of the

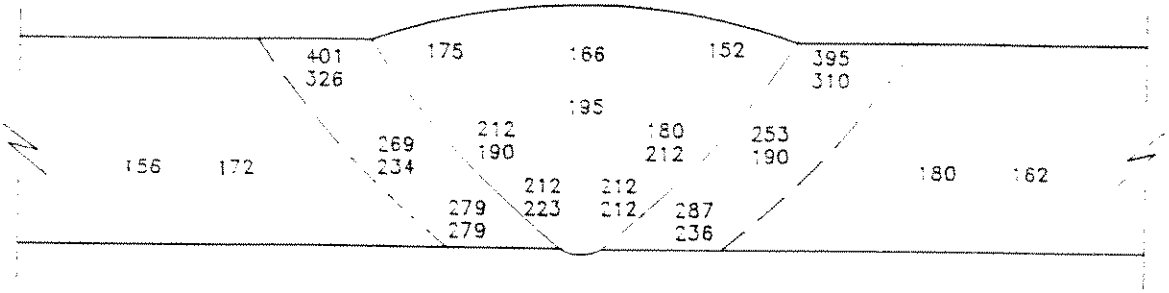
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers 10kg load hardness test on weld sample 3/4" X 16" weld(GD406178) 1G Wetweld With T.B.

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



HAZ Examined at 5X, 50X, & 100X Magnification.
No evidence of Hydrogen cracking was found.

EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 18, 1993

SRC Job No. 92-352

Certified By: [signature] Date: 6-28-93

Reviewed By: [signature] Date: 06-28-93

GLOBAL5.VIC

FIGURE 14

opinion that repeated bending "work hardened" the weld metal and reduced ductility. Subsequent tests indicated that there is no substantive differences in results produced by the two bending procedures. For specimens that had undergone 6T and 4T bends, 30 of 30 passed the 3-1/3T test. For single radius bends, 31 of 31 were satisfactory when bent only on the 3-1/3T radius mandrill.

Table VII. Side Bend Test Results of the Four Welding Positions. (Data expressed as bend radius at which results were satisfactory)

Flat	Horizontal	Vertical	Overhead
2 - 4 T	4 - 3-1/3 T	1 - 2 T	2 - 2 T
2 - 6 T		3 - 3-1/3 T	2 - 4 T

HAZ Impact Properties with the Notch Parallel to the HAZ

To further demonstrate the excellent mechanical properties obtained using the multiple temper bead technique, HAZ impact test specimens were prepared with notches machined parallel to the heat affected zone, instead of the conventional AWS D3.6 specified orientation. A drop of 16 ft lbs average absorbed energy, from 45 to 29 ft lbs, was observed as compared to 15 ft lbs average specified by AWS D3.6 for Class A welds. The decrease was expected since the new configuration forces the cracks to propagate directly into the heat affected zone.

Microscopic Examinations

For qualification of Class A welding procedures, AWS D3.6 specifies that micrographs of cross sections of welds shall not reveal any cracks at 5X magnification, and the only micrograph required is one from the first position. During examination of the all position confirmation welds on A537 steel, the first position (1G) cross section did not exhibit any cracks at 100X magnification. Supplemental examination, not required by AWS D3.6, of micrographs from four cross sections of weldments from each of the other three positions revealed heat affected zone cracking at 50X magnification. However, all unsatisfactory side bends failed at or near the center of the weld metal with no indication of cracks in the heat affected zone. Micrographs of the cross sections of the confirmation

welds in the vertical and overhead position are shown in Figure 15. Radiographic analyses were also performed on all welds with no indication of cracking. Global Divers welding reports and impact test results for the welds tested with the Charpy V-notch located parallel to the HAZ, vs. orientation specified by AWS D3.6, plus radiographs of the all position welds, are included in Appendix XIII.

Weldments With and Without MTB

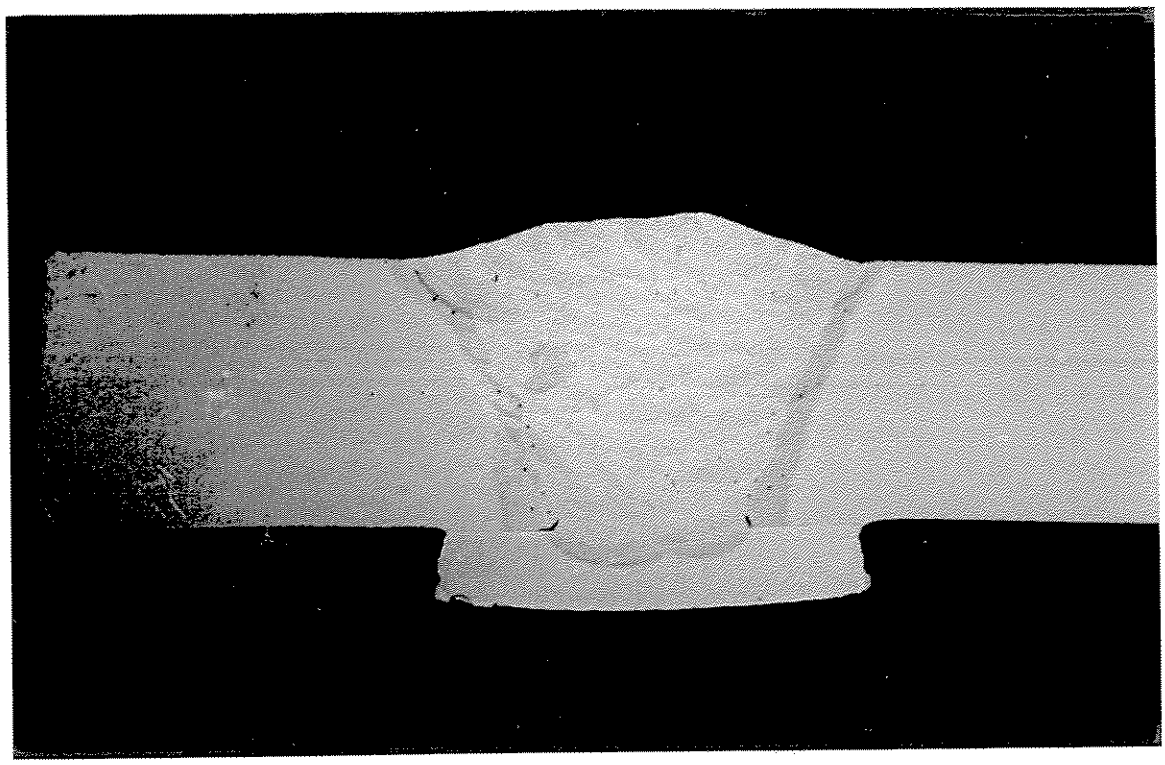
As discussed previously in the section on base metal selection, many of the existing offshore platforms were fabricated using ASTM A36 Grade steels for which no tight control of chemical composition is required. This task will verify the effectiveness of the MTB technique in reducing HAZ hardness and improving Charpy V-Notch impact properties by conducting parallel sets of welds with and without multiple temper bead application. This set of experiments includes both cracking susceptible and non-crack susceptible steels. In addition to the A537 steel, two A36 grade steels with 0.26 wt. pct. carbon equivalent and 0.14 wt. pct. carbon, and 0.415 wt. pct. carbon equivalent and 0.24 wt. pct. carbon were also used. The Global Divers welding reports with the welding parameters, joint design and plate compositions for the three groups of welds are included in Appendix XIV.

Base Metal 1

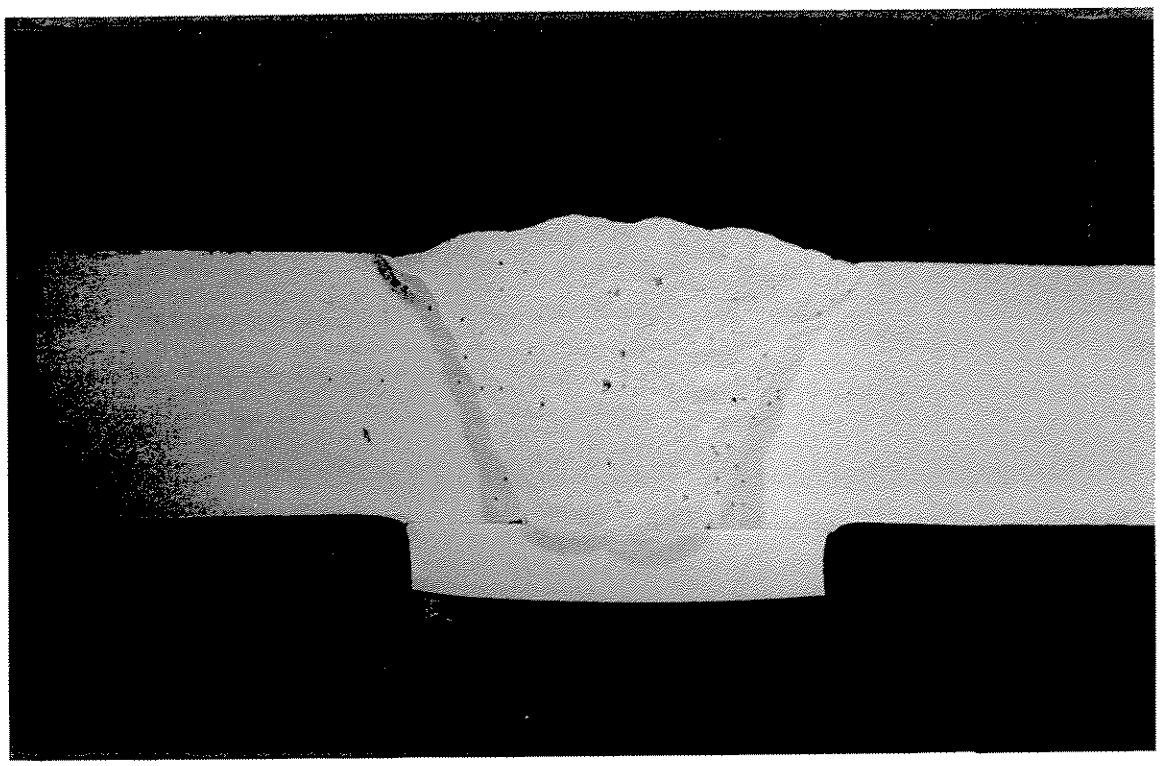
Based on the AWS D3.6 short formula and chemical composition information provided by the vendor before purchase, the carbon equivalent of this ASTM A 36 steel should have been approximately 0.38 wt. pct.. While not susceptible to HAZ hydrogen cracking, it should have exhibited significant hardening in the heat affected zone during welding. Chemical analysis performed with the actual plate material (after purchase) showed substantially lower alloying and low carbon (0.14 wt. pct.) content, which resulted in a very low carbon equivalent (0.26 wt. pct.).

Neither the weldments with MTB, nor the weldments without tempering, was subject to cracking or excessive hardness. Nevertheless, knowing the chemical composition of the alloy, it is not surprising that the mechanical properties (hardness and impact toughness) of both welds exceeded the requirements of AWS D3.6 for Class A welds. A comparison of the welds with and without multiple temper bead technique application is given in Table VIII.

Confirmation Welds on 3/4" ASTM A537 Class 1 (CE.462)



Overhead Position



Vertical Position

Fig. 15

Table VIII. Comparison of Charpy V-Notch Impact Results of Low Carbon Equivalent A36 Steel HAZ With and Without Multiple Temper Bead Technique Application.

	With MTB	Without MTB
Charpy Impact Properties at 28°F Average of Four Tests[1] (ft-lb)	71	73
Shear fracture (percent)	62	80
Lateral Expansion (mils)	57	70
Maximum HAZ Hardness[2] (HV_{10k})	226	244

[1] The individual data are reported in Appendix XV.
[2] The individual data are reported in Appendix XVI.

Base Metal 2

The second set of welds, with and without tempering, was made on ASTM A588-88A Grade B material with CE .449.

There were no significant differences in hardness and Charpy impact test results from the two weldments. Impacts at 28° F exceeded the AWS D3.6 requirements for Class A welds and maximum Vickers 10kg HAZ hardness of 370 was acceptable for most applications.

The lack of HAZ cracking, and the acceptable notch toughness and hardness, are attributed to the relatively high percentages of chromium (.59) and nickel (.27). Copper was also high (.28).

Figure 16 shows the good surface quality of both welds. Impact properties and VH 10 hardness are summarized in Table IX.

Table IX. Comparison of Charpy V-Notch Impact Results of A588 Grade Steel Weld HAZ With and Without Multiple Temper Bead Technique Application.

	With MTB	Without MTB
Charpy Impact Properties at 28°F Average of Four Tests (ft-lb)[a]	32	36
Shear fracture (percent)	68	63
Lateral Expansion (mils)	35	36
Maximum HAZ Hardness[b] (HV_{10k})	382[1]	370[2]

[a] The individual data are reported in Appendix XVII.
[b] The individual data are reported in Appendix XVIII.
[1] Thirteen of forty-eight readings were greater than 325 HV_{10k}. Average: 356 $HV_{10k.}$
[2] Eleven of forty-eight readings were greater that 325 HV_{10k}. Average: 347 $HV_{10k.}$

There were no significant differences in hardness and Charpy impact test results from the two weldments. Both Charpy impact toughness exceeded the requirements of AWS D3.6 for Class A welds. The HAZ hardness of the A588-88A HAZ was only marginally acceptable.

Use of the MTB wet welding method on Normalized A588-88A Grade B material did not improve the mechanical properties of weldments. The HAZ of the normalized material seems to have acceptable notch toughness with or without tempering. And, there was not enough heat impact at the toes of the welds to reduce HAZ hardness.

Base Metal 3

The third sets of groove welds, with and without multiple temper bead application, was performed on 1/2" thick ASTM A 36 Grade steels with a 0.415 wt. pct. carbon equivalent and 0.24 wt. pct. carbon content. Figure 17 demonstrates the excellent surface quality of the two welds. These welds and the testing procedure were proposed by the TAC members at the August 1993 meeting. (*Note: The majority of existing offshore platforms were constructed of A36 tubular members with chemical composition*

ranging between Base Metal 1 to Base Metal 3 in this experimental program.) Testing included side bends and Vickers hardness at 10kg load. Hardness measurements were made at four locations adjacent to the toe of the cap passes on each side of the weld, where maximum HAZ hardness usually occurs.

Both welds, with and without MTB practice, performed satisfactorily in the tests. Microscopic examinations at 100X magnification did not show any cracks (See Appendix XIX for the individual test reports.) All side bend tests (four) were satisfactory when bent successively from 6T to 4T to 31/3 T. The test certificates issued by SRC Engineers, Inc. are included in Appendix XX. This behavior is unexpected since previous Global Divers experience showed that untempered weldments of this same materials failed 6 T bend tests. (Three sets of four side bend tests failed 6 T bend tests.)

The effectiveness of the MTB wet welding method in reducing HAZ hardness on this type of material was clearly evident in Table X. A reduction of approximately 17 percent hardness in the "bulk" heat affected zone was achieved. The number of readings that exceeded 325 HV_{10k} also decreased significantly. The individual hardness data are compiled in Appendix XXI.

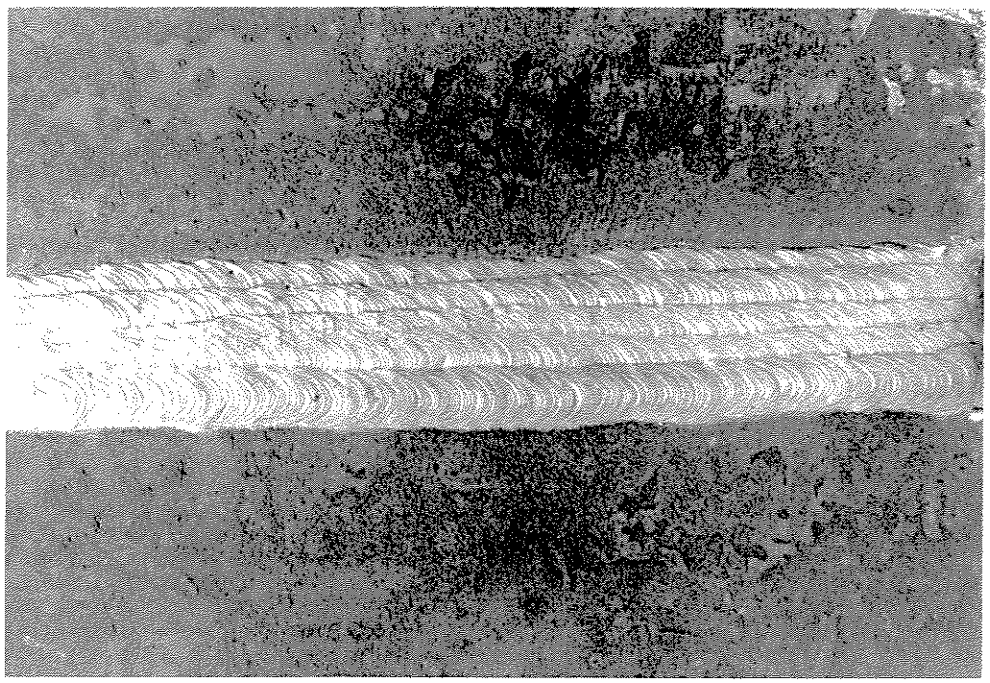
Welds on 5/8" A588-88A Gr. B (CE .449) Plate
With and Without Multiple Temper Beads

Without Temper Beads

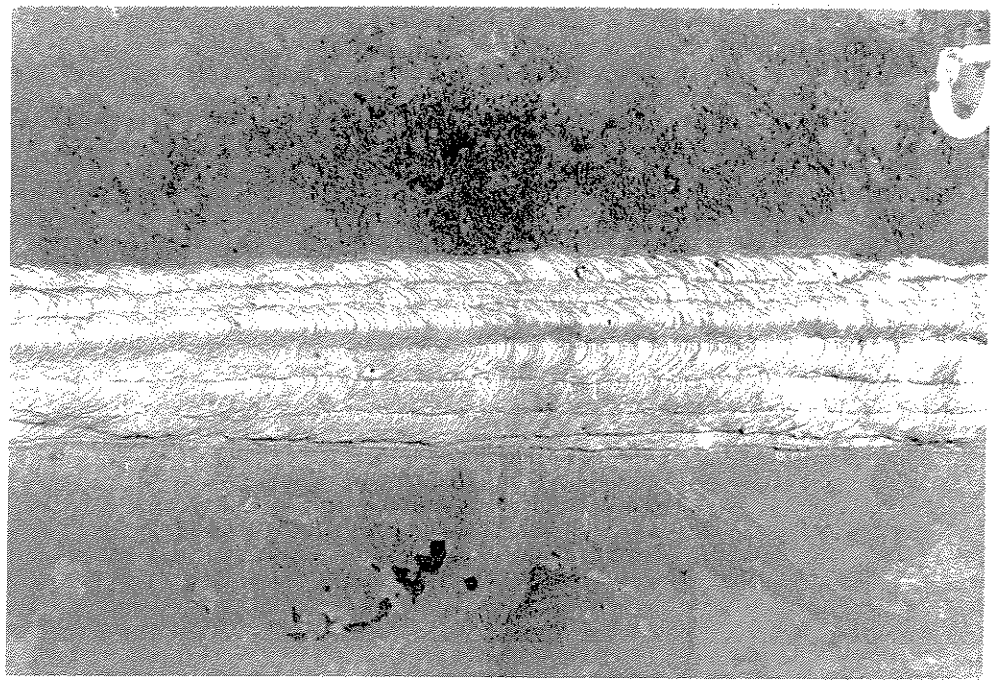
With Temper Beads

Fig. 16

Welds on 1/2" A36 (C.24 CE .415) Plate With and Without Multiple Temper Beads



Without Temper Beads



With Temper Beads

Fig. 17

Table X. Comparison of high carbon equivalent A36 Grade Steel Welds With and Without Multiple Temper Bead Technique Application.

	With MTB	Without MTB
Average Maximum Hardness of 8 Readings Under the Toes of the Cap Welds (HV_{10k})	453	463
Average Maximum Hardness of 24 Readings Other locations of the HAZ (HV_{10k})	282	338
Number of Readings Exceeded 352 HV_{10k} (Out of 32 Readings)	13	23

Supplemental Charpy V-notch Information (Weld Metal and HAZ)

Energy Absorption - Temperature Transition Curve For Wet Weld Metal

To quantify underwater wet welds for service, their impact properties must meet the application (fitness for purpose) requirements. It is highly desirable to have available a large database to support the fact that underwater wet welds can perform satisfactorily in structural applications. Current data on impact toughness of underwater wet welds are scarce and sometimes biased (for example, January 1994 Issue of the AWS Welding Journal). Members of the Technical Activities Committee requested the program to perform wet weldments and Charpy V-notch impact tests to determine the energy absorbed at fracture as a function of testing temperature.

Test Program

A wet groove weld with multiple temper beads was made on 3/4" thick A537 Class 1 steel with the Ex 7 welding electrodes in the vertical position at 33' water depth. Twenty one full-size Charpy V-notch impact specimens were extracted from the weldment and tested at temperatures ranging from 60 to -40°F. Prior to the underwater wet welding, the plate edges and backing bar were overlaid in air per AWS D3.6-93. Details of the welding parameters and joint design are shown in Global Divers welding report in the following pages.

Global Divers
& Contractors, Inc.

Sheet 1 of 2
W/O No. ED- 028-93

MATERIALS JOINING WORK REPORT
TEMPERATURE TRANSITION CURVE

Location Global Divers & Contractors, Inc. Port of Iberia Contract No. 91-M-4346

Mat'l (1) A537 Grade Cl.1
Ht./Slab No. 79006
Thick 3/4" in. Dia. _____ in.

Mat'l (2) _____ Grade _____
Ht./Slab No. _____
Thick _____ in. Dia. _____ in.

Electrode (AWS) E6013 A5.1 TN Program Ex 7 Mfr. Proprietary Batch No. 3201

Process SMAW Current/Polarity CC/DCEP Joint Type Groove Position 3G

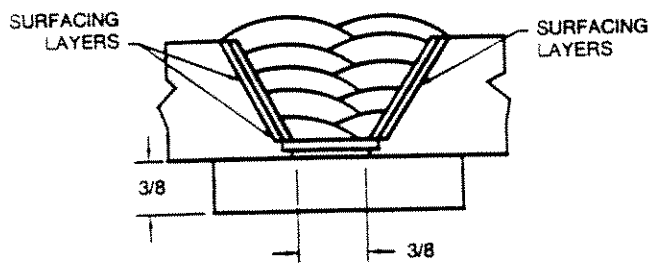
Water Depth 33' Dry _____ Wet X

Welding Variables:

R F & C	PASS	DIA.	AMPS	VOLTS	I.P.M.	REMARKS
ROOT	1 - 2	3/32"	125	30	9.7	Weld time 73 minutes.
FILL	3 - 31	1/8"	175	30	11.8	Plate edges and backing bar were
CAP	32 - 38	1/8"	175	30	11.9	overlayed in air per AWS D3.6-93.
						Figure 14 D.

Welder: Darryl R. Phillips Date: 10-28-93

Welding Joint Sketch:



Welding Techniques:

Stringer Beads - All Passes Down Hill.

Global Divers
& Contractors, Inc.

W/O No. ED-028-93

Tension Tests: (Reduced Section/All-Weld-Metal) N/A

SPECIMEN	ORIENTATION	ULTIMATE PSI.	YIELD PSI.	ELONGATION	FAILURE
1					
2					

Bends: N/A

SPECIMEN	ROOT	FACE	SIDE	RADIUS	RESULTS
1					
2					
3					
4					

Chemistry: A537 Cl.1

	CE	C	Mn	P	S	Si	Ni	Cr	Mo	Cu	V	Cb	Nb	Al
CTR														
LAB	.462	.20	1.50	.014	.019	.38	.03	.02	.01	.03	.01	.01	---	---

Hardness (Vickers/Rockwell): N/A

LOCATION	LEFT SIDE	RIGHT SIDE
BASE METAL (AVG.)		
HAZ (MAX)		
HAZ (AVG)		
WM (MAX)		

Purpose of Test:

Determine energy absorption temperature transition curve for the weld metal of wet weldments made with Ex 7 electrodes.

Remarks & Evaluation:

Twenty-one Charpy V-notch impact specimens were tested at temperatures ranging from 60° F (15.6° C) down to -40° F (-40° C). Test results on the wet welded specimen significantly exceed the AWS D3.6 requirements for Class A welds. (See accompanying Temperature Transition Curve Table.)

By: C.E. Grubbs Date: 11-23-93 Rev: ---

Results and Discussion

The Charpy impact results of the wet welded specimens are shown in Figure 18. The upper and lower shelf energies are approximately 30 and 15 ft-lbs, respectively. The ductile-brittle transition temperature is around 10°F. These data significantly exceeded the AWS D3.6 requirements for Class A (dry) welds, with the upper shelf temperature extending to 20°F. *For class A (dry) welds, AWS D3.6 specifies not less than 15 ft-lbs (20 J) average and 10 ft-lbs (14 J) minimum for welds made on 70 ksi (485 MPa) base metal at the minimum design service temperature (assumed to be 32°F (0°C).* In fact, the impact properties of this wet weld, made with the Ex 7 electrodes at a depth of 33', exceeded not only the AWS D3.6 requirements for Class A (dry) welds at the lowest practical service temperature (28° F) for an underwater structural repair, they also exceeded the D3.6 requirement to -25°F.

Figure 19 shows the experimental data on lateral expansion of the Charpy V-notch specimens as a function of testing temperature. As expected, lateral expansion decreased with decreasing testing temperature. The amount of lateral expansion of the Charpy specimens indicates the amount of shear (plastic deformation) involved in the fracture process. As such, decreasing testing temperature will decrease the amount of plastic deformation in the fracture, thus reducing the lateral expansion. The Charpy V-notch impact test results are compiled in Appendix XXII.

Energy Absorption - Heat Affected Zone of Wet Weldments

Table II summarizes the impact properties of heat affected zones of five different materials when welded with the Program Ex 7 electrodes:

1) A537 Class 1 with 0.462 wt. pct. carbon equivalent and 0.20 wt. pct. carbon content,
2) A36 steel with 0.26 wt. pct. carbon equivalent and 0.14 wt. pct. carbon content,
3) A588-88A steel with 0.449 wt. pct. carbon equivalent and 0.13 wt. pct. carbon content,
4) BS 4360 Grade 50D steel with 0.42 wt. pct. carbon equivalent, and
5) A106 Grade B steel with 0.42 wt. pct. carbon equivalent.

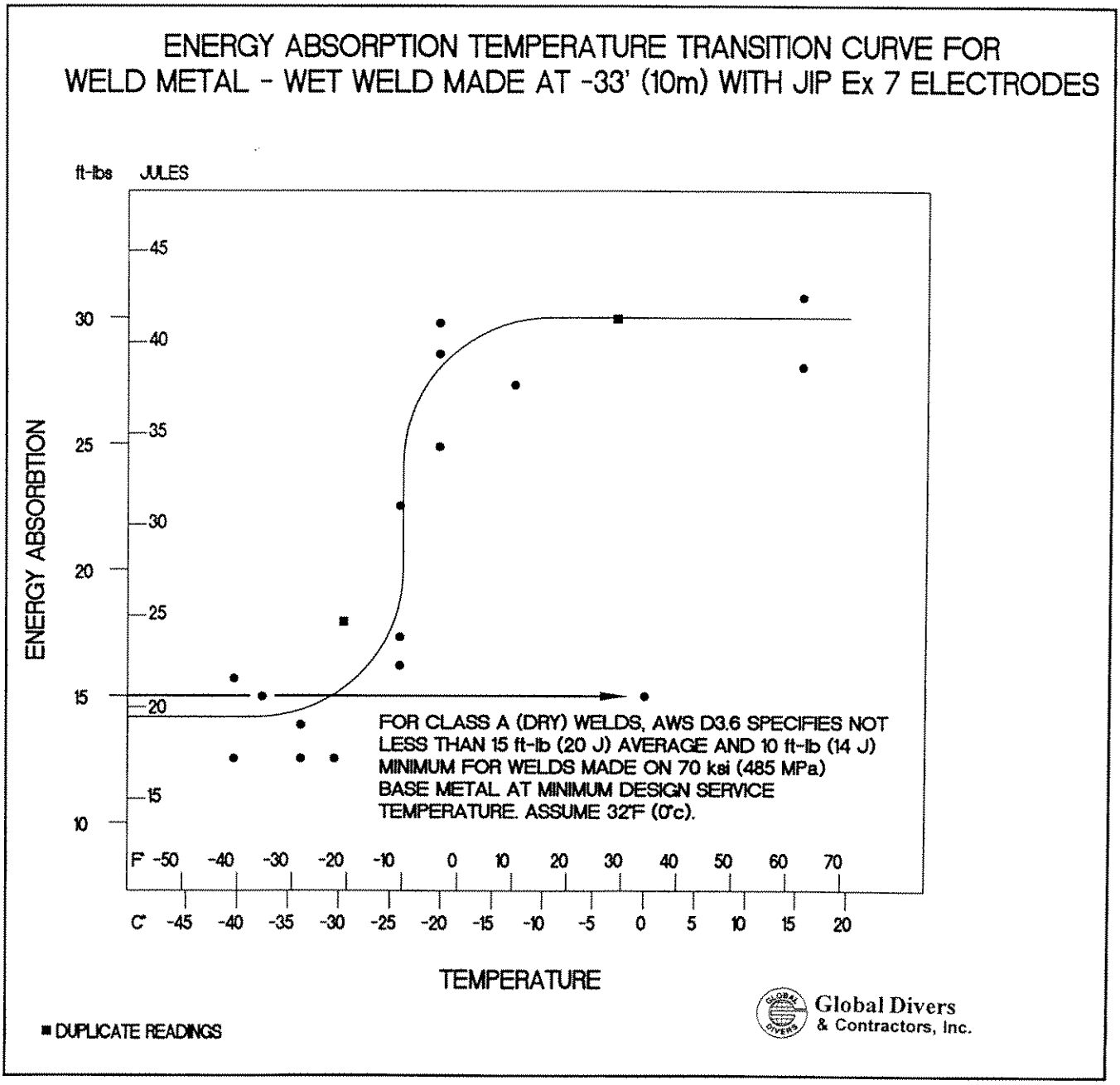

HAZ 51 ft-lbs • 28°F
69 JULES • -2°C
ENERGY ABSORPTION TEMPERATURE TRANSITION CURVE FOR
WELD METAL - WET WELD MADE AT -33' (10m) WITH JIP Ex 7 ELECTRODES
ft-lbs
JULES
45
40
35
30
25
20
15
30
25
20
15
10
ENERGY ABSORBTION
FOR CLASS A (DRY) WELDS, AWS D3.6 SPECIFIES NOT LESS THAN 15 ft-lb (20 J) AVERAGE AND 10 ft-lb (14 J) MINIMUM FOR WELDS MADE ON 70 ksi (485 MPa) BASE METAL AT MINIMUM DESIGN SERVICE TEMPERATURE. ASSUME 32°F (0°c).
F° -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70
C° -45 -40 -35 -30 -25 -20 -15 -10 -5 0 5 10 15 20
TEMPERATURE
■ DUPLICATE READINGS
Global Divers
& Contractors, Inc.

Figure 18

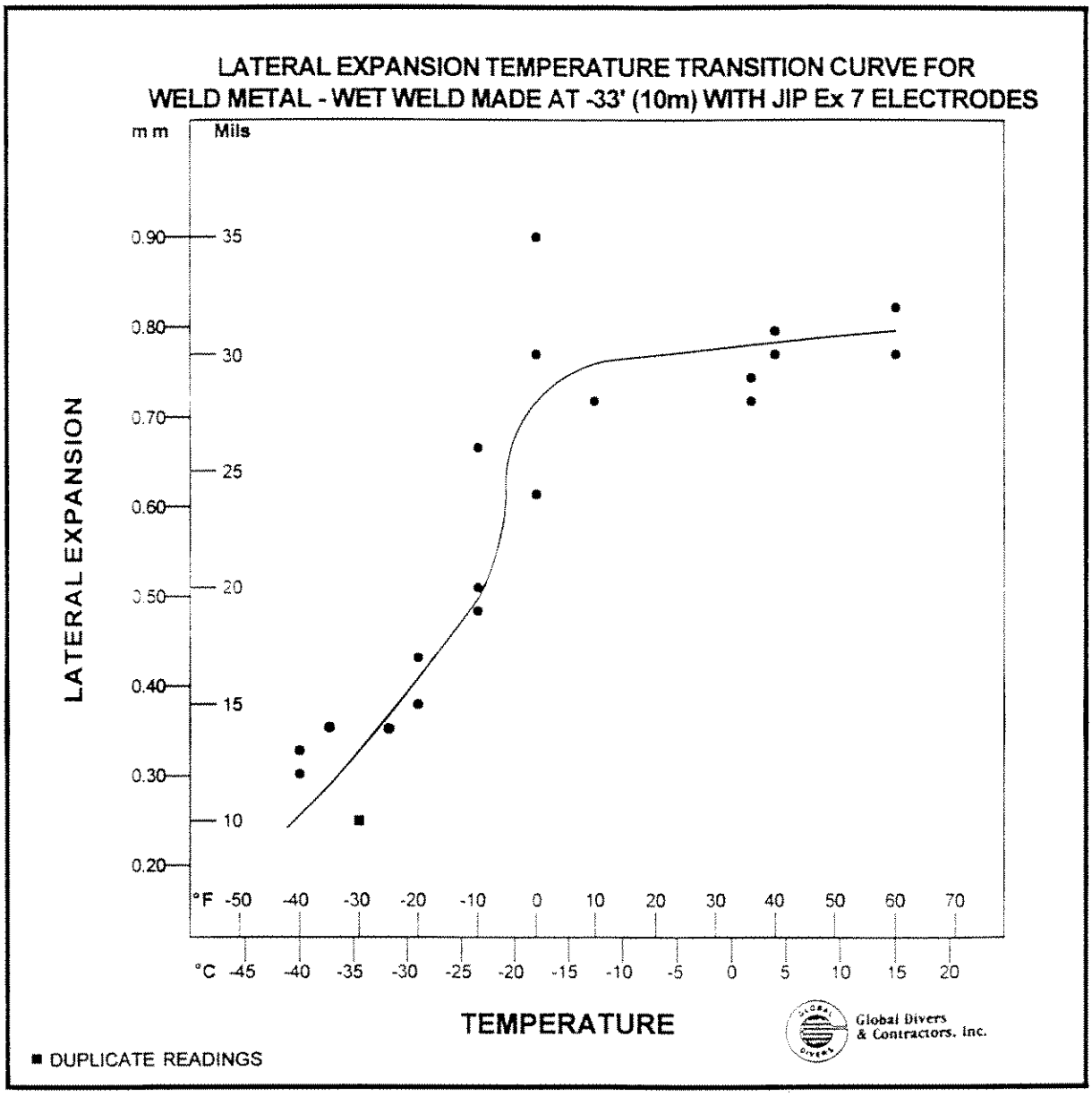

LATERAL EXPANSION TEMPERATURE TRANSITION CURVE FOR
WELD METAL - WET WELD MADE AT -33' (10m) WITH JIP Ex 7 ELECTRODES
m m
Mils
LATERAL EXPANSION
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
35
30
25
20
15
10
°F -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70
°C -45 -40 -35 -30 -25 -20 -15 -10 -5 0 5 10 15 20
TEMPERATURE
Global Divers
& Contractors, Inc.
■ DUPLICATE READINGS

Figure 19

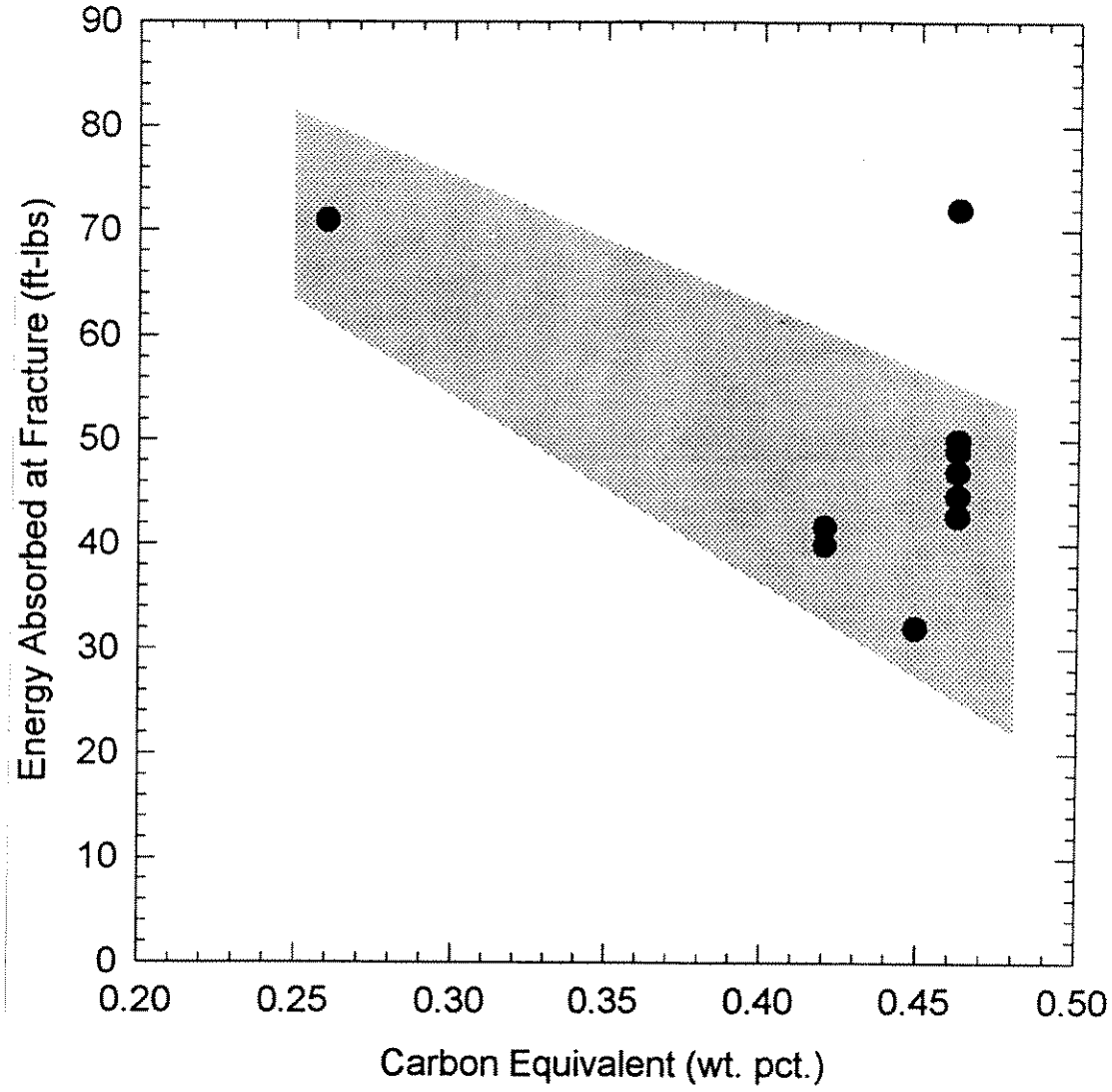

Energy Absorbed at Fracture (ft-lbs)
90
80
70
60
50
40
30
20
10
0
0.20
0.25
0.30
0.35
0.40
0.45
0.50
Carbon Equivalent (wt. pct.)

Figure 20

Based on the HAZ impact test results (51 ft-lbs average impact toughness) of the A537 Class 1 steel weldments reported in Table III, one may conclude that at 28°F, the impact properties of the HAZ of the weldments were significantly superior to those of the weld metal, which exceeded the AWS D3.6 requirements for Class A (dry) welds.

Finally, the relationship between impact energy and carbon equivalent can be clearly seen in Figure 20. As the alloy carbon equivalent increased, the amount of energy absorbed at fracture at 28/32°F decreased substantially. This trend clearly indicates the influence of alloy hardenability and microstructure on fracture resistance. High strength microstructures such as martensite will usually exhibit reduced impact toughness at low testing/application temperatures.

Table II. Heat Affected Zone Impact Toughness of Five Different Steels Using Charpy V-Notch Testing at 28°F.

Steel Type	Energy Absorbed at Fracture (ft-lbs)	Shear Fracture (percent)	Lateral Expansion (mils)	Carbon Equivalent (wt. pct.)
A537 Class 1	43	70	51	0.462
A537 Class 1	45	85	50	0.462
A537 Class 1	72	70	60	0.462
A537 Class 1	47	75	43	0.462
A537 Class 1	49	85	52	0.462
A537 Class 1	50	80	55	0.462
A36*	71	62	57	0.26
A588-88A Grade B*	32	68	35	0.449

Steel Type	Energy Absorbed at Fracture (ft-lbs)	Shear Fracture (percent)	Lateral Expansion (mils)	Carbon Equivalent (wt. pct.)
BS 4360 Grade 50D**	42	--	--	0.42
A106 Grade B**	40	57	37	0.42

* Testing Temperature: 28°F.

** Testing Temperature: 32°F. Test not performed for this program and data not reported in Interim Report #1.

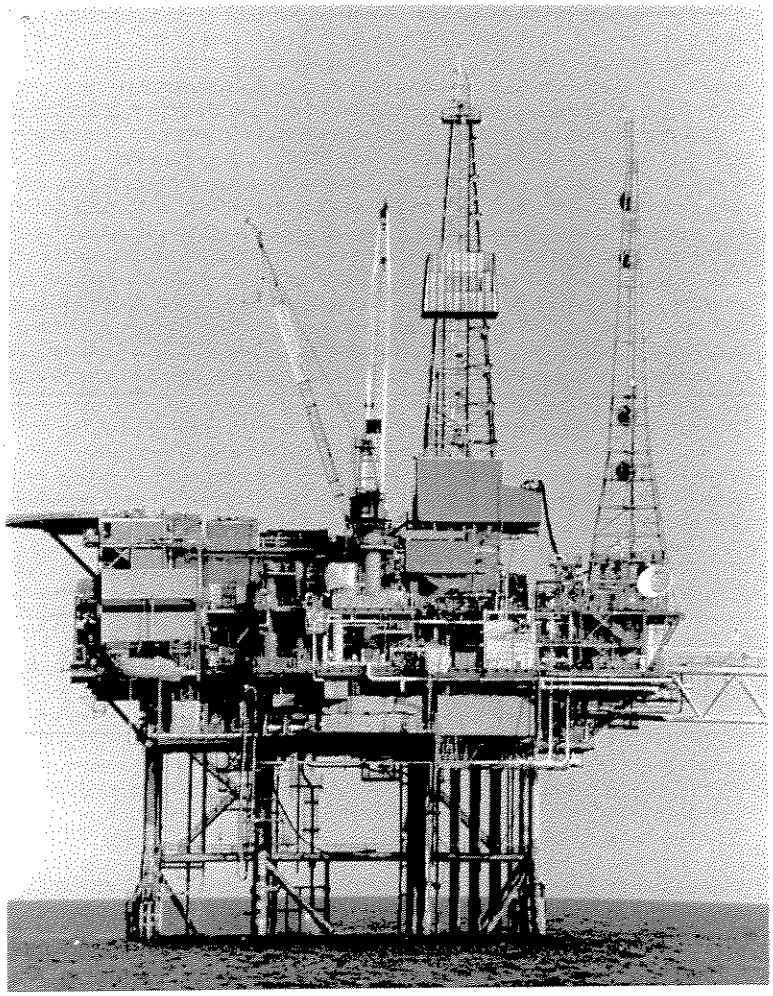
SUPPLEMENTAL MTB INFORMATION (Two Reports)

1. Using Global Divers' proprietary MTB wet welding method and electrodes under Global Divers' supervision, a North Sea diving company qualified wet welding procedures and sixteen welder/divers on British Standard 4360 Grade 5OD crack susceptible (CE = 0.416 wt. pct.) material in accordance with the requirements of AWS D3.6 for Class B welds. Supplemental Charpy V-notch impact tests at O° C (32° F) resulted in average HAZ absorbed energy of 41.7 ft-lb and weld metal 34.5 ft-lb (Dr. S. Ibarra, Amoco Research has detailed test results). This was the first use of the Multiple Temper Bead wet welding method which was developed specified for replacement of a 30" diameter, 65' long, 16 ton vertical diagonal brace on Amoco's U.K. Montrose platform in 1990. (See repair photographs on the following pages).

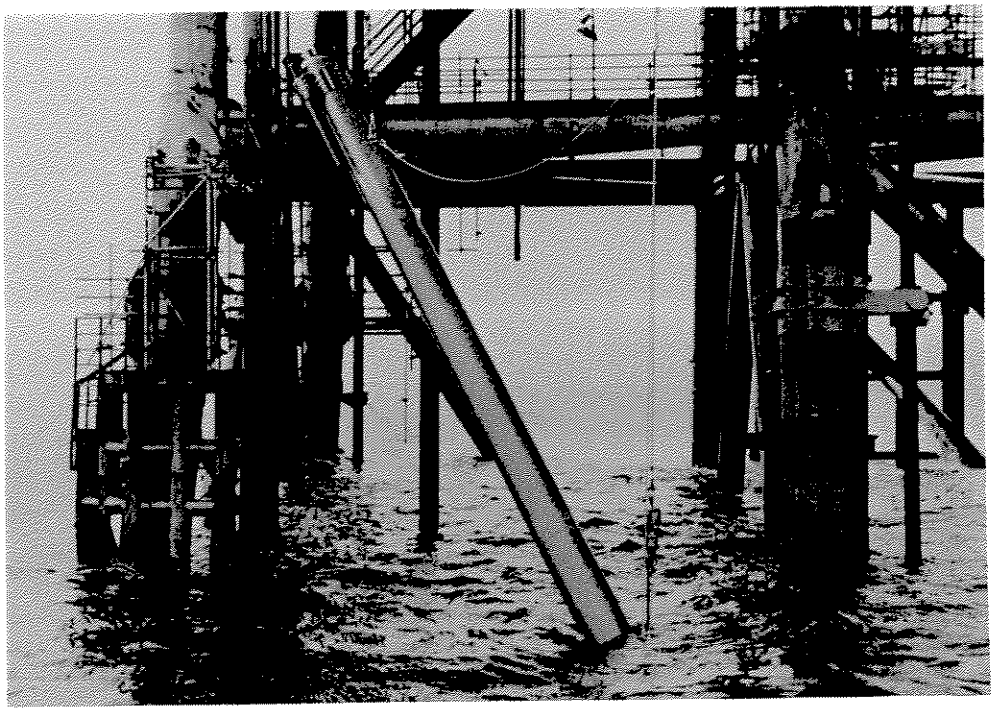
2. The following test results were obtained during qualification of all position fillet welds on ASTM A106 Grade B pipe for the repair of a hurricane damaged structure in the Gulf of Mexico. Carbon equivalent of the material at some of the repair locations was .42 and test welds demonstrated that it was susceptible to hydrogen induced under bead cracking in the HAZ. Welding procedures were qualified using the multiple temper bead wet welding method and Global 1 (Ex 7) electrodes. Two all weld metal tensile tests results were: 59,500 psi yield, 67,500

psi ultimate tensile with 12 % elongation and 64,000 psi yield, 74,600 psi ultimate with 15% elongation. HAZ Charpy V-notch impact test results at 32° F averaged: absorbed energy 40 ft-lb, shear fracture 57% and lateral expansion 37 mils, weld metal average results were: absorbed energy 32 ft-lb, shear fracture 100% and lateral expansion 37 mils. For Vickers 10 kg HAZ hardness, two of six readings (342 and 345) exceeded 325 specified by AWS D3.6 for Class A welds, HAZ average was 282. Weld metal maximum was 242.

First Use of The Multiple Temper Bead Wet Welding Method - North Sea August 1990

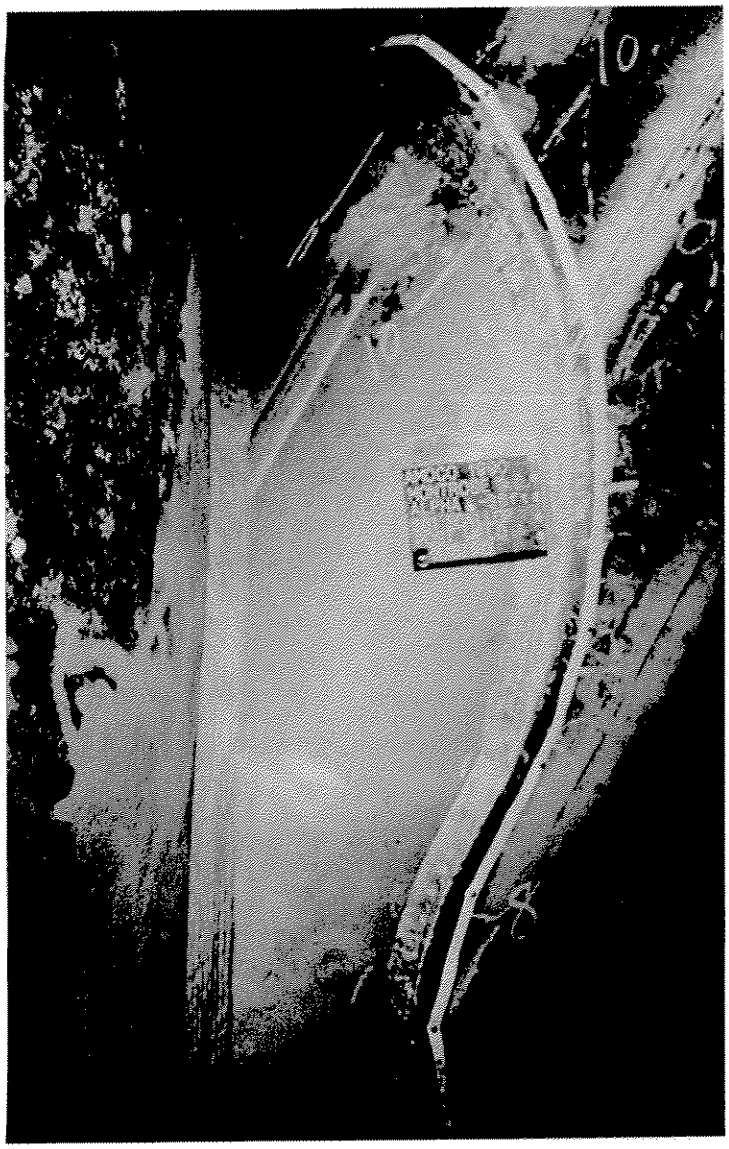


Amoco U.K. Montrose A Platform



30" Ø x 65' BS 4360 Grade D Brace

Welding With Global 1
Proprietary Electrodes



Wet Welding and Nondestructive
Examination Complete

MTB CONCLUSIONS/DISCUSSION

Except where noted otherwise, the following conclusions are based on test results of a multiplicity of carefully controlled experimental wet welds made at -33 ft in the vertical position with the Program Ex 7 electrodes on the A537 Class 1 material.

1. The acceptable time interval between deposition of primary weld beads that tie into crack susceptible (CE >.40) base metals, and the deposition of temper beads, was determined to be ≥ 2 hours. i.e., it took at least two hours for the hydrogen induced underbead cracks to develop in the HAZ of the base metal. This information is essential to the selection of the most efficient sequence for deposition of weld beads/layers.
2. The MTB technique was effective in preventing HAZ cracking with distances between toes of primary and temper beads varying from 1/16" to 3/16". This latitude of temper bead placement indicates that the MTB technique can be used under less than ideal underwater work conditions, and by less that highly skilled welder/divers.
3. Results of Vickers 10kg hardness test show that with or without, deliberate use of temper beads, excessive hardness (>325) was found only in the HAZ under the toes of cap passes. This emphasizes the need for increased temper bead heat input (≥ 37.0 kJin), or the half bead procedure as described in the Phase I Supplemental Report reference fillet welds.
4. The weld metal and HAZ Charpy V-notch impact properties at 28° F significantly exceeded the AWS D3.6 requirements for Class A (dry) welds. In fact, weld metal impacts met the AWS requirements at test temperatures down to -25° F.
5. Prior to the use of the Ex 7 electrodes, all evidence indicated that for wet welds, HAZ hydrogen cracking developed within less than 10 minutes. The fact that the Ex 7/A537 weldments took ≥ 2 hours to show evidence of HAZ cracking raised the question: Did use of the Ex 7 electrodes, or normalization of the A537 material delay the HAZ cracking? This doubt was dispelled when the Navy A516 Gr. 70 (CE .44) normalized plate was

welded with Ex 7 electrode with no temper beading and, not only were no cracks seen during welding or magnetic particle examination, but one of four macros from the 3/4" 3G weld did not reveal any HAZ cracks at 100x. As previously report, when this material was welded with commercial wet welding electrodes, the welder reported HAZ cracking as he was making the weld.

MULTIPLE TEMPER BEAD WELDING (Phase I, Part 1)

Appendices

Table of Contents

SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch on weld sample
P.O. #GD106064 Underwater Weld Sample-45 sec.

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 5X, 50X, & 100X Magnification.

No evidence of any Hydrogen Cracking were found.

EQUIPMENT UTILIZED FOR TEST
Type: Metallograph
Manufacturer: Olympus
Serial No.: 502796
Last Servicing: December, 1992

SRC Job No. 92-352

Certified By: Tim Brown Date: 6-24-93

Reviewed By: Joseph R Colley Date: 6-24-93

GLOBAL.MAC

SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch on weld sample
P.O. #GD106064 Underwater Weld Sample-105 sec.

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 5X, 50X, & 100X Magnification.

No evidence of any Hydrogen Cracking were found.

EQUIPMENT UTILIZED FOR TEST
Type: Metallograph
Manufacturer: Olympus
Serial No.: 502796
Last Servicing: December, 1992

SRC Job No. 92-352

Certified By: Tim Beam Date: 6-24-93

Reviewed By: Stephen R. Collins Date: 6-24-93

GLOBAL.MAC

SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch on weld sample
P.O. #GD106064 Underwater Weld Sample-120 sec.

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 5X, 50X, & 100X Magnification.

No evidence of any Hydrogen Cracking were found.

EQUIPMENT UTILIZED FOR TEST
Type: Metallograph
Manufacturer: Olympus
Serial No.: 502796
Last Servicing: December, 1992

SRC Job No. 92-352

Certified By: Tim Bass Date: 6-24-93

Reviewed By: Joseph R. Collins Date: 6-24-93

SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch on weld sample
P.O. #GD106064 Underwater Weld Sample-135 sec.

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 5X, 50X, & 100X Magnification.

No evidence of any Hydrogen Cracking were found.

EQUIPMENT UTILIZED FOR TEST
Type: Metallograph
Manufacturer: Olympus
Serial No.: 502796
Last Servicing: December, 1992

SRC Job No. 92-352

Certified By: Tim Bruner Date: 6-24-93

Reviewed By: Joseph A. Olden Date: 6-24-93

GLOBAL.MAC

SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch on weld sample
P.O. #GD106064 Underwater Weld Sample-195 sec.

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 5X, 50X, & 100X Magnification.

No evidence of any Hydrogen Cracking were found.

EQUIPMENT UTILIZED FOR TEST
Type: Metallograph
Manufacturer: Olympus
Serial No.: 502796
Last Servicing: December, 1992

SRC Job No. 92-352

Certified By: Tim Bernard Date: 6-29-93

Reviewed By: Scott A. Allen Date: 6-29-93

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SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch on weld sample
P.O. #GD106064 Underwater Weld Sample-60 sec.

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 5X, 50X, & 100X Magnification.

Indications of Unidentified Cracks were found.

Further study of these cracks by the Colorado School of Mines is advised.

EQUIPMENT UTILIZED FOR TEST
Type: Metallograph
Manufacturer: Olympus
Serial No.: 502796
Last Servicing: December, 1992

SRC Job No. 92-352

Certified By: Tim Pearson Date: 6-24-93

Reviewed By: Scott A Colley Date: 6-24-93

GLOBAL.MAC

SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch on weld sample
P.O. #GD106064 Underwater Weld Sample-90 sec.

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 5X, 50X, & 100X Magnification.

Indications of Unidentified Cracks were found.

Further study of these cracks by the Colorado School of Mines is advised.

EQUIPMENT UTILIZED FOR TEST
Type: Metallograph
Manufacturer: Olympus
Serial No.: 502796
Last Servicing: December, 1992

SRC Job No. 92-352

Certified By: Tim Lacour Date: 6-24-93

Reviewed By: Stephen R. Collyer Date: 6-24-93

GLOBAL.MAC

SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch on weld sample
P.O. #GD106064 Underwater Weld Sample-150 sec.

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 5X, 50X, & 100X Magnification.

Indications of Unidentified Cracks were found.

Further study of these cracks by the Colorado School of Mines is advised.

EQUIPMENT UTILIZED FOR TEST
Type: Metallograph
Manufacturer: Olympus
Serial No.: 502796
Last Servicing: December, 1992

SRC Job No. 92-352

Certified By: [signature] Date: 6-24-93

Reviewed By: [signature] Date: 6-24-93

GLOBAL.MAC

SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch on weld sample
P.O. #GD106064 Underwater Weld Sample-180 sec.

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 5X, 50X, & 100X Magnification.

Indications of Unidentified Cracks were found.

Further study of these cracks by the Colorado School of Mines is advised.

EQUIPMENT UTILIZED FOR TEST
Type: Metallograph
Manufacturer: Olympus
Serial No.: 502796
Last Servicing: December, 1992

SRC Job No. 92-352

Certified By: Tim Ramon Date: 6-24-93

Reviewed By: Date: 6-24-93

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SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch on weld sample
P.O. #GD106064 Underwater Weld Sample-210 sec.

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 5X, 50X, & 100X Magnification.

Indications of Unidentified Cracks were found.

Further study of these cracks by the Colorado School of Mines is advised.

EQUIPMENT UTILIZED FOR TEST
Type: Metallograph
Manufacturer: Olympus
Serial No.: 502796
Last Servicing: December, 1992

SRC Job No. 92-352

Certified By: Tim [signature] Date: 6-24-93

Reviewed By: [signature] Date: [illegible]

GLOBAL.MAC

TEMPERED BEAD TIMING WELDMENTS

Four Minutes to Ten Minutes

Thirty Second Intervals

No HAZ Cracks

SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch of Timing Beads on A537 Plate
P.O. #GD406936
Time: 240 seconds

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 50X, & 100X Magnification.

No evidence of Hydrogen Cracking were found.

EQUIPMENT UTILIZED FOR TEST	
Type:	Metallograph
Manufacturer:	Olympus
Serial No.:	502796
Last Servicing:	December, 1992

SRC Job No. 92-352

Certified By: Tim Rasmussen Date: 9-29-93

SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch of Timing Beads on A537 Plate
P.O. #GD406936
Time: 270 seconds

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 50X, & 100X Magnification.

No evidence of Hydrogen Cracking were found.

EQUIPMENT UTILIZED FOR TEST
Type: Metallograph
Manufacturer: Olympus
Serial No.: 502796
Last Servicing: December, 1992

SRC Job No. 92-352

Certified By: Tim Stevens Date: 9-29-93

SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch of Timing Beads on A537 Plate
P.O. #GD406936
Time: 300 seconds

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 50X, & 100X Magnification.

No evidence of Hydrogen Cracking were found.

EQUIPMENT UTILIZED FOR TEST	
Type:	Metallograph
Manufacturer:	Olympus
Serial No.:	502796
Last Servicing:	December, 1992

SRC Job No. 92-352

Certified By: Tim Emerson Date: 9-29-93

SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch of Timing Beads on A537 Plate
P.O. #GD406936
Time: 330 seconds

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 50X, & 100X Magnification.

No evidence of Hydrogen Cracking were found.

EQUIPMENT UTILIZED FOR TEST	
Type:	Metallograph
Manufacturer:	Olympus
Serial No.:	502796
Last Servicing:	December, 1992

SRC Job No. 92-352

Certified By: Tim Brennan Date: 9-29-93

SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch of Timing Beads on A537 Plate
P.O. #GD406936
Time: 360 seconds

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 50X, & 100X Magnification.

No evidence of Hydrogen Cracking were found.

EQUIPMENT UTILIZED FOR TEST	
Type:	Metallograph
Manufacturer:	Olympus
Serial No.:	502796
Last Servicing:	December, 1992

SRC Job No. 92-352

Certified By: Tim Broussard Date: 9-29-93

SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch of Timing Beads on A537 Plate
P.O. #GD406936
Time: 390 seconds

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 50X, & 100X Magnification.

No evidence of Hydrogen Cracking were found.

EQUIPMENT UTILIZED FOR TEST
Type: Metallograph
Manufacturer: Olympus
Serial No.: 502796
Last Servicing: December, 1992

SRC Job No. 92-352

Certified By: Tim Emmett Date: 9-29-93

SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch on Timing Beads on Plate
P.O. #GD407021
3/4" A537 Class 1 Mat'l.(.462 C.E.) 6.5 min.

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 100X Magnification.

There was no evidence of any cracking.

EQUIPMENT UTILIZED FOR TEST
Type: Metallograph
Manufacturer: Olympus
Serial No.: 502796
Last Servicing: December, 1992

SRC Job No. 92-352

Certified By: Tim Ford Date: 10-13-93

SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch on Timing Beads on Plate
P.O. #GD407021
3/4" A537 Class 1 Mat'l.(.462 C.E.) 7.0 min.

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 100X Magnification.

There was no evidence of any cracking.

EQUIPMENT UTILIZED FOR TEST
Type: Metallograph
Manufacturer: Olympus
Serial No.: 502796
Last Servicing: December, 1992

SRC Job No. 92-352

Certified By: Tim Brunel Date: 10-13 93

SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch on Timing Beads on Plate
P.O. #GD407021
3/4" A537 Class 1 Mat'l.(.462 C.E.) 7.5 min.

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 100X Magnification.

There was no evidence of any cracking.

EQUIPMENT UTILIZED FOR TEST
Type: Metallograph
Manufacturer: Olympus
Serial No.: 502796
Last Servicing: December, 1992

SRC Job No. 92-352

Certified By: Tim Fournet Date: 10-13-93

SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch on Timing Beads on Plate
P.O. #GD407021
3/4" A537 Class 1 Mat'l.(.462 C.E.) 8.0 min.

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 100X Magnification.

There was no evidence of any cracking.

EQUIPMENT UTILIZED FOR TEST	
Type:	Metallograph
Manufacturer:	Olympus
Serial No.:	502796
Last Servicing:	December, 1992

SRC Job No. 92-352

Certified By: Tim Brennan Date: 10-13-93

SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch on Timing Beads on Plate
P.O. #GD407021
3/4" A537 Class 1 Mat'l.(.462 C.E.) 8.5 min.

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 100X Magnification.

There was no evidence of any cracking.

EQUIPMENT UTILIZED FOR TEST
Type: Metallograph
Manufacturer: Olympus
Serial No.: 502796
Last Servicing: December, 1992

SRC Job No. 92-352

Certified By: Tim Brown Date: 10-13-93

SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch on Timing Beads on Plate
P.O. #GD407021
3/4" A537 Class 1 Mat'l.(.462 C.E.) 9.0 min.

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 100X Magnification.

There was no evidence of any cracking.

EQUIPMENT UTILIZED FOR TEST
Type: Metallograph
Manufacturer: Olympus
Serial No.: 502796
Last Servicing: December, 1992

SRC Job No. 92-352

Certified By: Tim Pierce Date: 10-13-93

SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch on Timing Beads on Plate
P.O. #GD407021
3/4" A537 Class 1 Mat'l.(.462 C.E.) 9.5 min.

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 100X Magnification.

There was no evidence of any cracking.

EQUIPMENT UTILIZED FOR TEST
Type: Metallograph
Manufacturer: Olympus
Serial No.: 502796
Last Servicing: December, 1992

SRC Job No. 92-352

Certified By: Tim Prescott Date: 10-13-93

SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch on Timing Beads on Plate
P.O. #GD407021
3/4" A537 Class 1 Mat'l.(.462 C.E.) 10.0 min.

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 100X Magnification.

There was no evidence of any cracking.

EQUIPMENT UTILIZED FOR TEST
Type: Metallograph
Manufacturer: Olympus
Serial No.: 502796
Last Servicing: December, 1992

SRC Job No. 92-352

Certified By: Tim Granier Date: 10-13-93

TEMPER BEAD TIMING WELDMENTS

Ten Minutes to Sixty Minutes

Ten Minute Intervals

No HAZ Cracks

SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch of Bead on Plate
P.O. #GD406534
A537 C1.1, (10 min.)

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 100X Magnification.

No evidence of any cracking was found.

EQUIPMENT UTILIZED FOR TEST
Type: Metallograph
Manufacturer: Olympus
Serial No.: 502796
Last Servicing: December, 1992

Certified By: [signature] Date: 8-3-93

SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch of Bead on Plate
P.O. #GD406534
A537 Cl.1, (20 min.)

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 100X Magnification.

No evidence of any cracking was found.

EQUIPMENT UTILIZED FOR TEST
Type: Metallograph
Manufacturer: Olympus
Serial No.: 502796
Last Servicing: December, 1992

Certified By: Tim Brand Date: 8-3-93

SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch of Bead on Plate
P.O. #GD406534
A537 C1.1, (30 min.)

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 100X Magnification.

No evidence of any cracking was found.

EQUIPMENT UTILIZED FOR TEST
Type: Metallograph
Manufacturer: Olympus
Serial No.: 502796
Last Servicing: December, 1992

Certified By: Tim Arnold Date: 8-3-93

SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch of Bead on Plate
P.O. #GD406534
A537 Cl.1, (40 min.)

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 100X Magnification.

No evidence of any cracking was found.

EQUIPMENT UTILIZED FOR TEST
Type: Metallograph
Manufacturer: Olympus
Serial No.: 502796
Last Servicing: December, 1992

Certified By: Tim Brunet Date: 8-3-93

SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch of Bead on Plate
P.O. #GD406534
A537 C1.1, (50 min.)

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 100X Magnification.

No evidence of any cracking was found.

EQUIPMENT UTILIZED FOR TEST
Type: Metallograph
Manufacturer: Olympus
Serial No.: 502796
Last Servicing: December, 1992

Certified By: Tim Brunet Date: 8-3-93

SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch of Bead on Plate
P.O. #GD406534
A537 Cl.1, (60 min.)

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 100X Magnification.

No evidence of any cracking was found.

EQUIPMENT UTILIZED FOR TEST
Type: Metallograph
Manufacturer: Olympus
Serial No.: 502796
Last Servicing: December, 1992

Certified By: [signature] Date: 8-3-93

TEMPER BEAD TIMING WELDMENTS

One Hour to Two Hours

Thirty Minute Intervals

No HAZ Cracks

SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch on Timing Beads on Plate
P.O. #GD106997
3/4" A537 Class 1 Mat'l.(.462 C.E.) 1.0 Hrs.

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 100X Magnification.

There was no evidence of any cracking.

EQUIPMENT UTILIZED FOR TEST
Type: Metallograph
Manufacturer: Olympus
Serial No.: 502796
Last Servicing: December, 1992

SRC Job No. 92-352

Certified By: Tim Brown Date: 10-21-93

SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch on Timing Beads on Plate
P.O. #GD106997
3/4" A537 Class 1 Mat'l.(.462 C.E.) 1.5 Hrs.

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 100X Magnification.

There was no evidence of any cracking.

EQUIPMENT UTILIZED FOR TEST
Type: Metallograph
Manufacturer: Olympus
Serial No.: 502796
Last Servicing: December, 1992

SRC Job No. 92-352

Certified By: Tim Brown Date: 10-21-93

SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch on Timing Beads on Plate
P.O. #GD106997
3/4" A537 Class 1 Mat'l.(.462 C.E.) 2.0 Hrs.

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 100X Magnification.

There was no evidence of any cracking.

EQUIPMENT UTILIZED FOR TEST
Type: Metallograph
Manufacturer: Olympus
Serial No.: 502796
Last Servicing: December, 1992

SRC Job No. 92-352

Certified By: Tim Reese Date: 10-21-93

TEMPERED BEAD TIMING WELDMENTS

Two and a-half Hours to Four Hours

Thirty Minute Intervals

all with HAZ Cracks

Rev. November 28, 1995

SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch on Timing Beads on Plate
P.O. #GD106997
3/4" A537 Class 1 Mat'l.(.462 C.E.) 2.5 Hrs.

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 100X Magnification.

There was evidence of typical Hydrogen Cracking

in the HAZ of the base metal under the Wet Primary Bead.

EQUIPMENT UTILIZED FOR TEST
Type: Metallograph
Manufacturer: Olympus
Serial No.: 502796
Last Servicing: December, 1992

SRC Job No. 92-352

Certified By: Tim Brown Date: 10-21-93

SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch on Timing Beads on Plate
P.O. #GD106997
3/4" A537 Class 1 Mat'l.(.462 C.E.) 3.0 Hrs.

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 100X Magnification.

There was evidence of typical Hydrogen Cracking

in the HAZ of the base metal under the Wet Primary Bead.

EQUIPMENT UTILIZED FOR TEST
Type: Metallograph
Manufacturer: Olympus
Serial No.: 502796
Last Servicing: December, 1992

SRC Job No. 92-352

Certified By: Tim Brand Date: 10-31-93

SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch on Timing Beads on Plate
P.O. #GD106997
3/4" A537 Class 1 Mat'l.(.462 C.E.) 3.5 Hrs.

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 100X Magnification.

There was evidence of typical Hydrogen Cracking

in the HAZ of the base metal under the Wet Primary Bead.

EQUIPMENT UTILIZED FOR TEST
Type: Metallograph
Manufacturer: Olympus
Serial No.: 502796
Last Servicing: December, 1992

SRC Job No. 92-352

Certified By: Tim Broussard Date: 10-21-93

SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch on Timing Beads on Plate
P.O. #GD106997
3/4" A537 Class 1 Mat'l.(.462 C.E.) 4.0 Hrs.

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 100X Magnification.

There was evidence of typical Hydrogen Cracking

in the HAZ of the base metal under the Wet Primary Bead.

EQUIPMENT UTILIZED FOR TEST
Type: Metallograph
Manufacturer: Olympus
Serial No.: 502796
Last Servicing: December, 1992

SRC Job No. 92-352

Certified By: Tim Pearson Date: 10-21-93

Global Divers
& Contractors, Inc.

Sheet 1 of 2
W/O No. ED-008-93

MATERIALS JOINING WORK REPORT
Part 1 MTB Toe-to-Toe Distance 3/32"

Location GLOBAL DIVERS - PORT OF IBERIA Contract No. 91-M-4346

Mat'l (1) A 537 Grade Cl 1
Ht./Slab No. 79006-12
Thick 5/8" in. Dia. _____ in.

Mat'l (2) _____ Grade _____
Ht./Slab No. _____
Thick _____ in. Dia. _____ in.

Electrode (AWS) E 6013 A5.1 TN Program Ex 7 Mfr. Proprietary Ctry _____

Process SMAW Current/Polarity CC/DCEP/PULSE Joint Type V-GROOVE (8") Position 3G

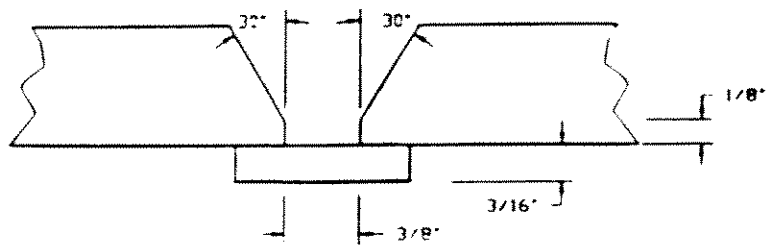
Water Depth 33' Dry _____ Wet X

Welding Variables:

R F & C	PASS	DIA.	AMPS	VOLTS	I.P.M.	REMARKS
ROOT	1	1/8"	150 - 160	28 - 30	5.7	Temper beads were deposited on all
ROOT	2	1/8"	150 - 160	28 - 30	5.3	beads that tied into the base metal.
TB	AVG	1/8"	155	30	8.9	Toe-to-toe distances were 3/32".
FILL	AVG	1/8"	155	30	8.7	Number of passes -32. Electrodes
CAP	AVG	1/8"	155	30	8.9	consumed -43. Welding time 45
						minutes.

Welder: Darryl R. Phillips Date: 6-1-93

Welding Joint Sketch:



Welding Techniques:

Stringer Beads with all passes downhill.

Global Divers
& Contractors, Inc.

Tension Tests: (Reduced Section/All-Weld-Metal) N/A

SPECIMEN	ORIENT	ULTIMATE S.	YIELD S.	ELONGATION	FAILURE
1					
2					

Bends: N/A

SPECIMEN	ROOT	FACE	SIDE	RADIUS	RESULTS
1					
2					
3					
4					

Chemistry:

	CE	C	Mn	P	S	Si	Ni	Cr	Mo	Cu	V	Cb	Nb	Al
CTR														
LAB	.462	.20	1.50	.014	.019	.38	.03	.02	.01	.03	.01	.01	---	---

Hardness (Vickers/Rockwell): Vickers 10 kg, combined test results on four macros.

LOCATION	LEFT SIDE	RIGHT SIDE
BASE METAL (AVG.)	176	180
HAZ (MAX)	369	345
HAZ (AVG)	312	241
WM (MAX)	207	260

Purpose of Test: Determine maximum acceptable distance between toes of primary beads and toes of temper beads.

Remarks & Evaluation: Charpy V-Notch HAZ impacts at 28° F averaged 47 ft. lbs. with 75% shear.
No HAZ cracks at 100X.

By: C.E. Grubbs Date: 6-1-93 Rev: —

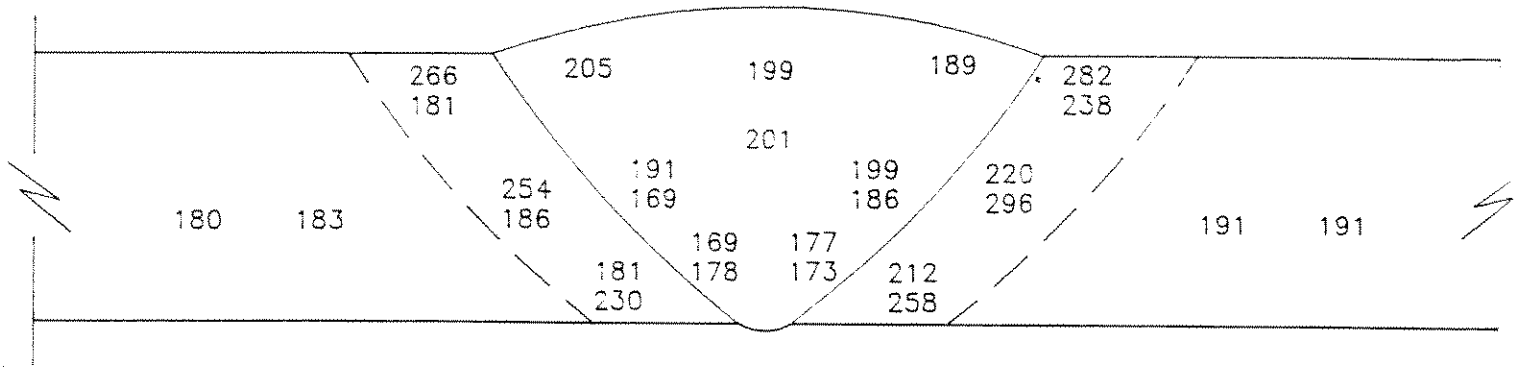
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers 10kg load hardness test on weld sample 3/32" - #1 (P.O. #GD106384) 3G - With T.B.

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



Note: HAZ Examined at 5X, 40X, & 100X Magnification.

EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 18, 1993

SRC Job No. 92-352

Certified By: _____ Date: 6-14-93

Reviewed By: _____ Date: 06-14-93

GLOBAL1.VIC

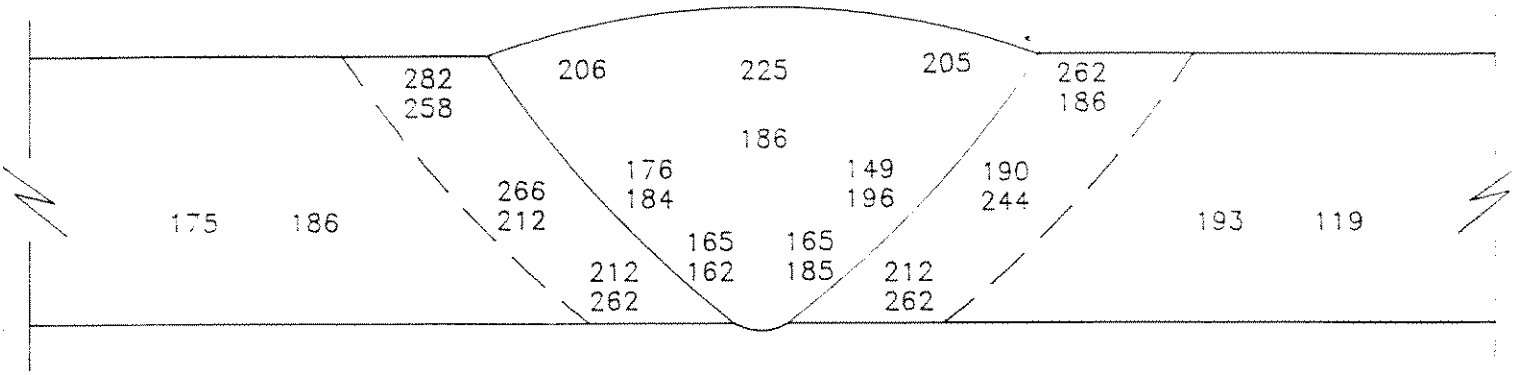
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers 10kg load hardness test on weld sample 3/32" - #2 (P.O. #GD106384) 3G - With T.B.

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



Note: HAZ Examined at 5X, 40X, & 100X Magnification.

EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 18, 1993

SRC Job No. 92-352

Certified By: Tim Brown Date: 6-14-93

Reviewed By: Stephen A. Ollison Date: 06-14-93

GLOBAL1.VIC

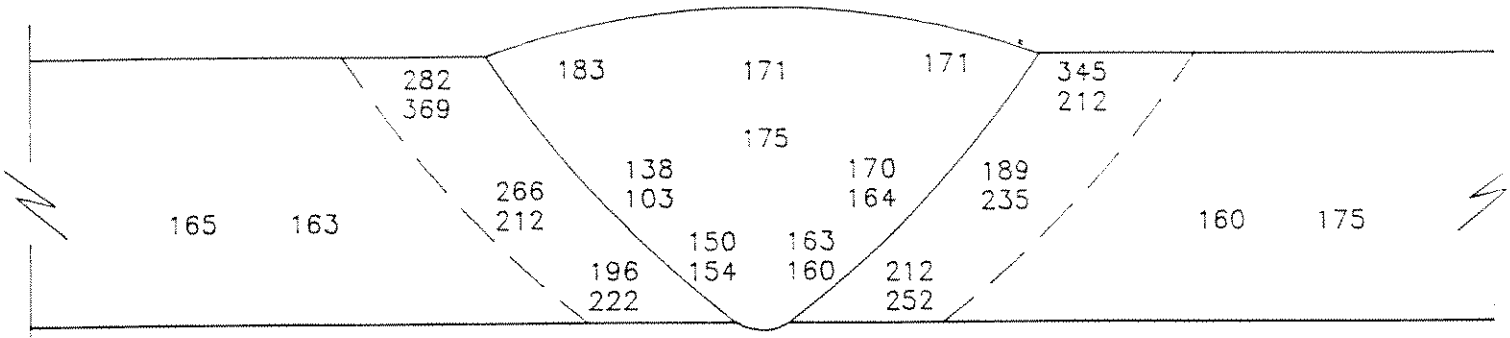
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers 10kg load hardness test on weld sample 3/32" - #3 (P.O. #GD106384) 3G - With T.B.

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



Note: HAZ Examined at 5X, 40X, & 100X Magnification.

EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 18, 1993

SRC Job No. 92-352

Certified By: Tim Pierce Date: 6-14-93

Reviewed By: Joseph A. Wilson Date: 06-14-93

GLOBAL1.VIC

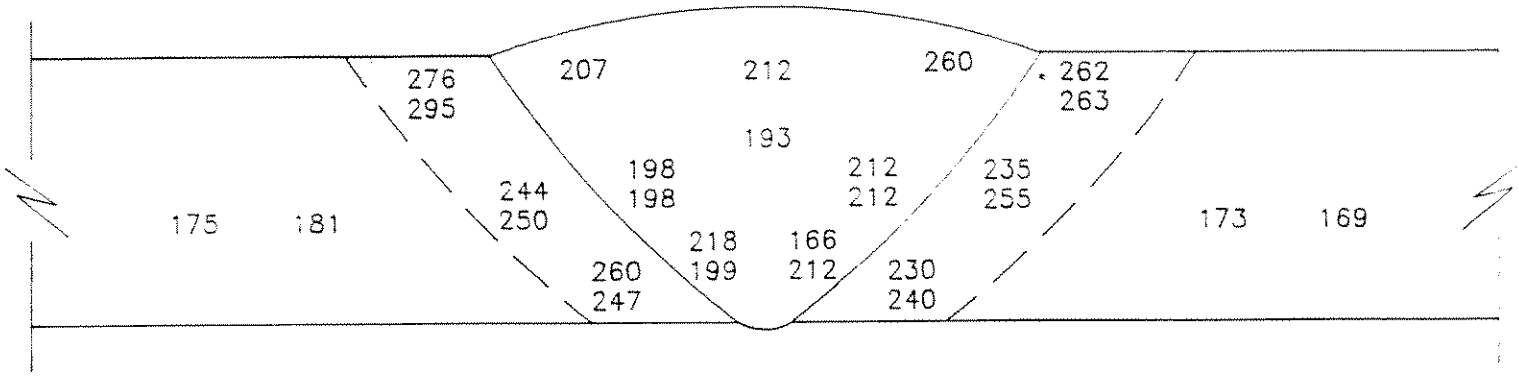
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers 10kg load hardness test on weld sample 3/32" - #4 (P.O. #GD106384) 3G - With T.B.

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



Note: HAZ Examined at 5X, 40X, & 100X Magnification.

EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 18, 1993

SRC Job No. 92-352

Certified By: [signature] Date: 6-14-93

Reviewed By: [signature] Date: 06.14.93

GLOBAL1.VIC

SRC ENGINEERS, INC.
P.O. BOX 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710
(318) 837-3810, 837-3819 STEPHEN R. CALLEGARI, P.E.

CERTIFICATE OF ANALYSIS

Date: 07-07-93 P.O. No. GD106384
Company: Global Divers & Contractors, Inc.
Test: Charpy V-Notch Impact Test per ASTM A-370, E-23
Test Performed on: 3/32" labeled weld

Size of Specimens: Full Size (10mm x 10mm x 55mm)

Test Temperature: 28°F

RESULTS			
SPECIMEN NUMBER	ABSORBED ENERGY ft - lbf	PERCENT SHEAR FRACTURE	LATERAL EXPANSION (mils)
H1(Heat Affected Zone)	41	85	39
H2(Heat Affected Zone)	41	70	42
H3(Heat Affected Zone)	53	85	45
H4(Heat Affected Zone)	47	70	46
H5(Heat Affected Zone)	54	70	43

EQUIPMENT UTILIZED FOR TEST
Type: Charpy V-Notch Impact Tester
Manufacturer: Tinius Olsen
Serial No.: 85900
Last Calibration: January 18, 1993

Certified By: Tim J. Broussard Date: 6-8-93
Tim J. Broussard
SRC Engineers, Inc.

Reviewed By: Date: 06-08-93

GLOBAL1.CHP

Global Divers
& Contractors, Inc.

Sheet 1 of 2
W/O No. ED-009-93

MATERIALS JOINING WORK REPORT
Part 1 MTB Toe-to-Toe Distance 1/8"

Location GLOBAL DIVERS - PORT OF IBERIA Contract No. 91-M-4346

Mat'l (1) A 537 Grade Cl 1
Ht./Slab No. 79006-12
Thick 5/8" in. Dia. _____ in.

Mat'l (2) _____ Grade _____
Ht./Slab No. _____
Thick _____ in. Dia. _____ in.

Electrode (AWS) E 6013 A5.1 TN Program Ex 7 Mfr. Proprietary Ctry _____

Process SMAW Current/Polarity CC/DCEP/PULSE Joint Type V-GROOVE (8") Position 3G

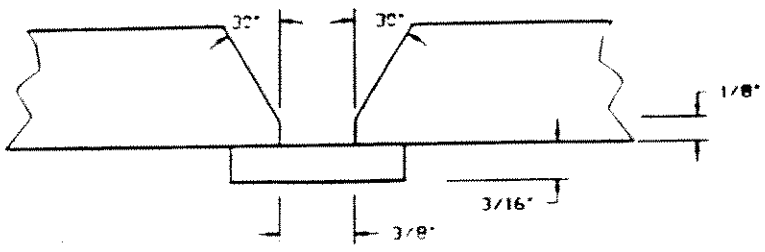
Water Depth 33' Dry _____ Wet X

Welding Variables:

R F & C	PASS	DIA.	AMPS	VOLTS	I.P.M.	REMARKS
ROOT	1	1/8"	150 - 160	28 - 30	6.2	Temper bead was deposited on all
ROOT	2	1/8"	150 - 160	28 - 30	6.1	beads that tied into the base metal.
TB	AVG	1/8"	155	30	9.1	Toe-to-toe distance was 1/8".
FILL	AVG	1/8"	155	30	8.4	Number of passes -34. Electrodes
CAP	AVG	1/8"	155	30	8.9	consumed -41. Welding time -54
						minutes.

Welder: Darryl R. Phillips Date: 6-1-93

Welding Joint Sketch:



Welding Techniques:

Stringer Beads with all passes downhill.

Global Divers
& Contractors, Inc.

Tension Tests: (Reduced Section/All-Weld-Metal) N/A

SPECIMEN	ORIENT	ULTIMATE S.	YIELD S.	ELONGATION	FAILURE
1					
2					

Bends: N/A

SPECIMEN	ROOT	FACE	SIDE	*RADIUS	RESULTS
1					
2					
3					
4					

Chemistry:

	CE	C	Mn	P	S	Si	Ni	Cr	Mo	Cu	V	Cb	Nb	Al
CTR														
LAB	.462	.20	1.50	.014	.019	.38	.03	.02	.01	.03	.01	.01	—	—

Hardness (Vickers/Rockwell): Vickers 10 kg, combined test results on four macros.

LOCATION	LEFT SIDE	RIGHT SIDE
BASE METAL (AVG.)	177	172
HAZ (MAX)	340	361
HAZ (AVG)	269	264
WM (MAX)	212	212

Purpose of Test: Determine maximum acceptable distance between toes of primary beads and toes of temper beads.

Remarks & Evaluation: Charpy HAZ V-Notch impacts at 28° F averaged 49 ft. lbs. with 85% shear.
No HAZ cracks at 100X.

By: C.E. Grubbs Date: 6-1-93 Rev: —

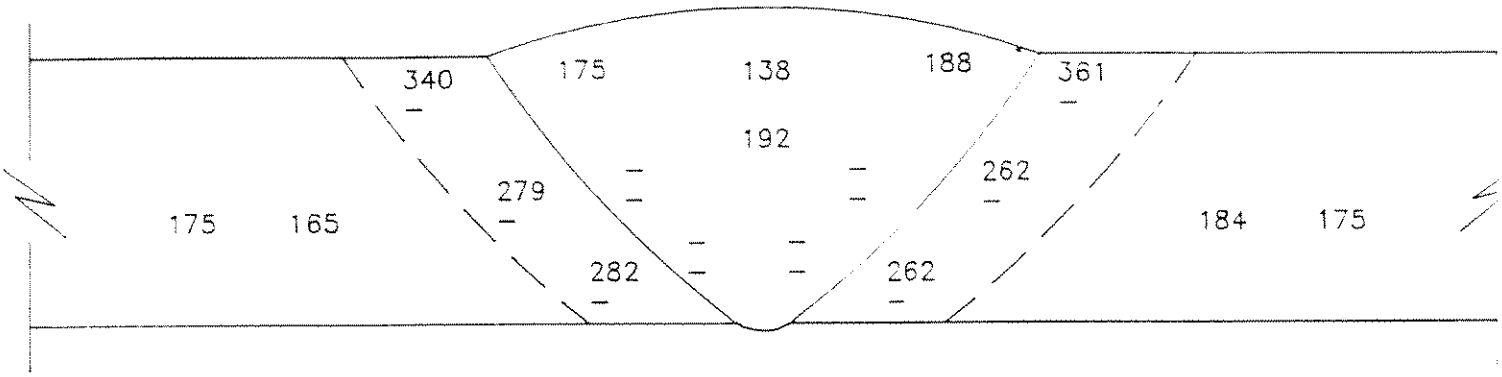
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers 10kg load hardness test on weld sample 1/8" - #1 (P.O. #GD106384) 3G - With T.B.

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



Note: HAZ Examined at 5X, 40X, & 100X Magnification.

EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 18, 1993

SRC Job No. 92-352

Certified By: [signature] Date: 6-14-93

Reviewed By: [signature] Date: 06-14-93

GLOBAL1.VIC

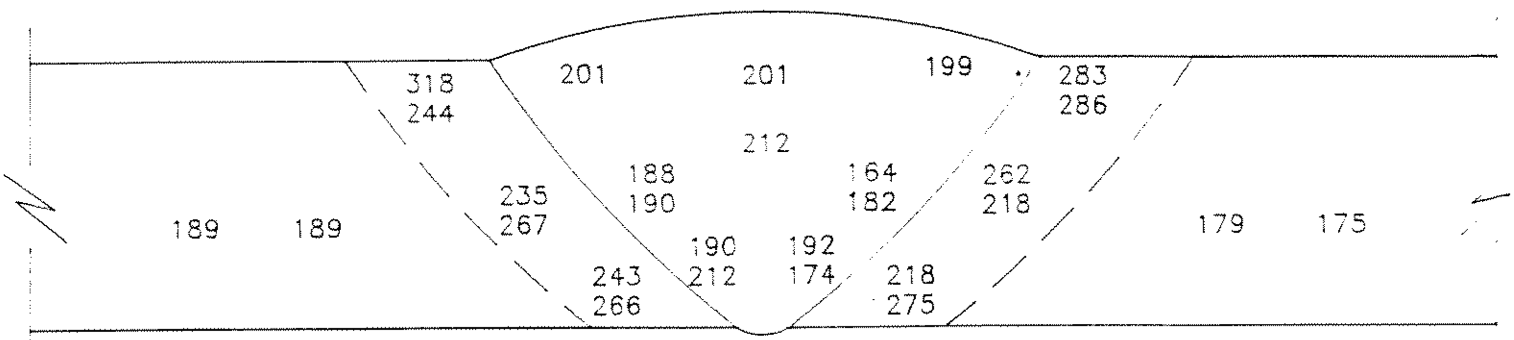
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers 10kg load hardness test on weld sample 1/8" - #2 (P.O. #GD106384) 3G - With T.B.

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



Note: HAZ Examined at 5X, 40X, & 100X Magnification.

EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 18, 1993

SRC Job No. 92-352

Certified By: ______ Date: 6-14-93

Reviewed By: ______ Date: 06-14-93

GLOBAL1.VIC

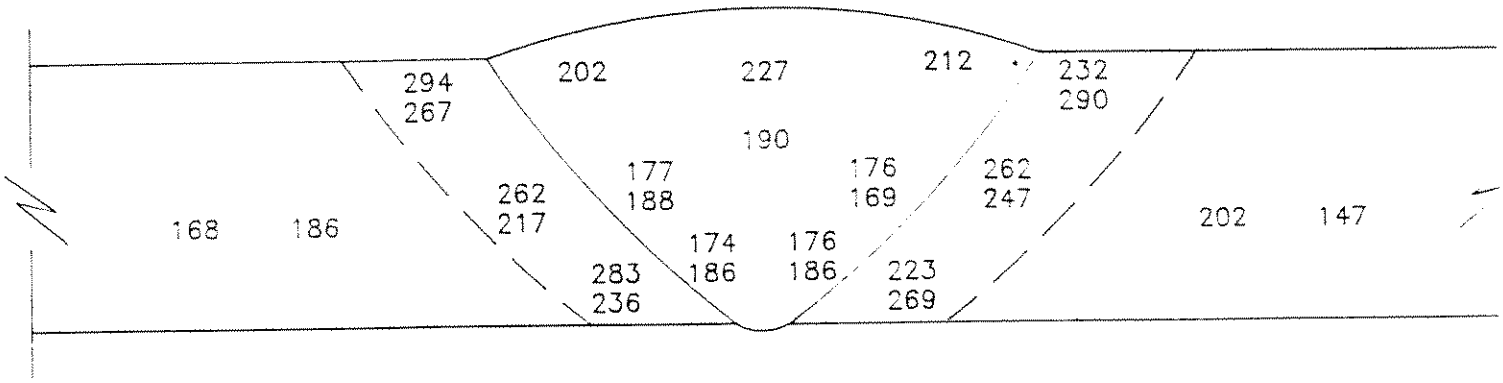
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers 10kg load hardness test on weld sample 1/8" - #3 (P.O. #GD106384) 3G - With T.B.

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



Note: HAZ Examined at 5X, 40X, & 100X Magnification.

EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 18, 1993

SRC Job No. 92-352

Certified By: Tim Barnard Date: 6-14-93

Reviewed By: Stephen A. Collins Date: 06-14-93

GLOBAL1.VIC

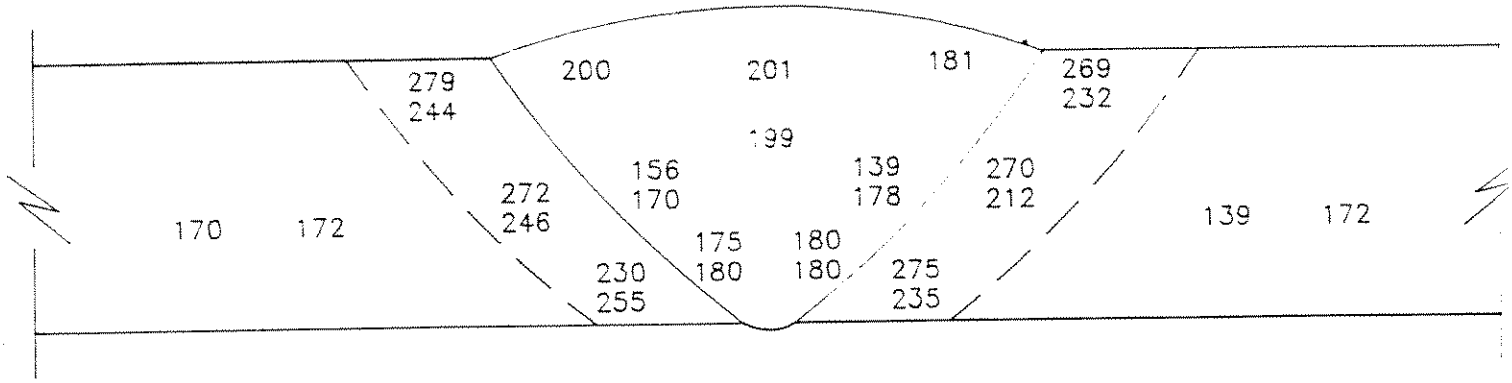
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers 10kg load hardness test on weld sample 1/8" - #4 (P.O. #GD106384) 3G- With T.B.

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



Note: HAZ Examined at 5X, 40X, & 100X Magnification.

EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 18, 1993

SRC Job No. 92-352

Certified By: _____ Date: 6-14-93

Reviewed By: _____ Date: 06-14-93

GLOBAL1.VIC

SRC ENGINEERS, INC.
P.O. BOX 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710
(318) 837-3810, 837-3819 STEPHEN R. CALLEGARI, P.E.

CERTIFICATE OF ANALYSIS

Date: 07-07-93 P.O. No. GD106384
Company: Global Divers & Contractors, Inc.
Test: Charpy V-Notch Impact Test per ASTM A-370, E-23
Test Performed on: 1/8" labeled weld

Size of Specimens: Full Size (10mm x 10mm x 55mm)

Test Temperature: 28°F

RESULTS			
SPECIMEN NUMBER	ABSORBED ENERGY ft - lbf	PERCENT SHEAR FRACTURE	LATERAL EXPANSION (mils)
H1(Heat Affected Zone)	42	85	48
H2(Heat Affected Zone)	52	85	63
H3(Heat Affected Zone)	68	85	55
H4(Heat Affected Zone)	42	85	38
H5(Heat Affected Zone)	54	85	52

EQUIPMENT UTILIZED FOR TEST
Type: Charpy V-Notch Impact Tester
Manufacturer: Tinius Olsen
Serial No.: 85900
Last Calibration: January 18, 1993

Certified By: Tim Broussard Date: 6-8-93
Tim J. Broussard
SRC Engineers, Inc.

Reviewed By: Date: 06-08-23

GLOBAL1.CHP

Global Divers
& Contractors, Inc.

Sheet 1 of 2
W/O No. ED-010-93

MATERIALS JOINING WORK REPORT
Part 1 MTB Toe-to-Toe Distance 3/16"

Location GLOBAL DIVERS - PORT OF IBERIA Contract No. 91-M-4346

Mat'l (1) A 537 Grade Cl 1
Ht./Slab No. 79006-12
Thick 5/8" in. Dia. _____ in.

Mat'l (2) _____ Grade _____
Ht./Slab No. _____
Thick _____ in. Dia. _____ in.

Electrode (AWS) E 6013 A5.1 TN Program Ex 7 Mfr. Proprietary Ctry _____

Process SMAW Current/Polarity CC/DCEP/PULSE Joint Type V-GROOVE (8") Position 3G

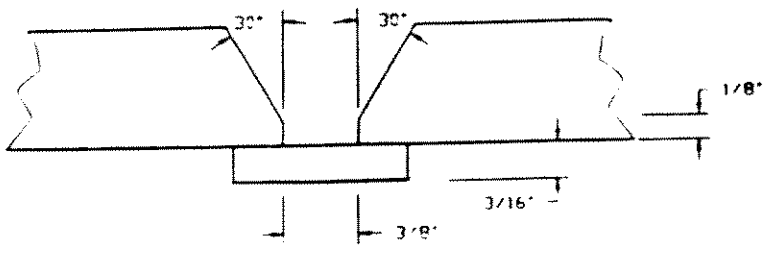
Water Depth 33' Dry _____ Wet X

Welding Variables:

R F & C	PASS	DIA.	AMPS	VOLTS	I.P.M.	REMARKS
ROOT	1	1/8"	150 - 160	28 - 30	6.2	Temper bead was deposited on all
ROOT	2	1/8"	150 - 160	28 - 30	6.1	primary beads that tied into the base
B	AVG	1/8"	155	30	8.9	metal . Toe-to-toe distance was
FILL	AVG	1/8"	155	30	8.6	3/16". Number of passes -34.
CAP	AVG	1/8"	155	30	8.9	Electrodes consumed -41. Welding
						time -54 minutes.

Welder: Darryl R. Phillips Date: 6-1-93

Welding Joint Sketch:



Welding Techniques:

Stringer Beads with all passes downhill.

Global Divers
& Contractors, Inc.

Sheet 2 of 2
W/O No. ED-010-93

Tension Tests: (Reduced Section/All-Weld-Metal) N/A

SPECIMEN	ORIENT	ULTIMATE S.	YIELD S.	ELONGATION	FAILURE
1					
2					

Bends: N/A

SPECIMEN	ROOT	FACE	SIDE	*RADIUS	RESULTS
1					
2					
3					
4					

Chemistry:

	CE	C	Mn	P	S	Si	Ni	Cr	Mo	Cu	V	Cb	Nb	Al
CTR														
LAB	.462	.20	1.50	.014	.019	.38	.03	.02	.01	.03	.01	.01	—	—

Hardness (Vickers/Rockwell): Vickers 10 kg, combined test results on four macros.

LOCATION	LEFT SIDE	RIGHT SIDE
BASE METAL (AVG.)	168	170
HAZ (MAX)	332	316
HAZ (AVG)	256	255
WM (MAX)	286	212

Purpose of Test:

Remarks & Evaluation: Charpy HAZ V-Notch impact test results at 28° F averaged 50 ft. lbs. with 80% shear. No HAZ cracks at 100X.

By: C.E. Grubbs Date: 6-1-93 Rev: ---

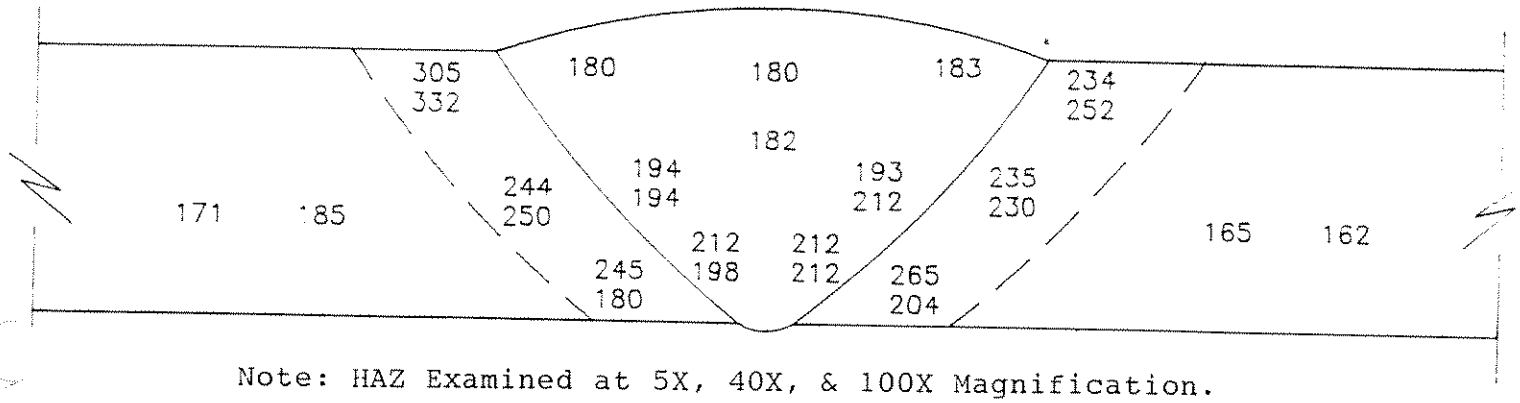
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers 10kg load hardness test on weld sample 3/16" - #1 (P.O. #GD106384) 3G - With T.B.

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



Note: HAZ Examined at 5X, 40X, & 100X Magnification.

EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 18, 1993

SRC Job No. 92-352

Certified By: _____ Date: 6-14-93

Reviewed By: _____ Date: 06-14-93

GLOBAL1.VIC

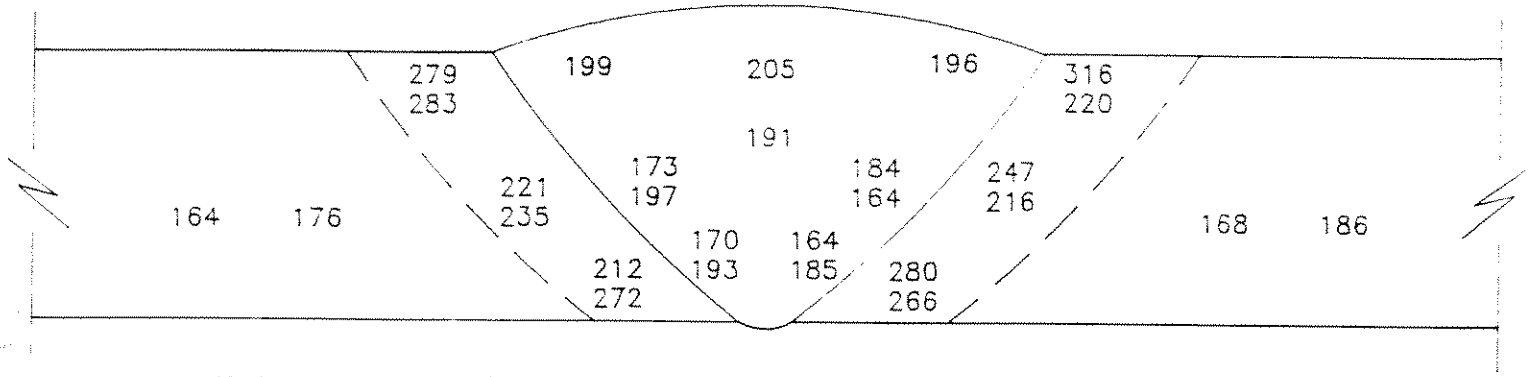
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers 10kg load hardness test on weld sample 3/16" - #2 (P.O. #GD106384) 3G - With T.B.

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



Note: HAZ Examined at 5X, 40X, & 100X Magnification.

EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 18, 1993

SRC Job No. 92-352

Certified By: Tim Brown Date: 6-14-93

Reviewed By: Stephen R. Allgeier Date: 06-14-93

GLOBAL1.VIC

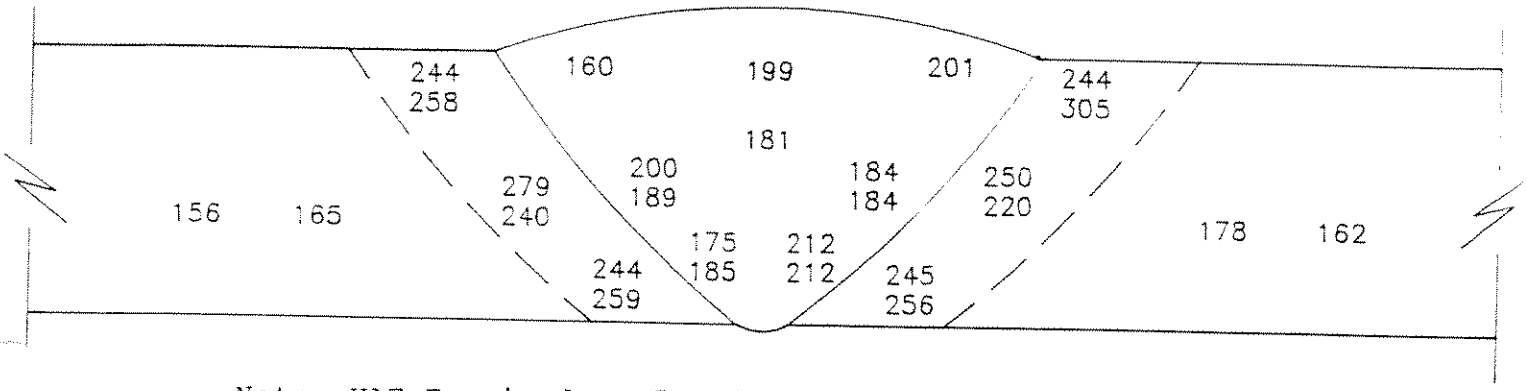
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers 10kg load hardness test on weld sample 3/16" - #3 (P.O. #GD106384) 3G - With T.B.

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



Note: HAZ Examined at 5X, 40X, & 100X Magnification.

EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 18, 1993

SRC Job No. 92-352

Certified By: Tim Brand Date: 6-14-93

Reviewed By: Stephen Date: 06-18-93

GLOBAL1.VIC

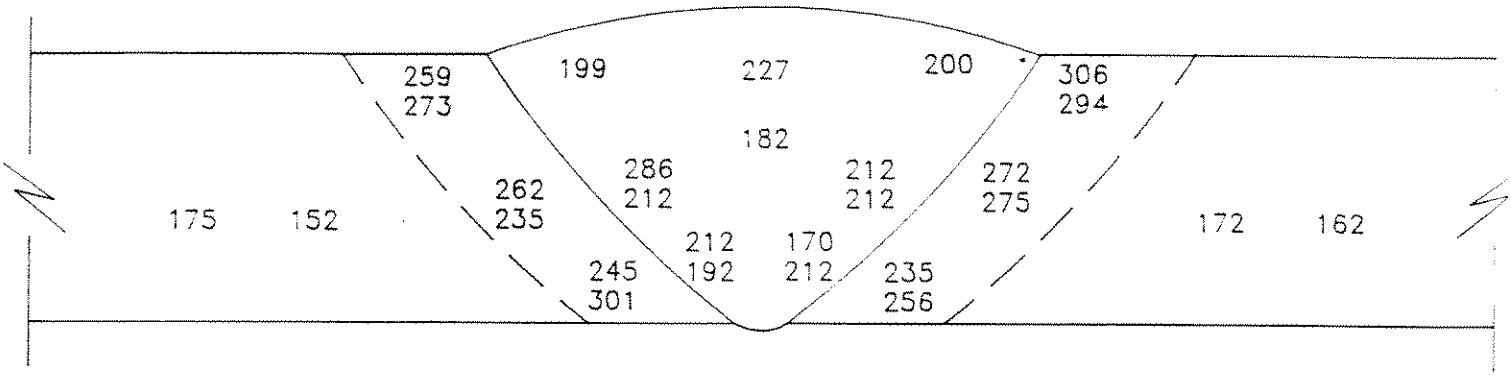
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers 10kg load hardness test on weld sample 3/16" - #4 (P.O. #GD106384) 3G - With T.B.

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



Note: HAZ Examined at 5X, 40X, & 100X Magnification.

EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 18, 1993

SRC Job No. 92-352

Certified By: Tim Barnard Date: 6-14-93

Reviewed By: Stephen R. Collins Date: 06-14-93

GLOBAL1.VIC

SRC ENGINEERS, INC.
P.O. BOX 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710
(318) 837-3810, 837-3819 STEPHEN R. CALLEGARI, P.E.

CERTIFICATE OF ANALYSIS

Date: 07-07-93 P.O. No. GD106384
Company: Global Divers & Contractors, Inc.
Test: Charpy V-Notch Impact Test per ASTM A-370, E-23
Test Performed on: 3/16" labeled weld

Size of Specimens: Full Size (10mm x 10mm x 55mm)

Test Temperature: 28°F

RESULTS			
SPECIMEN NUMBER	ABSORBED ENERGY ft - lbf	PERCENT SHEAR FRACTURE	LATERAL EXPANSION (mils)
H1(Heat Affected Zone)	48	70	57
H2(Heat Affected Zone)	47	85	60
H3(Heat Affected Zone)	56	85	52
H4(Heat Affected Zone)	45	70	50
H5(Heat Affected Zone)	62	85	55

EQUIPMENT UTILIZED FOR TEST
Type: Charpy V-Notch Impact Tester
Manufacturer: Tinius Olsen
Serial No.: 85900
Last Calibration: January 18, 1993

Certified By: Tim Broussard Date: 6-8-93
Tim J. Broussard
SRC Engineers, Inc.

Reviewed By: Stephen R. Callegari Date: 06-08-93

GLOBAL1.CHP

Appendix IX

Global Divers
& Contractors, Inc.

Sheet 1 of 2
W/O No. ED-001-94

MATERIALS JOINING WORK REPORT
MTB WELD FOR REDUCTION OF HAZ TOE HARDNESS, LEVEL 2 HEAT INPUT

Location Global Divers & Contrctors, Inc. Port of Iberia Contract No. 91-M-4346

Mat'l (1) A537 Grade Cl.1
Ht./Slab No. 79006
Thick 3/4" in. Dia. _____ in.

Mat'l (2) _____ Grade _____
Ht./Slab No. _____
Thick _____ in. Dia. _____ in.

Electrode (AWS) E6013 A.51 TN Program Ex 7 Mfr. Proprietary Batch No. 3201

Process SMAW Current/Polarity CC/DCEP Joint Type Fillet Position Vertical

Water Depth 33' Dry _____ Wet X

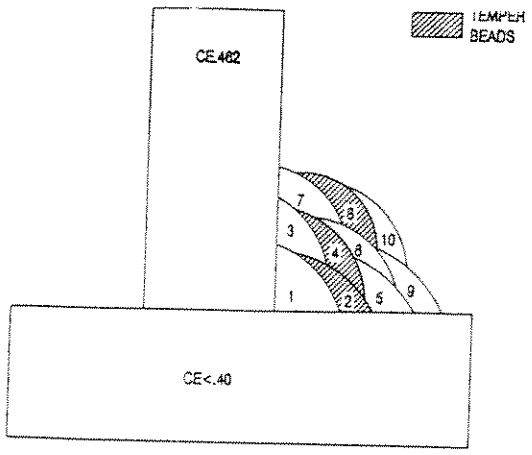
Welding Variables:

R F & C	PASS	DIA.	AMPS	VOLTS	I.P.M.	REMARKS
Root	1	1/8"	170	30	9.0	Weld was restrained by an opposing
Fill	10	1/8"	170	30	9.2	wet fillet weld i.e., welder deposited
Cap/TB	4	1/8"	170	30	9.5	weld passes on alternate sides of
						flange plate.

Welder: Darryl Phillips

Date: February 10,1994

Welding Joint Sketch:



1/8" DIA. ELECTRODES USED FOR ALL BEADS

Welding Techniques:

Multiple temper bead technique was used with stringer beads and all passes downhill.

Global Divers
& Contractors, Inc.

W/O No. ED-001-94

Tension Tests: (Reduced Section/All-Weld-Metal) N/A

SPECIMEN	ORIENTATION	ULTIMATE PSI.	YIELD PSI.	ELONGATION	FAILURE
1					
2					

Bends: N/A

SPECIMEN	ROOT	FACE	SIDE	RADIUS	RESULTS
1					
2					
3					
4					

Chemistry: A 537 Class 1

	CE	C	Mn	P	S	Si	Ni	Cr	Mo	Cu	V	Cb	Nb	Al
CTR														
LAB	.462	.20	1.50	.014	.019	.38	.03	.02	.01	.03	.01	.01	---	---

Hardness (10 kg Vickers): Fillet weld on one side. Heat affected zone only.

LOCATION	~~LEFT SIDE~~	~~RIGHT SIDE~~
BASE METAL (AVG.)	N/A	Without Tempering
HAZ (MAX)	Toe 478 Midpoint 320 Root 282	Toe 482 Midpoint 327 Root 306
AZ (AVG)	Toe 410 Midpoint 281 Root 267	Toe 463 Midpoint 293 Root 289
WM (MAX)	N/A	N/A

Purpose of Test:

Reduce the HAZ hardness at the toe of the weldment to the Vickers 10 kg 325 maximum specified by AWS D3.6 for Class A (Dry) welds by progressively increasing temper bead heat input.

Remarks & Evaluation:

For this weld, calculated (see text of report) temper bead heat input was 32.2 kJ/in which was the second level of heat input of a series of five levels used for this set of tests. (For welds reported in the Jan. '94 Interim Report, the first level of heat input was 25.5 kJ/in). As shown in the above hardness report, the procedure produced some, but no significant, reduction in HAZ toe hardness.

By: C.E. Grubbs Date: February 17, 1994 Rev:

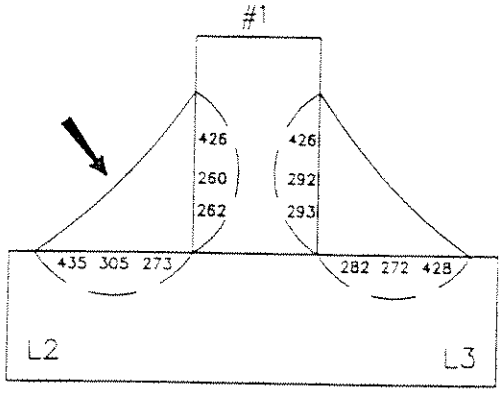
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers hardness test on Double Fillet Weld
3/4"-A537 welded to 3/4"-A537 Material
One side - MTB with Level 2 Heat Input ←
One side - MTB with Level 3 Heat Input
Sample #1
P.O. #GD107497

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



HAZ examined at 100X. No cracks were found.

EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 10, 1994

SRC Job No. 94-045

Certified By: [signature] Date: 2-14-94

GLOBAL16.FIL

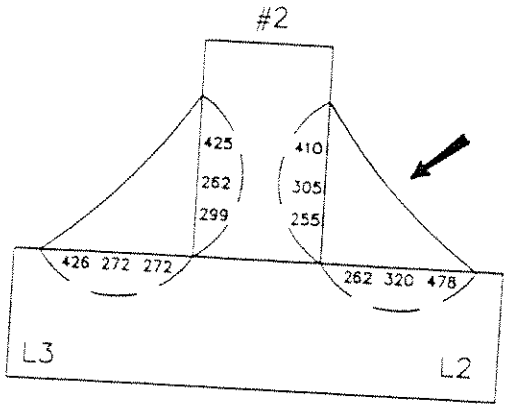
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers hardness test on Double Fillet Weld
3/4"-A537 welded to 3/4"-A537 Material
One side - MTB with Level 2 Heat Input ←
One side - MTB with Level 3 Heat Input
Sample #2
P.O. #GD107497

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



HAZ examined at 100X. No cracks were found.

EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 10, 1994

SRC Job No. 94-045

Certified By: Tim Brand Date: 2-14-94

GLOBAL16.FIL

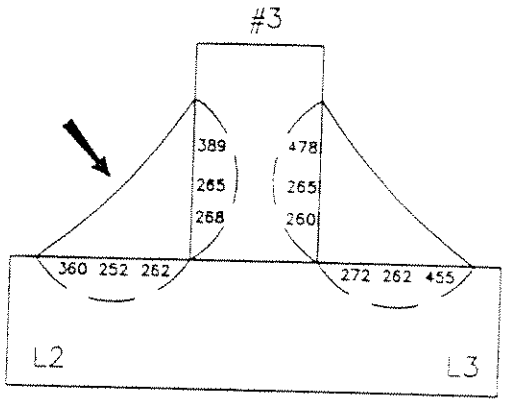
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers hardness test on Double Fillet Weld
3/4"-A537 welded to 3/4"-A537 Material
One side - MTB with Level 2 Heat Input ←
One side - MTB with Level 3 Heat Input
Sample #3
P.O. #GD107497

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



HAZ examined at 100X. No cracks were found.

EQUIPMENT UTILIZED FOR TEST	
Type:	Tukon Model LR Microhardness Tester
Manufacturer:	Wilson
Serial No.:	LR-997
Last Calibration:	January 10, 1994

SRC Job No. 94-045

Certified By: _____ Date: 2-14-94

GLOBAL16.FIL

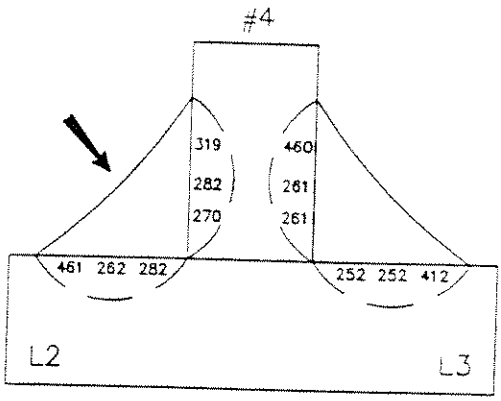
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers hardness test on Double Fillet Weld
3/4"-A537 welded to 3/4"-A537 Material
One side - MTB with Level 2 Heat Input ←
One side - MTB with Level 3 Heat Input
Sample #4
P.O. #GD107497

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



HAZ examined at 100X. No cracks were found.

EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 10, 1994

SRC Job No. 94-045

Certified By: [signature] Date: 2-14-94

GLOBAL16.FIL

Global Divers
& Contractors, Inc.

Sheet 1 of 2
W/O No. ED-002-94

MATERIALS JOINING WORK REPORT
MTB WELD FOR REDUCTION OF HAZ TOE HARDNESS, LEVEL 3 HEAT INPUT

Location Global Divers & Contrctors, Inc. Port of Iberia Contract No. 91-M-4346

Mat'l (1) A537 Grade Cl.1
Ht./Slab No. 79006
Thick 3/4" in. Dia. _____ in.

Mat'l (2) _____ Grade _____
Ht./Slab No. _____
Thick _____ in. Dia. _____ in.

Electrode (AWS) E6013 A.51 TN Program Ex 7 Mfr. Proprietary Batch No. 3201

Process SMAW Current/Polarity CC/DCEP Joint Type Fillet Position Vertical

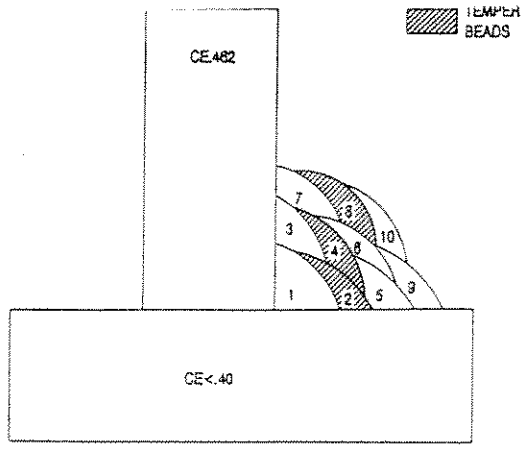
Water Depth 33' Dry _____ Wet X

Welding Variables:

R F & C	PASS	DIA.	AMPS	VOLTS	I.P.M.	REMARKS
Root	1	1/8"	170	30	8.6	Weld was restrained by an opposing
Fill	10	1/8"	170	30	9.0	wet fillet weld i.e., welder deposited
Cap/TB	4	1/8"	170-180	30-32	9.4	weld passes on alternate sides of
						flange plate.

Welder: Darryl Phillips Date: February 10,1994

Welding Joint Sketch:



1/8" DIA. ELECTRODES USED FOR ALL BEADS

Welding Techniques:

Multiple temper bead technique was used with stringer beads and all passes downhill.

Global Divers
& Contractors, Inc.

Tension Tests: (Reduced Section/All-Weld-Metal) N/A

SPECIMEN	ORIENTATION	ULTIMATE PSI.	YIELD PSI.	ELONGATION	FAILURE
1					
2					

Bends: N/A

SPECIMEN	ROOT	FACE	SIDE	RADIUS	RESULTS
1					
2					
3					
4					

Chemistry: A 537 Class 1

	CE	C	Mn	P	S	Si	Ni	Cr	Mo	Cu	V	Cb	Nb	Al
CTR														
LAB	.462	.20	1.50	.014	.019	.38	.03	.02	.01	.03	.01	.01	---	---

Hardness (10 kg Vickers): Fillet weld on one side. Heat affected zone only.

LOCATION	~~LEFT SIDE~~	~~RIGHT SIDE~~
BASE METAL (AVG.)	N/A	Previous Heat Input Level 2
HAZ (MAX)	Toe 478 Midpoint 272 Root 299	Toe 478 Midpoint 320 Root 282
HAZ (AVG)	Toe 439 Midpoint 267 Root 274	Toe 410 Midpoint 281 Root 267
WM (MAX)	N/A	N/A

Purpose of Test:

Reduce the HAZ hardness at the toe of the weldment to the Vickers 10 kg 325 maximum specified by AWS D3.6 for Class A (Dry) welds by progressively increasing temper bead heat input.

Remarks & Evaluation:

For this weld, calculated (see text of report) temper bead heat input was 34.6 kJ/in which was the third level of heat input of a series of five levels used for this set of tests. Previous and second level of temper bead calculated heat input was 32.2 kJ/in. As shown in the above hardness report, the increased calculated heat input did not cause any reduction in hardness.

The explanation of this is probably related to the fact that the calculated heat input formula does not include some essential variables which are controlled by the welder.

By: C.E. Grubbs Date: February 17, 1994 Rev:

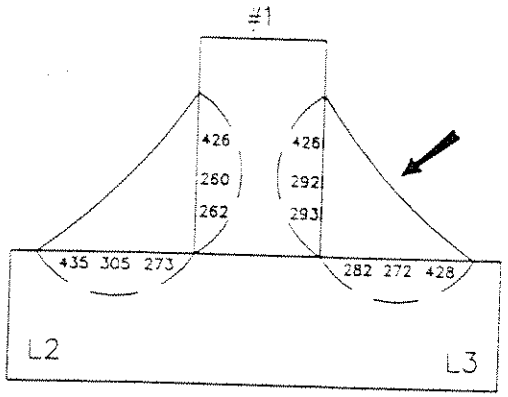
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers hardness test on Double Fillet Weld
3/4"-A537 welded to 3/4"-A537 Material
One side - MTB with Level 2 Heat Input
One side - MTB with Level 3 Heat Input ←
Sample #1
P.O. #GD107497

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



HAZ examined at 100X. No cracks were found.

EQUIPMENT UTILIZED FOR TEST	
Type:	Tukon Model LR Microhardness Tester
Manufacturer:	Wilson
Serial No.:	LR-997
Last Calibration:	January 10, 1994

SRC Job No. 94-045

Certified By: [signature] Date: 2-14-94

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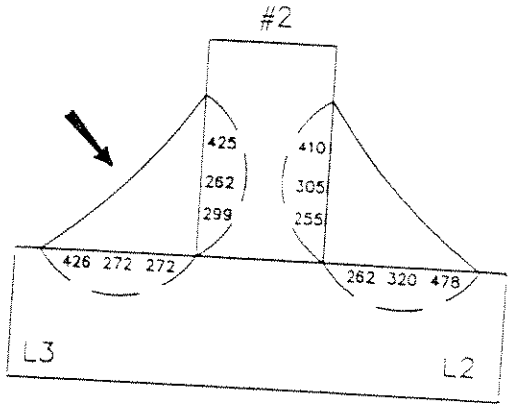
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers hardness test on Double Fillet Weld
3/4"-A537 welded to 3/4"-A537 Material
One side - MTB with Level 2 Heat Input
One side - MTB with Level 3 Heat Input ←
Sample #2
P.O. #GD107497

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



HAZ examined at 100X. No cracks were found.

EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 10, 1994

SRC Job No. 94-045

Certified By: Tim Brand Date: 2-14-94

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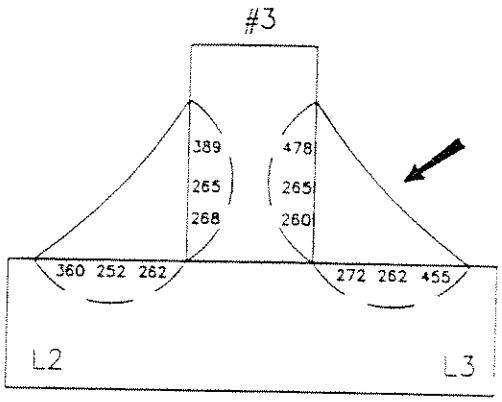
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers hardness test on Double Fillet Weld
3/4"-A537 welded to 3/4"-A537 Material
One side - MTB with Level 2 Heat Input
One side - MTB with Level 3 Heat Input ←
Sample #3
P.O. #GD107497

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



HAZ examined at 100X. No cracks were found.

EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 10, 1994

SRC Job No. 94-045

Certified By: Tim Brown Date: 2-14-94

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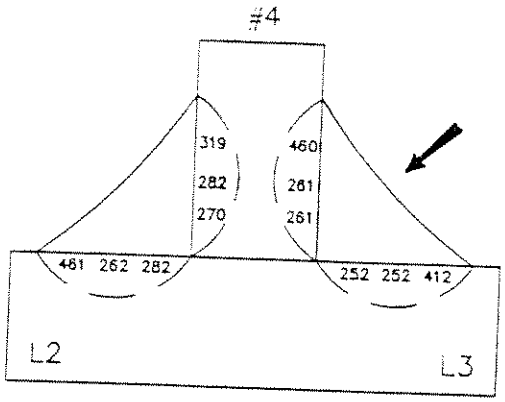
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers hardness test on Double Fillet Weld
3/4"-A537 welded to 3/4"-A537 Material
One side - MTB with Level 2 Heat Input
One side - MTB with Level 3 Heat Input ←
Sample #4
P.O. #GD107497

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



HAZ examined at 100X. No cracks were found.

EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 10, 1994

SRC Job No. 94-045

Certified By: [signature] Date: 2-14-94

GLOBAL16.FIL

Global Divers
& Contractors, Inc.

Sheet 1 of 2
W/O No. ED-003-94

MATERIALS JOINING WORK REPORT
MTB WELD FOR REDUCTION OF HAZ TOE HARDNESS, LEVEL 4 HEAT INPUT

Location Global Divers & Contrctors, Inc. Port of Iberia Contract No. 91-M-4346

Mat'l (1) A537 Grade Cl.1
Ht./Slab No. 79006
Thick 3/4" in. Dia. _____ in.

Mat'l (2) A 36 < CE .40 Grade _____
Ht./Slab No. _____
Thick 5/8" in. Dia. _____ in.

Electrode (AWS) E6013 A.51 TN Program Ex 7 Mfr. Proprietary Batch No. 3201

Process SMAW Current/Polarity CC/DCEP Joint Type Fillet Position Vertical

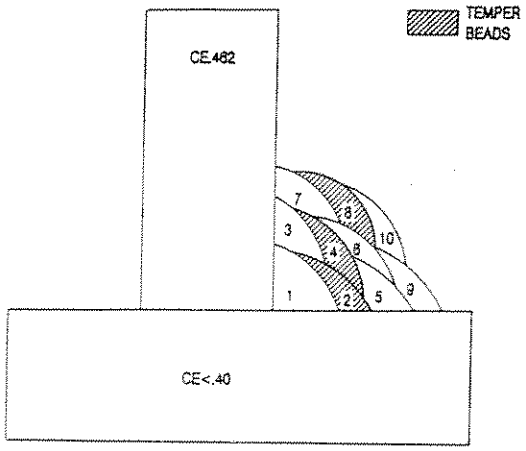
Water Depth 33' Dry _____ Wet X

Welding Variables:

R F & C	PASS	DIA.	AMPS	VOLTS	I.P.M.	REMARKS
Root	1	1/8"	170	30	8.7	Wet fillet weld restrained by 1/2" x 4"
Fill	10	1/8"	170	30	9.2	bar welded to top of 5/8" flange plate
Cap/TB	4	1/8"	170-180	30-32	8.8	and to the edge of the 3/4" base plate

Welder: Darryl Phillips Date: February 15, 1994

Welding Joint Sketch:



1/8" DIA. ELECTRODES USED FOR ALL BEADS

Welding Techniques:

Multiple temper bead technique was used with stringer beads and all passes downhill.

Global Divers
& Contractors, Inc.

Sheet 2 of 2
W/O No. ED-003-94

Tension Tests: (Reduced Section/All-Weld-Metal) N/A

SPECIMEN	ORIENTATION	ULTIMATE PSI.	YIELD PSI.	ELONGATION	FAILURE
1					
2					

Bends: N/A

SPECIMEN	ROOT	FACE	SIDE	RADIUS	RESULTS
1					
2					
3					
4					

Chemistry: A 537 Class 1

	CE	C	Mn	P	S	Si	Ni	Cr	Mo	Cu	V	Cb	Nb	Al
CTR														
LAB	.462	.20	1.50	.014	.019	.38	.03	.02	.01	.03	.01	.01	---	---

Hardness (10 kg Vickers): Fillet weld on one side. Heat affected zone only.

LOCATION	~~LEFT SIDE~~	~~RIGHT SIDE~~
BASE METAL (AVG.)	N/A	Previous Heat Input Level 3
HAZ (MAX)	Toe 355 Midpoint 282 Root 267	Toe 478 Midpoint 272 Root 299
HAZ (AVG)	Toe 324 Midpoint 267 Root 251	Toe 439 Midpoint 267 Root 274
WM (MAX)	N/A	N/A

Purpose of Test:

Reduce the HAZ toe hardness of the weldment to the Vickers 10 kg 325 maximum specified by AWS D3.6 for Class A (Dry) welds by progressively increasing the temper bead heat input.

Remarks & Evaluation:

For this weld, calculated temper bead heat input was 37.0 kJ/in, which was the fourth level of heat input of a series of five levels used for this set of tests. Previous and third level of temper bead calculated heat input was 34.6 kJ/in. As shown in the hardness report above, this level of heat input resulted in, for practical purposes, a totally acceptable level of hardness. However, two of the three HAZ toe hardness (332 and 355) exceed our goal of 325 maximum.

By: C.E. Grubbs Date: February 22, 1994 Rev:

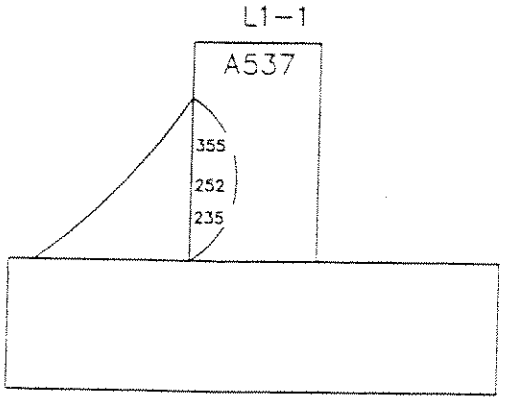
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers hardness test on Single Fillet Weld
3/4"-A537 welded to 5/8"-C.S. Material
MTB with Level 4 Heat Input
Sample #L1-1
P.O. #GD107513

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



HAZ examined at 100X. No cracks were found.

EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 10, 1994

SRC Job No. 94-045

Certified By: Tim Brown Date: 2-18-94

GD106513

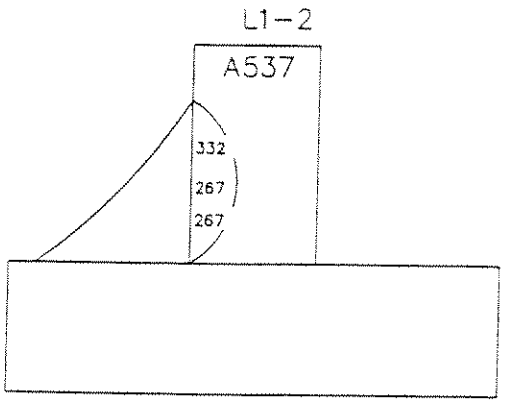
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers hardness test on Single Fillet Weld
3/4"-A537 welded to 5/8"-C.S. Material
MTB with Level 4 Heat Input
Sample #L1-2
P.O. #GD107513

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



HAZ examined at 100X. No cracks were found.

EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 10, 1994

SRC Job No. 94-045

Certified By: Tim Broussard Date: 2-18-94

GD106513

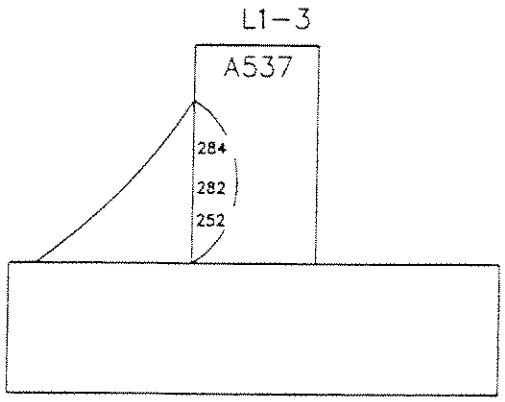
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers hardness test on Single Fillet Weld
3/4"-A537 welded to 5/8"-C.S. Material
MTB with Level 4 Heat Input
Sample #L1-3
P.O. #GD107513

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



HAZ examined at 100X. No cracks were found.

EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 10, 1994

SRC Job No. 94-045

Certified By: Tim Brand Date: 2-18-94

GD106513

Global Divers
& Contractors, Inc.

Sheet 1 of 2
W/O No. ED-004-94

MATERIALS JOINING WORK REPORT
MTB/HALF-BEAD WELD FOR REDUCTION OF HAZ TOE HARDNESS, LEVEL 5 HEAT INPUT

Location Global Divers & Contrctors, Inc. Port of Iberia Contract No. 91-M-4346

Mat'l (1) A537 Grade Class 1
Ht./Slab No. 79006
Thick 3/4" in. Dia. _____ in.

Mat'l (2) A 36 < CE .40 Grade _____
Ht./Slab No. _____
Thick 5/8" in. Dia. _____ in.

Electrode (AWS) E6013 TN Program Ex 7 Mfr. Proprietary Batch No. 3201

Process SMAW Current/Polarity CC/DCEP Joint Type Fillet Position Vertical

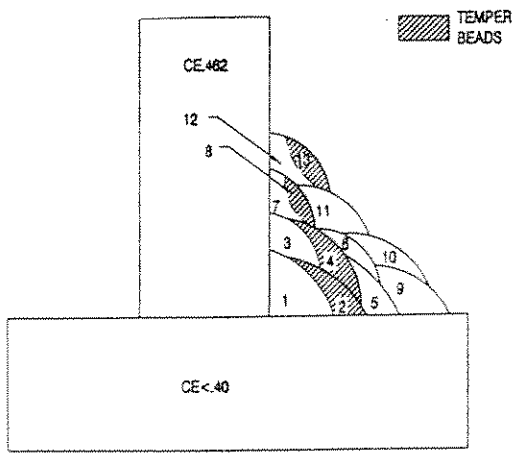
Water Depth 33' Dry _____ Wet X

Welding Variables:

R F & C	PASS	DIA.	AMPS	VOLTS	I.P.M.	REMARKS
Root	1	1/8"	170	30	8.8	Wet fillet weld was restrained by
Fill	9	1/8"	170	30	9.2	1/2" x 4" bar welded to top of 5/8"
TB	1	1/8"	170	30	9.1	flange plate and to the edge of the
Half TB	2	3/32"	130	30	8.0	3/4" base plate.
Cap	4	1/8"	170	30	10.1	

Welder: Darryl Phillips Date: February 15, 1994

Welding Joint Sketch:



1/8" DIA. ELECTRODES USED FOR ALL PASSES
EXCEPT 3/32" DIA USED FOR PASSES 8 AND 13.

PASSES 7 AND 12 GROUND DOWN TO "HALF-BREADS"

Welding Techniques:

The multiple temper bead wet welding technique was employed as usual with downhill stringer beads. However, after filler beads/passes were deposited, passes 8 and 13 (See Fig 2) were ground down to approximately one-half thickness and retempered with 3/32" Ø welding electrodes.

Global Divers
& Contractors, Inc.

W/O No. ED-004-94

Tension Tests: (Reduced Section/All-Weld-Metal) N/A

SPECIMEN	ORIENTATION	ULTIMATE PSI.	YIELD PSI.	ELONGATION	FAILURE
1					
2					

Bends: N/A

SPECIMEN	ROOT	FACE	SIDE	RADIUS	RESULTS
1					
2					
3					
4					

Chemistry: A 537 Class 1

	CE	C	Mn	P	S	Si	Ni	Cr	Mo	Cu	V	Cb	Nb	Al
CTR														
LAB	.462	.20	1.50	.014	.019	.38	.03	.02	.01	.03	.01	.01	---	---

Hardness (10 kg Vickers): Fillet weld on one side. Heat affected zone only.

LOCATION	~~LEFT SIDE~~	~~RIGHT SIDE~~
BASE METAL (AVG.)	N/A	Previous Level 4 Heat Input
HAZ (MAX)	Toe 300 Midpoint 297 Root 278	Toe 355 Midpoint 282 Root 267
HAZ (AVG)	Toe 282 Midpoint 279 Root 275	Toe 324 Midpoint 267 Root 251
WM (MAX)	N/A	N/A

Purpose of Test:

Reduce the HAZ toe hardness of the weldment to the Vickers 10 kg 325 maximum specified by AWS D3.6 for Class A (Dry) welds by progressively increasing the temper bead heat input.

Remarks & Evaluation:

A new wet welding technique was used for this weldment. The MTB technique was used to prevent HAZ hydrogen cracking plus, at the toe of the weld, a half-bead procedure was used to further reduce HAZ hardness. I.e., two weld beads/passes at the toe of the weld were ground down to approximately half-thickness and then retempered. Calculated heat input was comparatively low at 29.3 kJ/in. However, the actual heat input was significantly increased due to reduced thickness of the primary beads. This unique wet welding procedure made it possible to reduce the HAZ to less than the 325 specified by AWS D3.6 for Class A (dry) welds.

By: C.E. Grubbs Date: February 22, 1994 Rev:

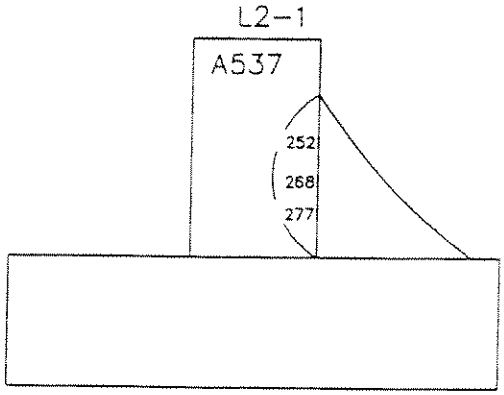
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers hardness test on Single Fillet Weld
3/4"-A537 welded to 5/8"-C.S. Material
MTB with Level 5 Heat Input
Sample #L2-1
P.O. #GD107513

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



HAZ examined at 100X. No cracks were found.

EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 10, 1994

SRC Job No. 94-045

Certified By: Tim Brand Date: 2-18-94

GD106513

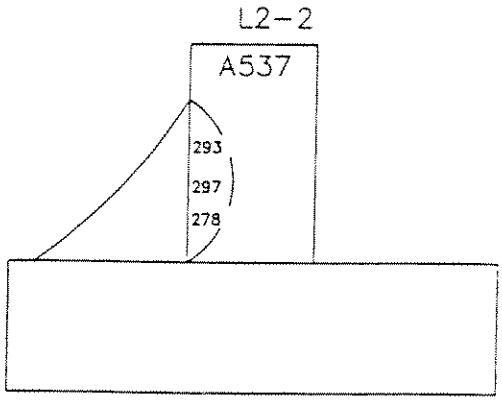
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers hardness test on Single Fillet Weld
3/4"-A537 welded to 5/8"-C.S. Material
MTB with Level 5 Heat Input
Sample #L2-2
P.O. #GD107513

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



HAZ examined at 100X. No cracks were found.

EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 10, 1994

SRC Job No. 94-045

Certified By: Tim Broussard Date: 2-18-94

GD106513

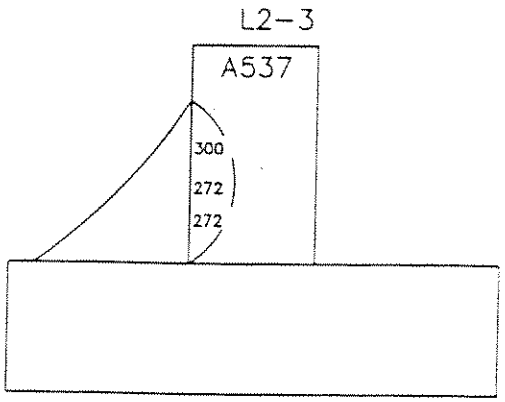
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers hardness test on Single Fillet Weld
3/4"-A537 welded to 5/8"-C.S. Material
MTB with Level 5 Heat Input
Sample #L2-3
P.O. #GD107513

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



HAZ examined at 100X. No cracks were found.

EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 10, 1994

SRC Job No. 94-045

Certified By: [signature] Date: 2-18-94

GD106513

SRC ENGINEERS, INC.
P.O. BOX 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710
(318) 837-3810, 837-3819 STEPHEN R. CALLEGARI, P.E.

CERTIFICATE OF ANALYSIS

Date: 4-02-93 P.O. No. GD105927
Company: Global Divers
Test: Reduced Section Tensile Test per ASTM A-370
Test Performed on: Sample V Welding Procedure

All-Weld-Metal Tensile Test						
SPEC. NO.	DIA.	AREA	LOAD AT YIELD PT.	YIELD STRENGTH	TOTAL LOAD LBS.	UNIT STRESS PSI(Tensile)
V	.500"	.1964"	14,800	75,356	15,650	79,684

DUCTILITY TEST			
SPEC. NO.	GUAGE MARKS	FINAL MARKS	% ELONGATION
V	2.000"	2.240"	12.0

REDUCTION OF AREA			
SPEC. NO.	ORIGINAL AREA	FINAL AREA	% REDUCTION OF AREA
V	.1964"	.1576"	19.8

EQUIPMENT UTILIZED FOR TEST
Type: Tensile Tester
Manufacturer: Reihle
Serial No.: R-1957
Last Calibration: January 18, 1993

SRC Job No. 92-352

Certified By: Tim J. Broussard Date: 4-2-93

Reviewed By: Date: 4-2-93

GLOBAL.RED

SRC ENGINEERS, INC.
P.O. BOX 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710
(318) 837-3810, 837-3819 STEPHEN R. CALLEGARI, P.E.

CERTIFICATE OF ANALYSIS

Date: 6-28-93 P.O. No. GD406178

Company: Global Divers

Test: Reduced Section Tensile Test per AWS D3.6(1989)

Test Performed on: 3/4" x 16" Underwater wet weld(Conf. weld)
1G - With T.B.

REDUCED SECTION TENSILE TEST					
SPEC. NO.	THK.	WIDTH	AREA	TOTAL LOAD LBS.	UNIT STRESS PSI (Tensile)
T1	.670"	1.465"	.9816"	74,800	76,202
T2	.697"	1.464"	1.020"	80,200	78,627

EQUIPMENT UTILIZED FOR TEST
Type: Tensile Tester
Manufacturer: Reihle
Serial No.: R-1957
Last Calibration: January 18, 1993

Certified By: Tim Broussard Date: 7-6-93
Tim J. Broussard
SRC Engineers, Inc.

Reviewed By: [signature] Date: 07-06-93

GLOBAL5.TEN

SRC ENGINEERS, INC.
P.O. BOX 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710
(318) 837-3810, 837-3819 STEPHEN R. CALLEGARI, P.E.

CERTIFICATE OF ANALYSIS

Date: 06-29-93 P.O. No. GD406178
Company: Global Divers & Contractors, Inc.
Test: Charpy V-Notch Impact Test per ASTM A-370, E-23
Test Performed on: 3/4" x 16"Lg. Weld(Conf. Weld) 1G Wetweld With T.B.
Size of Specimens: Full Size (10mm x 10mm x 55mm)

Test Temperature: 28°F

RESULTS			
SPECIMEN NUMBER	ABSORBED ENERGY ft - lbf	PERCENT SHEAR FRACTURE	LATERAL EXPANSION (mils)
H1(Heat Affected Zone)	40	70	42
H2(Heat Affected Zone)	37	70	55
H3(Heat Affected Zone)	48	70	55
H4(Heat Affected Zone)	50	70	56
H5(Heat Affected Zone)	40	70	37

EQUIPMENT UTILIZED FOR TEST
Type: Charpy V-Notch Impact Tester
Manufacturer: Tinius Olsen
Serial No.: 85900
Last Calibration: January 18, 1993

Certified By: Tim Broussard Date: 6-29-93
Tim J. Broussard
SRC Engineers, Inc.

Reviewed By: Stephen R. Callegari Date: 06-29-93

GLOBAL5.chp

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(318) 837-3810, 837-3819 STEPHEN R. CALLEGARI, P.E.

CERTIFICATE OF ANALYSIS

Date: 06-29-93 P.O. No. GD406178
Company: Global Divers & Contractors, Inc.
Test: Charpy V-Notch Impact Test per ASTM A-370, E-23
Test Performed on: 3/4" x 16"Lg. Weld(Conf. Weld) 1 G

Size of Specimens: Full Size (10mm x 10mm x 55mm)

Test Temperature: 28°F

RESULTS			
SPECIMEN NUMBER	ABSORBED ENERGY ft - lbf	PERCENT SHEAR FRACTURE	LATERAL EXPANSION (mils)
W1(Weld)	32	100	38
W2(Weld)	32	100	37
W3(Weld)	33	100	36
W4(Weld)	32	100	36
W5(Weld)	32	100	49

EQUIPMENT UTILIZED FOR TEST
Type: Charpy V-Notch Impact Tester
Manufacturer: Tinius Olsen
Serial No.: 85900
Last Calibration: January 18, 1993

Certified By: _____ Date: 6-29-93
Tim J. Broussard
SRC Engineers, Inc.

Reviewed By: _____ Date: 6-29-93

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(318) 837-3810, 837-3819 STEPHEN R. CALLEGARI, P.E.

CERTIFICATE OF ANALYSIS

Date: 7-23-93 P.O. No. GD406395

Company: Global Divers & Contractors, Inc.

Test: Guided Bend Test per AWS D3.6-93

Test Performed on: Supplemental Weldments(Conf.)1G,2G,3G Welds on A537 Class 1 Material

Welders Name: Darryl Phillips

These Side Bend Tests were conducted to improve the bend radii of these three weldments. Bend radii were progressively reduced from 6T to 4T and 3 1/3T. The results were as follows:

Eight specimens 1G Position - No 6T's were bent
Passed 2(4T's)
Failed 6(4T's)

Eight specimens 2G Position - Passed 8(6T's)
Passed 6(4T's)
Failed 2(4T's)
Passed 4(3 1/3T's)
Failed 2(3 1/3T's)

Eight specimens 3G Position - Passed 8(6T's)
Passed 7(4T's)
Failed 1(4T)
Passed 7(3 1/3T's)

All failures occurred in the weld metal

EQUIPMENT UTILIZED FOR TEST
Type: Guided Bend Tester
Manufacturer: CRC

Certified By: Tim J. Broussard Date: 7-23-93
Tim J. Broussard
SRC Engineers, Inc.

Reviewed By: Date: 07-23-93

END.CLO

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(318) 837-3810, 837-3819 STEPHEN R. CALLEGARI, P.E.

CERTIFICATE OF ANALYSIS

Date: 7-01-93 P.O. No. GD406178

Company: Global Divers & Contractors, Inc.

Test: Guided Bend Test per AWS D3.6-93

Test Performed on: Weld Sample 3/4" X 8"Lg. (Conf. weld) 4G With T.B.

Welders Name: Darryl Phillips

GUIDED BEND TESTS	
SAMPLE TYPE & NUMBER	RESULTS
Side Bend(6T,4T,2T) S1	Satisfactory
Side Bend(6T,4T) S2	Satisfactory
Side Bend(6T,4T) S3	Satisfactory
Side Bend(6T,4T,2T) S4	Satisfactory

EQUIPMENT UTILIZED FOR TEST
Type: Guided Bend Tester
Manufacturer: CRC

Certified By: Tim J. Broussard Date: 7-1-93
Tim J. Broussard
SRC Engineers, Inc.

Reviewed By: Stephen R. Callegari Date: 07-01-93

GLOBAL6.BND

Global Divers
& Contractors, Inc.

Sheet 1 of 2
W/O No. ED-016-93

MATERIALS JOINING WORK REPORT
Part 1 Confirmation Weld - Compare Charpy HAZ Notch Orientations

Location GLOBAL DIVERS - PORT OF IBERIA Contract No. 91-M-4346

Mat'l (1) A 537 Grade Cl.1
Ht./Slab No. 79006-12
Thick 3/4" in. Dia. _____ in.

Mat'l (2) _____ Grade _____
Ht./Slab No. _____
Thick _____ in. Dia. _____ in.

Electrode (AWS) E 6013 A5.1 TN Program Ex 7 Mfr. Proprietary Ctry _____

Process SMAW Current/Polarity CC/DCEP/Pulse Joint Type V-Groove Position 3 G (8")

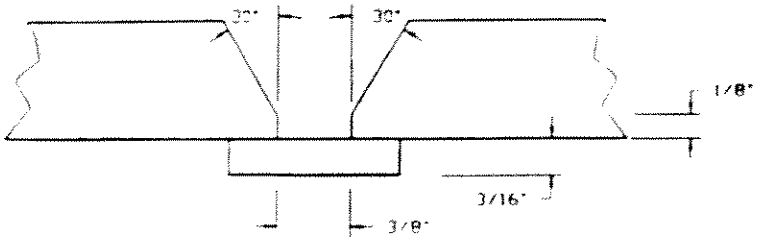
Water Depth 33' Dry _____ Wet X

Welding Variables:

R F & C	PASS	DIA.	AMPS	VOLTS	I.P.M.	REMARKS
Root	1	1/8"	155 - 160	33 - 35	8.0	PPS - 150
Temper	1	1/8"	155 - 160	33 - 35	6.7	PW - 70%
Root	2	1/8"	155 - 160	33 - 35	8.0	Background - 30%
Temper	2	1/8"	155 - 160	33 - 35	6.7	41 Passes
Fill	3 - 35	1/8"	155 - 160	33 - 35	8.0	Weld time - 46 min.
Cap	36 - 41	1/8"	155 - 160	33 - 35	9.2	Used Multiple temper bead technique

Welder: Darryl R. Phillips Date: 7-1-93

Welding Joint Sketch:



Welding Techniques:

Stringer Beads. All passes downhill

Global Divers
& Contractors, Inc.

Tension Tests: (Reduced Section/All-Weld-Metal) N/A

SPECIMEN	ORIENT	ULTIMATE S.	YIELD S.	ELONGATION	FAILURE
1					
2					

Bends: N/A

SPECIMEN	ROOT	FACE	SIDE	RADIUS	RESULTS
1					
2					
3					
4					

Chemistry:

	CE	C	Mn	P	S	Si	Ni	Cr	Mo	Cu	V	Cb	Nb	Al
CTR														
LAB	.462	.20	1.50	.014	.019	.38	.03	.02	.01	.03	.01	.01	---	---

Hardness (Vickers/Rockwell): N/A

LOCATION	LEFT SIDE	RIGHT SIDE
BASE METAL (AVG.)		
HAZ (MAX)		
HAZ (AVG)		
WM (MAX)		

Purpose of Test: Compare Charpy V-notch HAZ impact test results with notch oriented per AWS D3.6 Vs parallel to HAZ.

Remarks & Evaluation: For Charpy tests on this weldment, the notch was oriented per AWS D3.6. Average results of tests on four macros were: Absorbed Energy, 44.7 ft. lbs. shear fracture, 85%. Lateral expansion, 49.5 mils.

By: C.E. Grubbs Date: 7-1-93 Rev: ---

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(318) 837-3810, 837-3819 STEPHEN R. CALLEGARI, P.E.

CERTIFICATE OF ANALYSIS

Date: 07-08-93 P.O. No. GD406178
Company: Global Divers & Contractors, Inc.
Test: Charpy V-Notch Impact Test per ASTM A-370, E-23
Test Performed on: 3/4" x 8"Lg. Weld(Conf. Weld)3G-With T.B. 60° Bevel Groove
Size of Specimens: Full Size (10mm x 10mm x 55mm)

Test Temperature: 28°F

RESULTS			
SPECIMEN NUMBER	ABSORBED ENERGY ft - lbf	PERCENT SHEAR FRACTURE	LATERAL EXPANSION (mils)
H1(Heat Affected Zone)	42	85	46
H2(Heat Affected Zone)	41	85	52
H3(Heat Affected Zone)	47	85	52
H4(Heat Affected Zone)	45	85	50
H5(Heat Affected Zone)	51	85	44

EQUIPMENT UTILIZED FOR TEST
Type: Charpy V-Notch Impact Tester
Manufacturer: Tinius Olsen
Serial No.: 85900
Last Calibration: January 18, 1993

Certified By: Tim Broussard Date: 7-8-93
Tim J. Broussard
SRC Engineers, Inc.

Reviewed By: Raphael Date: 7-8-93

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Global Divers
& Contractors. Inc.

Sheet 1 of 2
W/O No. ED-017-93

MATERIALS JOINING WORK REPORT
Part 1 Confirmation Weld - Compare Charpy HAZ Notch Orientations

Location GLOBAL DIVERS - PORT OF IBERIA Contract No. 91-M-4346

Mat'l (1) A 537 Grade Cl.1
Ht./Slab No. 79006-12
Thick 3/4" in. Dia. _____ in.

Mat'l (2) _____ Grade _____
Ht./Slab No. _____
Thick _____ in. Dia. _____ in.

Electrode (AWS) E 6013 A5.1 TN Program Ex 7 Mfr. Proprietary Ctry _____

Process SMAW Current/Polarity CC/DCEP/Pulse Joint Type Single bevel Position 3G (8")

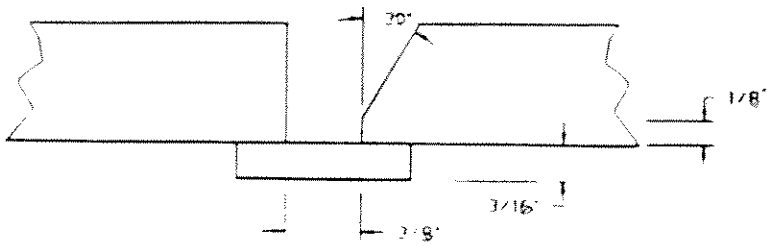
Water Depth 33' Dry _____ Wet X

Welding Variables:

R F & C	PASS	DIA.	AMPS	VOLTS	I.P.M.	REMARKS
Root	1	1/8"	160 - 165	32 - 34	5.7	PPS - 150
Temper	1	1/8"	160 - 165	32 - 34	5.5	PW - 70%
Root	2	1/8"	160 - 165	32 - 34	5.6	Background - 30%
Temper	2	1/8"	160 - 165	32 - 34	5.7	42 Passes
Fill	3 - 36	1/8"	160 - 165	32 - 34	8.6	Weld time 56 min.
Cap	37 - 42	1/8"	160 - 165	32 - 34	9.2	Used Multiple Temper Bead Technique

Welder: Darryl R. Phillips Date: 7-1-93

Welding Joint Sketch:



Welding Techniques:

Stinger beads all passes down hill

Global Divers
& Contractors, Inc.

Sheet 2 of 2
W/O No. ED-017-93

Tension Tests: (Reduced Section/All-Weld-Metal) N/A

SPECIMEN	ORIENT	ULTIMATE S.	YIELD S.	ELONGATION	FAILURE
1					
2					

Bends: N/A

SPECIMEN	ROOT	FACE	SIDE	RADIUS	RESULTS
1					
2					
3					
4					

Chemistry:

	CE	C	Mn	P	S	Si	Ni	Cr	Mo	Cu	V	Cb	Nb	Al
CTR														
LAB	.462	.20	1.50	.014	.019	.38	.03	.02	.01	.03	.01	.01	---	---

Hardness (Vickers/Rockwell): N/A

LOCATION	LEFT SIDE	RIGHT SIDE
BASE METAL (AVG.)		
HAZ (MAX)		
HAZ (AVG)		
WM (MAX)		

Purpose of Test: Compare Charpy V-notch HAZ impact test results with notch parallel to HAZ vs AWS D3.6 orientation.

Remarks & Evaluation: For Charpy impacts on this weldment, the notch was parallel to the HAZ. Average results of tests on four macros were: Absorbed Energy, 29.3 ft. lbs. Shear Fracture, 70%. Lateral Expansion, 31.7 mils.

By: C.E. GRUBBS Date: 7-1-93 Rev: ---

SRC ENGINEERS, INC.
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(318) 837-3810, 837-3819 STEPHEN R. CALLEGARI, P.E.

CERTIFICATE OF ANALYSIS

Date: 07-08-93 P.O. No. GD406178
Company: Global Divers & Contractors, Inc.
Test: Charpy V-Notch Impact Test per ASTM A-370, E-23
Test Performed on: 3/4" x 8"Lg. Weld(Conf. Weld)3G-With T.B. Square Groove
Size of Specimens: Full Size (10mm x 10mm x 55mm)

Test Temperature: 28°F

RESULTS			
SPECIMEN NUMBER	ABSORBED ENERGY ft - lbf	PERCENT SHEAR FRACTURE	LATERAL EXPANSION (mils)
H1(Heat Affected Zone)	33	70	35
H2(Heat Affected Zone)	31	70	36
H3(Heat Affected Zone)	19	70	30
H4(Heat Affected Zone)	30	70	27
H5(Heat Affected Zone)	27	70	32

EQUIPMENT UTILIZED FOR TEST
Type: Charpy V-Notch Impact Tester
Manufacturer: Tinius Olsen
Serial No.: 85900
Last Calibration: January 18, 1993

Certified By: Tim Broussard Date: 7-8-93
Tim J. Broussard
SRC Engineers, Inc.

Reviewed By: Raphael Date: 7-8-93

GLOBAL6.chp

Bayou Testers, Inc.

24 Hour Service

Main Office: Amelia, LA 70340
P.O. Box 369
Phone (504) 631-2873
FAX (504) 631-3920

Branch: New Iberia, LA
6019 South Lewis
Phone (318) 364-9055

Branch: Houma, LA
3139 Grand Caillou Rd
Phone (504) 876-3194

Operation: Houston, Tx. Aransas Pass, Tx.

RADIOGRAGHIC REPORT

CLIENT: Globe [illegible]
DATE: [illegible]
CONTRACTOR:
JOB#:
JOB LOCATION: [illegible]
PO#/WO#:
CLIENTS #:

WELD NO.	PIPE SIZE	LOCATION	GRADING ACCEPT	GRADING REJ.	Plate Position (REMARKS)	WELD NO.	PIPE SIZE	LOCATION	GRADING ACCEPT	GRADING REJ.	REMARKS
EX7	36-33				3G						
2-B			✓								
[illegible]	[illegible]				1G						
[illegible]			✓								

Part 1 Confirmation weld

HOURS
TRAVEL
WORK TIME
STAND BY
TOTAL HOURS [illegible]
MILEAGE
PER DIEM

NUMBER OF WELDS
FILM USED

AMOUNT	SIZE	TYPE
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

REMARKS: [illegible] (1) [illegible]

TECHNICAN: [illegible]
TECHNICAN: [illegible]
ASSISTANT:
ACCEPTED: [illegible]
CLIENT'S REPRESENTATIVE

(1) Re-classified as AWS D3.6 Class B by Tom West and C.E. Grubbs

Bayou Testers, Inc.

24 Hour Service

Main Office: Amelia, LA 70340
P.O. Box 369
Phone (504) 631-2873
FAX (504) 631-3920

Branch: New Iberia, LA
6019 South Lewis
Phone (318) 364-9055

Branch: Houma, LA
3139 Grand Ca... Dr. Rd
Phone (504) 876-3124

Operation: Houston, TX; Aransas Pass, TX

RADIOGRAGHIC REPORT

CLIENT: Global [illegible]
CONTRACTOR: SAM
JOB LOCATION: [illegible] Iberia

DATE: 6-29-93
JOB #:
PO #: GD406179
CLIENT'S #:

WELD NO.	PIPE SIZE	LOCATION	RADIOGRAPH ACCEPT	RADIOGRAPH REJ.	Plate Beveled Position	WELD NO.	PIPE SIZE	LOCATION	GRADING ACCEPT	GRADING REJ.	REMARKS
X-7	SA537 CL1 DEEP 3/4" PLATE				3G						
A-B			✓								
X-7	SA537 CL1 DEEP 3/4" PLATE				4G						
A-B			✓								
A-2	3/4" Plate 3-G		✓		3G						
A-2	3/4 Plate 2-G		✓		2G						
Lot 1	Confirmatory Welds										

HOURS: TRAVEL
WORK TIME
STAND BY
TOTAL HOURS: 6
MILEAGE
PER DIEM

NUMBER OF WELDS: 4

FILM USED:

AMOUNT	SIZE	TYPE
4pcs	3½ X 10	F-5

REMARKS: Examination of [illegible] PLATE (1) AWS D3.6 Class B

TECHNICIAN: Edward [illegible]
TECHNICIAN: Milton [illegible]
ASSISTANT

N-986

ACCEPTED

CLIENT'S REPRESENTATIVE

(1) Reclassified as AWS D3.6, Class B by Tom West and C.E. Grubbs

Bayou Testers, Inc.

24 Hour Service

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P.O. Box 369
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6019 South Lewis
Phone (318) 364-9055

Branch: Houma, LA
3139 Grand Caillou Rd
Phone 504 876-5182

Operation: Houston TX Aransas Pass TX

RADIOGRAGHIC REPORT

CLIENT Global Divers
CONTRACTOR SAME
JOB LOCATION East of Iberia

DATE 6-29-93
JOB#
PO# GD4041179
CLIENT'S #

WELD NO.	PIPE SIZE	LOCATION	PAINT ACCEPT	PAINT REJ.	Plate Position	WELD NO.	PIPE SIZE	LOCATION	GRADING ACCEPT	GRADING REJ.	REMARKS
X-7	SA537 CL 1 DEEP 3/4" PLATE				3G						
A-B			✓								
X-7	SA537 CL 1 DEEP 3/4" Plate				4G						
A-B			✓								
A-12	3/4" Plate 3-G		✓		3G						
A-12	3/4 Plate 2-G		✓		2G						
Part 1	Confirmation Welds										

HOURS TRAVEL
WORK TIME
STAND BY
TOTAL HOURS 5
MILEAGE
PER DIEM

NUMBER OF WELDS 4

FILM USED

AMOUNT	SIZE	TYPE
4pcs	5"x10"	F-5

REMARKS Examination of PLATE (1) AWS D3.6 Class B

TECHNICIAN Edward [illegible]
TECHNICIAN Hilton [illegible]
ASSISTANT

ACCEPTED

N-486

CLIENT'S REPRESENTATIVE

(1) Reclassified as AWS D3.6, Class B by Tom West and C.E. Grubbs

Bayou Testers, Inc.

24 Hour Service

Main Office: Amelia, LA 70340
P.O. Box 369
Phone (504) 631-2873
FAX (504) 631-3920

Branch: New Iberia, LA
6019 South Lewis
Phone (318) 364-9055

Branch: Houma, LA
3739 Grand Caillou Rd
Phone (504) 872-5194

Operation: Houston TX, Aransas Pass TX

RADIOGRAGHIC REPORT

CLIENT Global Divers
CONTRACTOR SAME
JOB LOCATION Fort of Iberia

DATE 6-29-93
JOB#
PO# GD406179
CLIENT'S #

WELD NO.	PIPE SIZE	LOCATION	GRADING ACCEPT	GRADING REJ.	Plate Pipe Position	WELD NO.	PIPE SIZE	LOCATION	GRADING ACCEPT	GRADING REJ.	REMARKS
X-7	SA537 CL 1 DEEP 3/4" PLATE				3G						
A-B			✓								
X-7	SA537 CL 1 DEEP 3/4" Plate				4G						
A-B			✓								
A-B	3/4" Plate 3-G		✓		3G						
A-B	3/4" Plate 2-G		✓		2G						
Part 1	Confirmation Welds										

HOURS
TRAVEL
WORK TIME
STAND BY
TOTAL HOURS 2
MILEAGE
PER DIEM

NUMBER OF WELDS 4

FILM USED

AMOUNT	SIZE	TYPE
4pcs	2 1/2 X 10	F-50

REMARKS Gamma Ray of test PLATES (1) AWS D3.6 Class B

TECHNICIAN Edward [illegible]
TECHNICIAN Hilton Terrell
ASSISTANT

ACCEPTED

N-986

CLIENT'S REPRESENTATIVE

(1) Reclassified as AWS D3.6, Class B by Tom West and C.E. Grubbs

Global Divers
& Contractors, Inc.

Sheet 1 of 2
W/O No. ED-018-93

MATERIALS JOINING WORK REPORT
Part 1 Groove Weld with Multiple Temper Bead

Location GLOBAL DIVERS - PORT OF IBERIA Contract No. 91-M4346

Mat'l (1) A 36 Grade
Ht./Slab No. 0274
Thick 5/8" in. Dia. in.

Mat'l (2) Grade
Ht./Slab No.
Thick in. Dia. in.

Electrode (AWS) E 6013 A5.1 TN Program Ex 7 Mfr. Proprietary Ctry

Process SMAW Current/Polarity CC/DCEP/PULSE Joint Type V-GROOVE Position 3G (8")

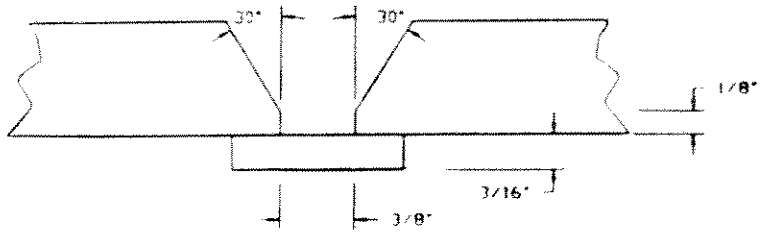
Water Depth 33' Dry Wet X

Welding Variables:

R F & C	PASS	DIA.	AMPS	VOLTS	I.P.M.	REMARKS
Root	1	1/8"	150 - 160	33 - 34	8.7	PPS - 125
Temper	1	1/8"	150 - 160	33 - 34	8.4	PW - 50%
Root	2	1/8"	155 - 160	33 - 34	8.8	Background 30%
Temper	2	1/8"	155 - 160	33 - 34	8.2	Weld Time - 54 Min.
Fill	3 - 37	1/8"	155 - 160	33 - 34	8.4	Used MPT Welding Technique
Cap	38 - 44	1/8"	155 - 160	33 - 34	9.1	

Welder: Darryl R. Phillips Date: 6-18-93

Welding Joint Sketch:



Welding Techniques:

Stringer Beads with all passes downhill.

Global Divers
& Contractors, Inc.

Tension Tests: (Reduced Section/All-Weld-Metal) N/A

SPECIMEN	ORIENT	ULTIMATE S.	YIELD S.	ELONGATION	FAILURE
1					
2					

Bends: N/A

SPECIMEN	ROOT	FACE	SIDE	RADIUS	RESULTS
1					
2					
3					
4					

Chemistry: A-36

	CE	C	Mn	P	S	Si	Ni	Cr	Mo	Cu	V	Cb	Nb	Al
CTR														
LAB	.26	.14	.68	.011	.005	.25	.02	.02	---	.02	---	---	---	.033

Hardness (Vickers/Rockwell): Vickers 10 kg, combined test results on four macros.

LOCATION	LEFT SIDE	RIGHT SIDE
BASE METAL (AVG.)	153	150
HAZ (MAX)	226	244
HAZ (AVG)	199	197
WM (MAX)	240	226

Purpose of Test: Compare properties of weldments made with and without, the multiple temper bead wet welding technique.

Remarks & Evaluation: Four Haz Charpy V-Notch impacts results at 28° F averaged :
Absorbed energy - 71 ft lbs, Shear Fracture - 62%, Lateral Expansion - 57 mils.
Four of four macros revealed no HAZ cracks at ≤100X.

By: C.E. Grubbs Date: 6-18-93 Rev: ---

Global Divers
& Contractors, Inc.

Sheet 1 of 2
W/O No. ED-019-93

MATERIALS JOINING WORK REPORT
Part 1 Groove Weld Without Temper Bead

Location GLOBAL DIVERS - PORT OF IBERIA Contract No. 91-M-4346

Mat'l (1) A 36 Grade _____ Mat'l (2) _____ Grade _____
Ht./Slab No. 0274 Ht./Slab No. _____

Thick 5/8" in. Dia. _____ in. Thick _____ in. Dia. _____ in.

Electrode (AWS) E 6013 A5.1 TN Program Ex 7 Mfr. Proprietary Ctry _____

Process SMAW Current/Polarity CC/DCEP/Pulse Joint Type V-Groove Position 3 G

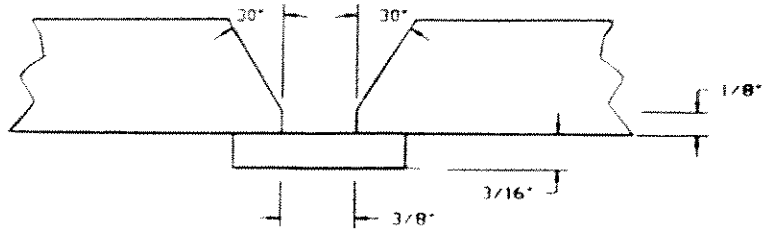
Water Depth 33' Dry _____ Wet X

Welding Variables:

R F & C	PASS	DIA.	AMPS	VOLTS	I.P.M.	REMARKS
Root	1 - 2	1/8"	155 - 160	33 - 34	5.7	PPS - 125
Fill	3 - 36	1/8"	155 - 160	33 - 34	6.3	PW - 50%
Cap	37 - 42	1/8"	155 - 160	33 - 34	9.1	Background 30%
						Weld Time - 56 Min.
						No temper beads were used.

Welder: Darryl R. Phillips Date: 6-18-93

Welding Joint Sketch:



Welding Techniques:

Stringer Beads. All Passes Down Hill.

Global Divers
& Contractors, Inc.

W/O No. ED-019-93

Tension Tests: (Reduced Section/All-Weld-Metal) N/A

SPECIMEN	ORIENT	ULTIMATE S.	YIELD S.	ELONGATION	FAILURE
1					
2					

Bends: N/A

SPECIMEN	ROOT	FACE	SIDE	RADIUS	RESULTS
1					
2					
3					
4					

Chemistry: A 36

	CE	C	Mn	P	S	Si	Ni	Cr	Mo	Cu	V	Cb	Nb	Al
CTR														
LAB	.26	.14	.68	.001	.005	.25	.02	.02	---	.02	---	---	---	.033

Hardness (Vickers/Rockwell): Vickers 10 kg (combined test results for four macros)

LOCATION	LEFT SIDE	RIGHT SIDE
BASE METAL (AVG.)	139	151
HAZ (MAX)	220	244
HAZ (AVG)	195	196
WM (MAX)	227	227

Purpose of Test: Compare properties of weldments made with and without, the multiple temper bead wet welding technique.

Remarks & Evaluation: Four HAZ Charpy V-notch impact results at 28° F. averaged:
Absorbed energy 73 ft. lbs. Shear Fracture - 80%. Lateral Expansion - 70 mils.
Four of four macros revealed no cracks at ≤100 x.

By: C. E. Grubbs Date: 6-18-93 Rev: ---

Global Divers
& Contractors, Inc.

Sheet 1 of 2
W/O No. ED-022 -93

MATERIALS JOINING WORK REPORT
Part 1 Groove Weld with Multiple Temper Bead

Location GLOBAL DIVERS - PORT OF IBERIA Contract No. 91-M-4346

Mat'l (1) ASTM A36 Grade
Ht./Slab No.
Thick 1/2" in. Dia. in.

Mat'l (2) Grade
Ht./Slab No.
Thick in. Dia. in.

Electrode (AWS) E 6013 A5.1 TN Program Ex 7 Mfr. Proprietary Ctry

Process SMAW Current/Polarity CC/DCEP Joint Type V-Groove Position 3G (8")

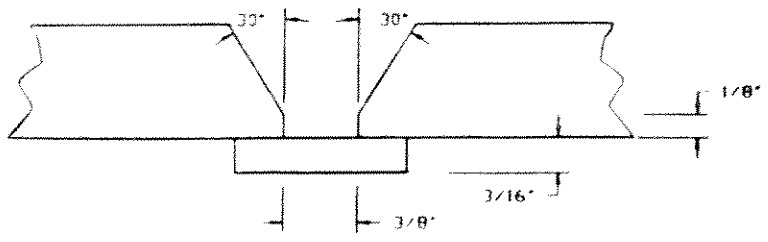
Water Depth 33' Dry Wet X

Welding Variables:

R F & C	PASS	DIA.	AMPS	VOLTS	I.P.M.	REMARKS
ROOT	3	3/32"	105 - 110	25 - 30	5	Used MTB
TEMPER	2	3/32"	105 - 110	25 - 30	5	Weld Time 45 Minutes
FILL	16	1/8"	175 - 180	25 - 30	8	
TEMPER	6	3/32"	105 - 110	25 - 30	5	Used MTB
CAP	4	1/8"	175 - 180	25 - 30	8	Weld Time 45 Minutes
TEMPER	2	3/32"	110 - 120	25 - 30	6	
TOTAL	33					

Welder: Darryl R. Phillips Date: 9-10-93

Welding Joint Sketch:



Welding Techniques:

Stringer Beads - All Passes Downhill

Global Divers
& Contractors, Inc.

Tension Tests: (Reduced Section/All-Weld-Metal) N/A

SPECIMEN	ORIENT	ULTIMATE S.	YIELD S.	ELONGATION	FAILURE
1					
2					

Bends:

SPECIMEN	ROOT	FACE	SIDE	RADIUS	RESULTS
1			X	3-1/3 T	SATISFACTORY
2			X	3-1/3 T	SATISFACTORY
3			X	3-1/3 T	SATISFACTORY
4			X	3-1/3 T	SASTISFACTORY

Chemistry: ASTM A36

	CE	C	Mn	P	S	Si	Ni	Cr	Mo	Cu	V	Cb	Nb	Al
CTR														
LAB	.4154	.24	1.01	.006	.014	.07	.02	.01	.01	.02	.002	.002	.002	.008

Hardness (Vickers/Rockwell): Vickers 10 kg (Combined results of four macros)

LOCATION	LEFT SIDE	RIGHT SIDE
BASE METAL (AVG.)	N/A	N/A
HAZ (MAX)	496	478
HAZ (AVG)	346	304
WM (MAX)	N/A	N/A

Purpose of Test: Compare properties of weldments mad with and without the multiple temper bead wet welding method.

Remarks & Evaluation: Four of four cross sections had no HAZ cracks at ≤ 100X. Four of four side bends passed 3-1/3 T.

By: C.E. Grubbs Date: 9-10-93 Rev: —

Global Divers
& Contractors, Inc.

Sheet 1 of 2
W/O No. ED-023-93

MATERIALS JOINING WORK REPORT
Part 1 Groove Weld With No Tempering

Location GLOBAL DIVERS - PORT OF IBERIA Contract No. 91-M-4346

Mat'l (1) ASTM A36 Grade
Ht./Slab No.
Thick 1/2" in. Dia. in.

Mat'l (2) Grade
Ht./Slab No.
Thick in. Dia. in.

Electrode (AWS) E 6013 TN Program Ex 7 Mfr. Proprietary Ctry

Process SMAW Current/Polarity CC/DCEP Joint Type V-Groove Position 3G (8")

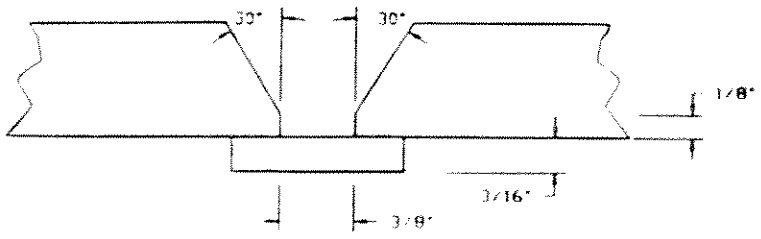
Water Depth 33' Dry Wet X

Welding Variables:

R F & C	PASS	DIA.	AMPS	VOLTS	I.P.M.	REMARKS
ROOT	2	3/32"	110-120	25 - 30	5	No Tempering Weld Time 43 min.
FILL	3	3/32"	110-120	25 - 30	6	
FILL	20	1/8"	175-180	25 - 30	8	
CAP	4	1/8"	175-180	25 - 30	8	
TOTAL	29					

Welder: Darryl R. Phillips Date: 9-10-93

Welding Joint Sketch:



Welding Techniques:

Stringer Beads with all passes downhill.

Global Divers
& Contractors, Inc.

Sheet 2 of 2
W/O No. ED-023-93

Tension Tests: (Reduced Section/All-Weld-Metal) N/A

SPECIMEN	ORIENT	ULTIMATE S.	YIELD S.	ELONGATION	FAILURE
1					
2					

Bends: N/A

SPECIMEN	ROOT	FACE	SIDE	RADIUS	RESULTS
1			X	3-1/3 T	SATISFACTORY
2			X	3-1/3 T	SATISFACTORY
3			X	3-1/3 T	SATISFACTORY
4			X	3-1/3 T	SATISFACTORY

Chemistry:

	CE	C	Mn	P	S	Si	Ni	Cr	Mo	Cu	V	Cb	Nb	Al
CTR														
LAB	.4154	.24	1.01	.006	.014	.07	.02	.01	.01	.02	.002	.002	.002	.008

Hardness (Vickers/Rockwell): Vickers 10 kg (Combined results of four macros)

LOCATION	LEFT SIDE	RIGHT SIDE
BASE METAL (AVG.)	N/A	N/A
HAZ (MAX)	482	510
HAZ (AVG)	374	365
WM (MAX)	N/A	N/A

Purpose of Test: Compare properties of weldments made with and without the multiple temper bead wet welding method.

Remarks & Evaluation: Four of four cross sections had no HAZ cracks at 100X. Four of four side bends passed on 3-1/3T.

By: C.E. Grubbs Date: 9-10-93 Rev: —

Global Divers
& Contractors, Inc.

Sheet 1 of 2
W/O No. ED-020-93

MATERIALS JOINING WORK REPORT
Part 1 Groove Weld With Temper Beads

Location GLOBAL DIVERS - PORT OF IBERIA Contract No. 91-M-4346

Mat'l (1) A588-88A Grade B
Ht./Slab No. 803L3250
Thick 5/8" in. Dia. _____ in.

Mat'l (2) _____ Grade _____
Ht./Slab No. _____
Thick _____ in. Dia. _____ in.

Electrode (AWS) E 6013 A5.1 TN Program Ex 7 Mfr. Proprietary Ctry _____

Process SMAW Current/Polarity CC/DCEP/Pulse Joint Type V-Groove (8") Position 3 G

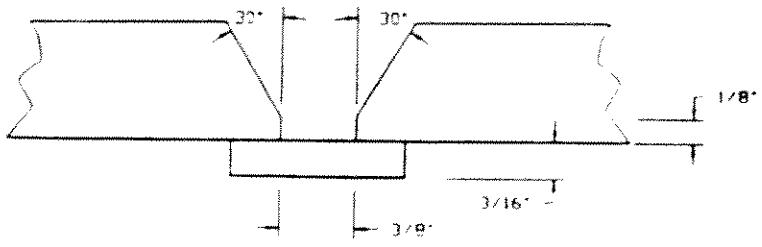
Water Depth 33' Dry _____ Wet X

Welding Variables:

R F & C	PASS	DIA.	AMPS	VOLTS	I.P.M.	REMARKS
Root	1 - 2	1/8"	150 - 160	28 - 30	5.6	PPS - 125
Fill	3 - 36	1/8"	150 - 160	28 - 30	6.2	PW - 50%
Cap	37 - 42	1/8"	155	30	9.1	Background 30%
Temper	Avg	1/8"	155	30	8.6	Weld Time - 55 Min.
						Used MTB Wet Welding Technique.

Welder: Darryl R. Phillips Date: 7-12-93

Welding Joint Sketch:



Welding Techniques:

Stringer Beads. All Passes Down Hill.

Global Divers
& Contractors, Inc.

Tension Tests: (Reduced Section/All-Weld-Metal) N/A

SPECIMEN	ORIENT	ULTIMATE S.	YIELD S.	ELONGATION	FAILURE
1					
2					

Bends: N/A

SPECIMEN	ROOT	FACE	SIDE	RADIUS	RESULTS
1					
2					
3					
4					

Chemistry: A5 88-88A Gr. B

	CE	C	Mn	P	S	Si	Ni	Cr	Mo	Cu	V	Cb	Nb	Al
CTR	.449	.13	.98	.016	.011	.377	.27	.59	---	.281	.03	---	---	---
LAB														

Hardness (Vickers/Rockwell): Vickers 10 kg (combined test results for four macros)

LOCATION	LEFT SIDE	RIGHT SIDE
BASE METAL (AVG.)	198	197
HAZ (MAX)	382	370
HAZ (AVG)	298	304
WM (MAX)	252	232

Purpose of Test: Compare properties of weldments made on A588-88A Gr B plate with, and without, the multiple temper bead wet welding technique.

Remarks & Evaluation: With MTB, Charpy V-notch impact results at 28° F. averaged:
Absorbed energy -32 ft. lbs. Shear Fracture - 68% and Lateral Expansion -35 mils.

By: C. E. Grubbs Date: 7-12-93 Rev: ---

Global Divers
& Contractors, Inc.

Sheet 1 of 2
W/O No. ED-021-93

MATERIALS JOINING WORK REPORT
Part 1 Groove Weld Without Temper Bead

Location GLOBAL DIVERS - PORT OF IBERIA Contract No. 91-M-4346

Matl (1) A588-88A Grade B
Ht./Slab No. 803L3250
Thick 5/8" in. Dia. _____ in.

Matl (2) _____ Grade _____
Ht./Slab No. _____
Thick _____ in. Dia. _____ in.

Electrode (AWS) E 6013 A5.1 TN Program Ex 7 Mfr. Proprietary Ctry _____

Process SMAW Current/Polarity CC/DCEP/Pulse Joint Type V-Groove (8") Position 3 G

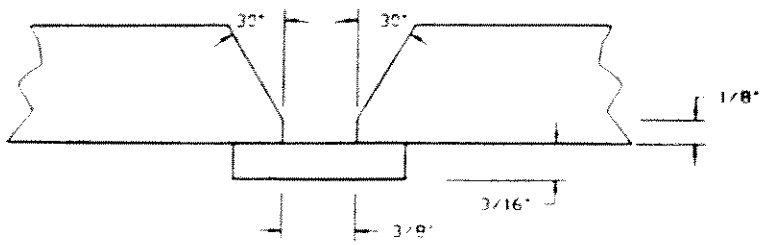
Water Depth 33' Dry _____ Wet X

Welding Variables:

R F & C	PASS	DIA.	AMPS	VOLTS	I.P.M.	REMARKS
Root	1 - 2	1/8"	150 - 160	28 - 30	5.6	PPS - 125
Fill	3 - 36	1/8"	150 - 160	28 - 30	6.2	PW - 50%
Cap	37 - 42	1/8"	150 - 160	28 - 30	9.1	Background 30%
						Weld Time - 54 Min.
						Welded without temper beads.

Welder: Darryl R. Phillips Date: 7-12-93

Welding Joint Sketch:



Welding Techniques:

Stringer Beads. All Passes Down Hill.

Global Divers
& Contractors, Inc.

Tension Tests: (Reduced Section/All-Weld-Metal) N/A

SPECIMEN	ORIENT	ULTIMATE S.	YIELD S.	ELONGATION	FAILURE
1					
2					

Bends: N/A

SPECIMEN	ROOT	FACE	SIDE	RADIUS	RESULTS
1					
2					
3					
4					

Chemistry: A5-88-88A Gr. B

	CE	C	Mn	P	S	Si	Ni	Cr	Mo	Cu	V	Cb	Nb	Al
CTR	.449	.13	.98	.016	.011	.377	.27	.59	---	.281	.03	---	---	---
LAB														

Hardness (Vickers/Rockwell): Vickers 10 kg (combined test results for four macros)

LOCATION	LEFT SIDE	RIGHT SIDE
BASE METAL (AVG.)	193	190
HAZ (MAX)	360	370
HAZ (AVG)	288	301
WM (MAX)	260	228

Purpose of Test: Compare properties of weldments made on A588-88A Gr B plate with, and without, the multiple temper bead wet welding technique.

Remarks & Evaluation: With no MTB, Charpy V-notch impact results at 28° F. averaged: Absorbed energy -36.3 ft. lbs. Shear Fracture - 63.3% and Lateral Expansion - 35.7 mils.

By: C. E. Grubbs Date: 7-12-93 Rev: ---

SRC ENGINEERS, INC.
P.O. BOX 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710
(318) 837-3810, 837-3819 STEPHEN R. CALLEGARI, P.E.

CERTIFICATE OF ANALYSIS

Date: 06-22-93 P.O. No. GD406139
Company: Global Divers & Contractors, Inc.
Test: Charpy V-Notch Impact Test per ASTM A-370, E-23
Test Performed on: Weld (With) Temper Bead

Size of Specimens: Full Size (10mm x 10mm x 55mm)

Test Temperature: 28°F

RESULTS			
SPECIMEN NUMBER	ABSORBED ENERGY ft - lbf	PERCENT SHEAR FRACTURE	LATERAL EXPANSION (mils)
H1(Heat Affected Zone)	91	50	64
H2(Heat Affected Zone)	54	60	52
H3(Heat Affected Zone)	74	50	54
H4(Heat Affected Zone)	62	50	33
H5(Heat Affected Zone)	77	85	72

EQUIPMENT UTILIZED FOR TEST
Type: Charpy V-Notch Impact Tester
Manufacturer: Tinius Olsen
Serial No.: 85900
Last Calibration: January 18, 1993

Certified By: Tim Broussard Date: 6-22-93
Tim J. Broussard
SRC Engineers, Inc.

Reviewed By: Raphael Date: 6-22-93

GLOBAL4.chp

SRC ENGINEERS, INC.
P.O. BOX 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710
(318) 837-3810, 837-3819 STEPHEN R. CALLEGARI, P.E.

CERTIFICATE OF ANALYSIS

Date: 06-22-93 P.O. No. GD406139
Company: Global Divers & Contractors, Inc.
Test: Charpy V-Notch Impact Test per ASTM A-370, E-23
Test Performed on: Weld (Without) Temper Bead

Size of Specimens: Full Size (10mm x 10mm x 55mm)

Test Temperature: 28°F

RESULTS			
SPECIMEN NUMBER	ABSORBED ENERGY ft - lbf	PERCENT SHEAR FRACTURE	LATERAL EXPANSION (mils)
H1(Heat Affected Zone)	69	50	60
H2(Heat Affected Zone)	78	70	73
H3(Heat Affected Zone)	71	85	61
H4(Heat Affected Zone)	70	85	76
H5(Heat Affected Zone)	80	85	75

EQUIPMENT UTILIZED FOR TEST
Type: Charpy V-Notch Impact Tester
Manufacturer: Tinius Olsen
Serial No.: 85900
Last Calibration: January 18, 1993

Certified By: Tim Broussard Date: 6-22-93
Tim J. Broussard
SRC Engineers, Inc.

Reviewed By: Raphael Tonna Date: 6-22-93

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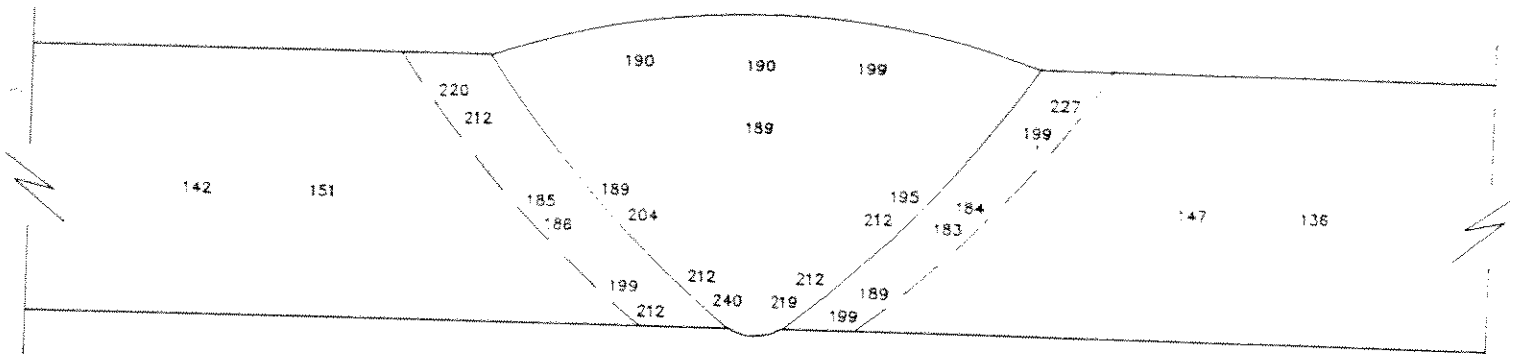
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers 10kg load hardness test on weld sample
P.O. #GD406139 Underwater Weld Sample #TB-1

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



Note: **HAZ Examined at 5X, 50X, & 100X Magnification.**
No HAZ Hydrogen Cracks were present.

EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 18, 1993

SRC Job No. 92-352

Certified By: _____ Date: 6-24-93

Reviewed By: _____ Date: 6-24-93

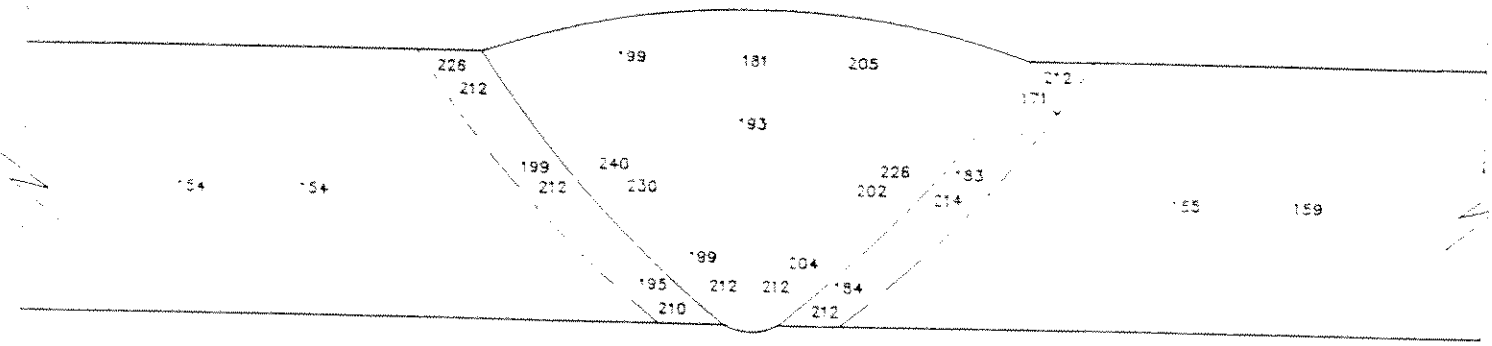
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers 10kg load hardness test on weld sample
P.O. #GD406139 Underwater Weld Sample #TB-2

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



Note: **HAZ Examined at 5X, 50X, & 100X Magnification.**
No HAZ Hydrogen Cracks were present.

EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 18, 1993

SRC Job No. 92-352

Certified By: [signature] Date: 6-24-93

Reviewed By: [signature] Date: 6-24-93

GLOBAL4.VIC

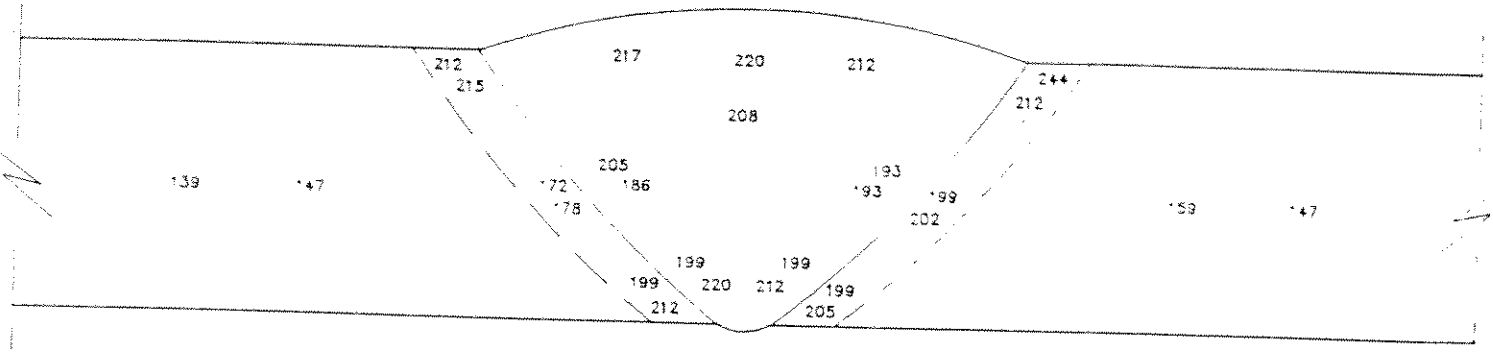
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers 10kg load hardness test on weld sample
P.O. #GD406139 Underwater Weld Sample #TB-3

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



Note: **HAZ Examined at 5X, 50X, & 100X Magnification.**
No HAZ Hydrogen Cracks were present.

EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 18, 1993

SRC Job No. 92-352

Certified By: [signature] Date: 6-24-93

Reviewed By: [signature] Date: 6-24-93

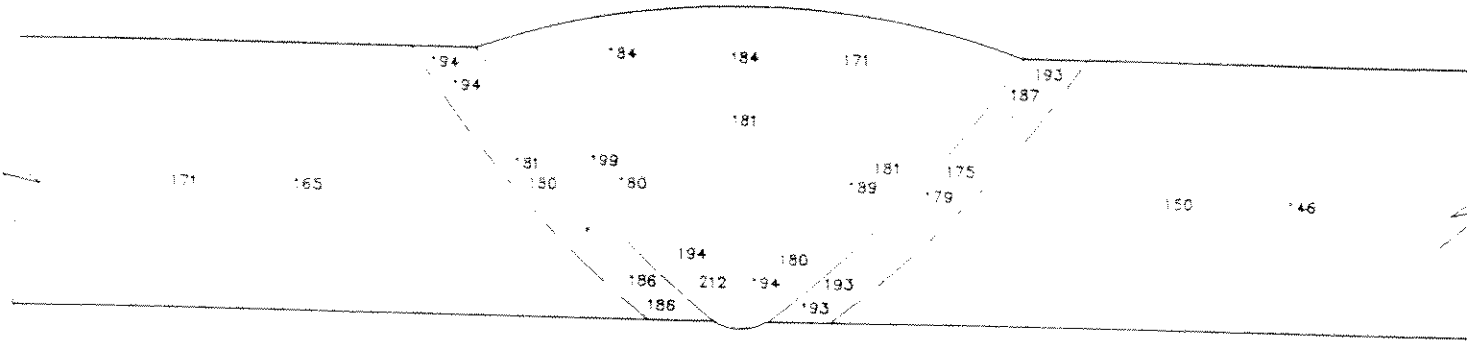
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers 10kg load hardness test on weld sample
P.O. #GD406139 Underwater Weld Sample #TB-4

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



Note: **HAZ Examined at 5X, 50X, & 100X Magnification.**
No HAZ Hydrogen Cracks were present.

EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 18, 1993

SRC Job No. 92-352

Certified By: [signature] Date: 6-24-93

Reviewed By: [signature] Date: 6-24-93

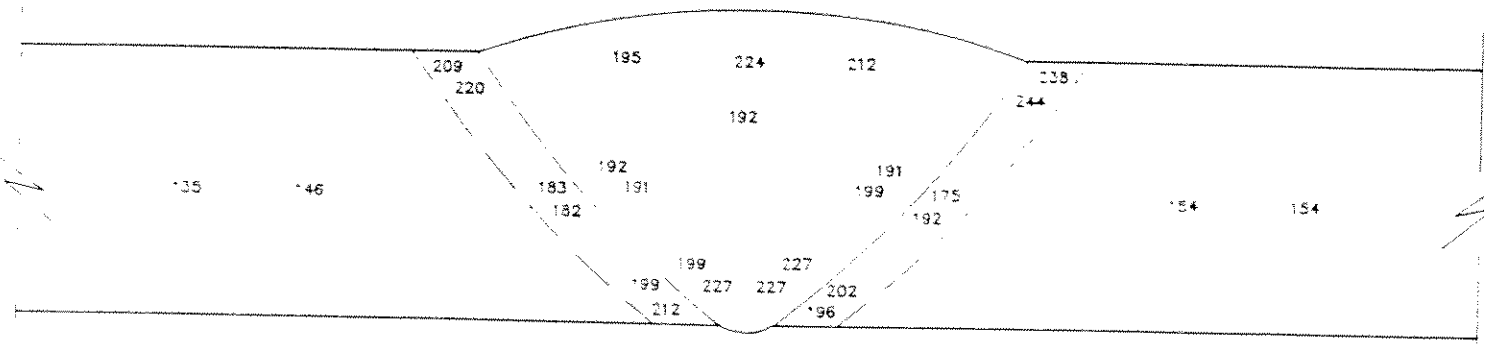
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers 10kg load hardness test on weld sample
P.O. #GD406139 Underwater Weld Sample #NTB-1

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



Note: HAZ Examined at 5X, 50X, & 100X Magnification.
No HAZ Hydrogen Cracks were present.

EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 18, 1993

SRC Job No. 92-352

Certified By: [signature] Date: 6-24-93

Reviewed By: [signature] Date: 6-24-93

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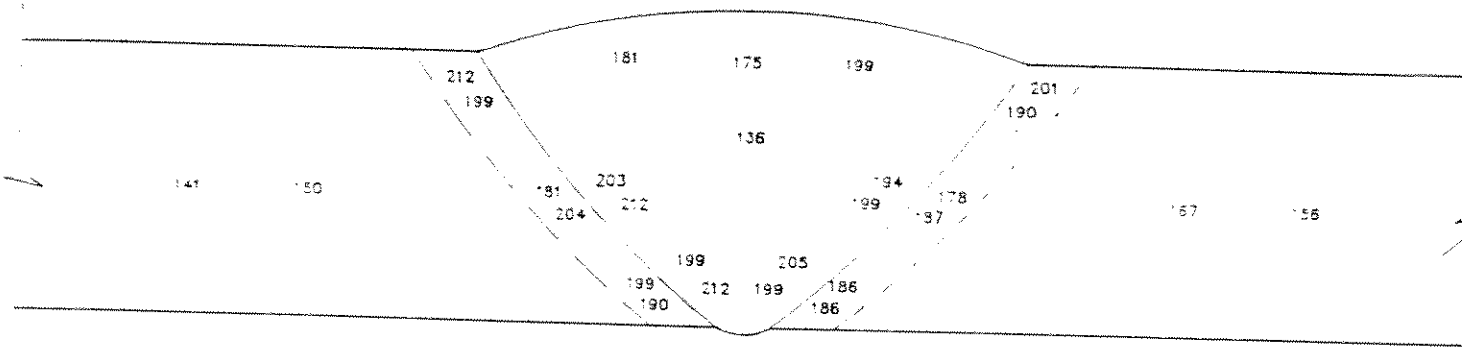
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers 10kg load hardness test on weld sample
P.O. #GD406139 Underwater Weld Sample #NTB-2

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



Note: HAZ Examined at 5X, 50X, & 100X Magnification.
No HAZ Hydrogen Cracks were present.

EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 18, 1993

SRC Job No. 92-352

Certified By: [signature] Date: 6-24-93

Reviewed By: [signature] Date: 6-24-93

GLOBAL4.VIC

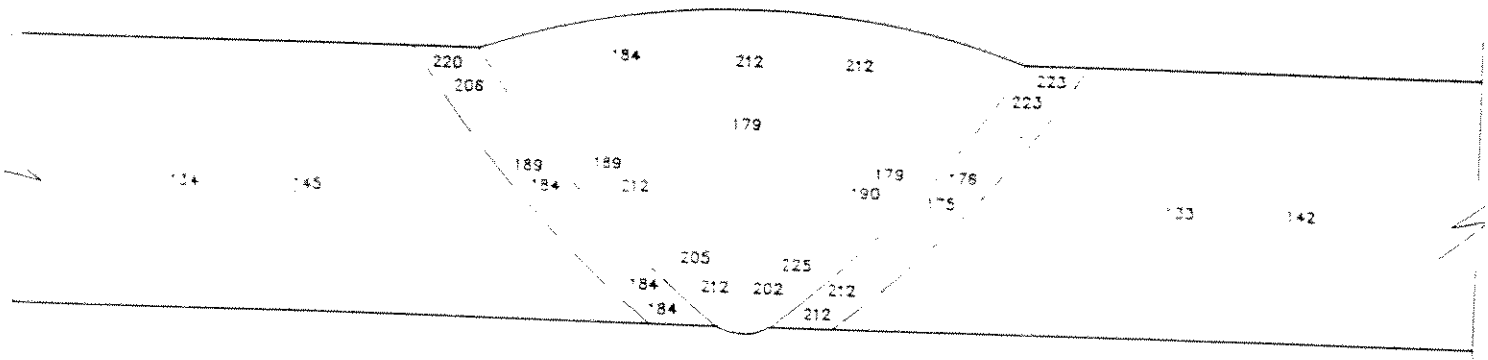
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers 10kg load hardness test on weld sample
P.O. #GD406139 Underwater Weld Sample #NTB-3

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



Note: **HAZ Examined at 5X, 50X, & 100X Magnification.**
No HAZ Hydrogen Cracks were present.

EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 18, 1993

SRC Job No. 92-352

Certified By: [signature] Date: 6-24-93

Reviewed By: [signature] Date: 6-24-93

GLOBAL4.VIC

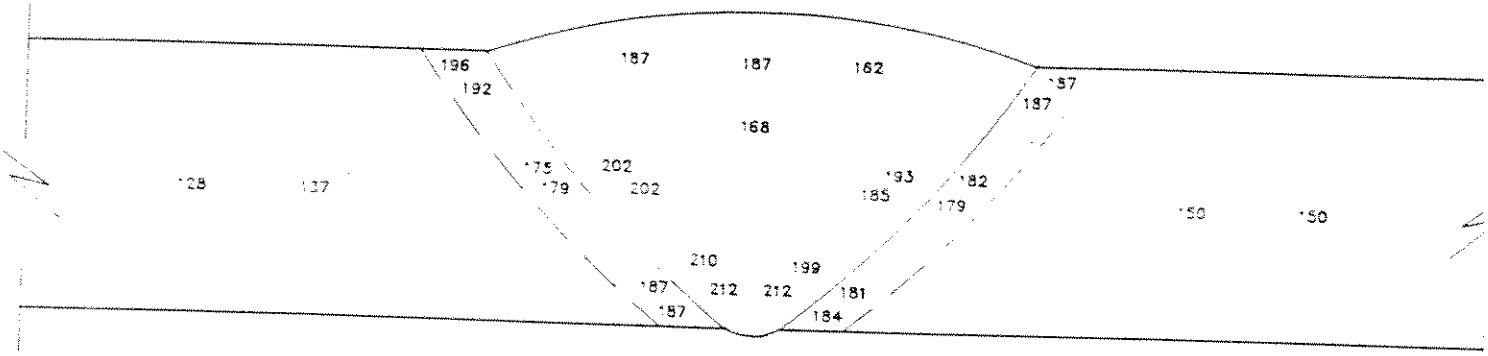
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers 10kg load hardness test on weld sample
P.O. #GD406139 Underwater Weld Sample #NTB-4

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



Note: HAZ Examined at 5X, 50X, & 100X Magnification.
No HAZ Hydrogen Cracks were present.

EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 18, 1993

SRC Job No. 92-352

Certified By: Tim Brown Date: 6-24-93

Reviewed By: Steph R Ott Date: 6-28-93

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SRC ENGINEERS, INC.
P.O. BOX 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710
(318) 837-3810, 837-3819 STEPHEN R. CALLEGARI, P.E.

CERTIFICATE OF ANALYSIS

Date: 07-14-93 P.O. No. GD406294
Company: Global Divers & Contractors, Inc.
Test: Charpy V-Notch Impact Test per ASTM A-370, E-23
Test Performed on: 5/8" x 8"Lg. MTB weld on A588 - 3G
Remake
Size of Specimens: Full Size (10mm x 10mm x 55mm)

Test Temperature: 28°F

RESULTS			
SPECIMEN NUMBER	ABSORBED ENERGY ft - lbf	PERCENT SHEAR FRACTURE	LATERAL EXPANSION (mils)
H1(Heat Affected Zone)	26	70	28
H2(Heat Affected Zone)	34	60	41
H3(Heat Affected Zone)	34	85	32
H4(Heat Affected Zone)	27	60	33
H5(Heat Affected Zone)	34	70	35

EQUIPMENT UTILIZED FOR TEST
Type: Charpy V-Notch Impact Tester
Manufacturer: Tinius Olsen
Serial No.: 85900
Last Calibration: January 18, 1993

Certified By: _____ Date: 7-15-93
Tim J. Broussard
SRC Engineers, Inc.

Reviewed By: _____ Date: 7-15-93

GLOBAL7.chp

SRC ENGINEERS, INC.
P.O. BOX 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710
(318) 837-3810, 837-3819 STEPHEN R. CALLEGARI, P.E.

CERTIFICATE OF ANALYSIS

Date: 07-14-93 P.O. No. GD406294
Company: Global Divers & Contractors, Inc.
Test: Charpy V-Notch Impact Test per ASTM A-370, E-23
Test Performed on: 5/8" x 8"Lg. No MTB weld on A588 - 3G
Remake
Size of Specimens: Full Size (10mm x 10mm x 55mm)

Test Temperature: 28°F

RESULTS			
SPECIMEN NUMBER	ABSORBED ENERGY ft - lbf	PERCENT SHEAR FRACTURE	LATERAL EXPANSION (mils)
H1(Heat Affected Zone)	42	70	38
H2(Heat Affected Zone)	47	70	36
H3(Heat Affected Zone)	37	60	37
H4(Heat Affected Zone)	22	60	29
H5(Heat Affected Zone)	30	60	32

EQUIPMENT UTILIZED FOR TEST
Type: Charpy V-Notch Impact Tester
Manufacturer: Tinius Olsen
Serial No.: 85900
Last Calibration: January 18, 1993

Certified By: Tim Broussard Date: 7-15-93
Tim J. Broussard
SRC Engineers, Inc.

Reviewed By: Richard Date: 7-15-93

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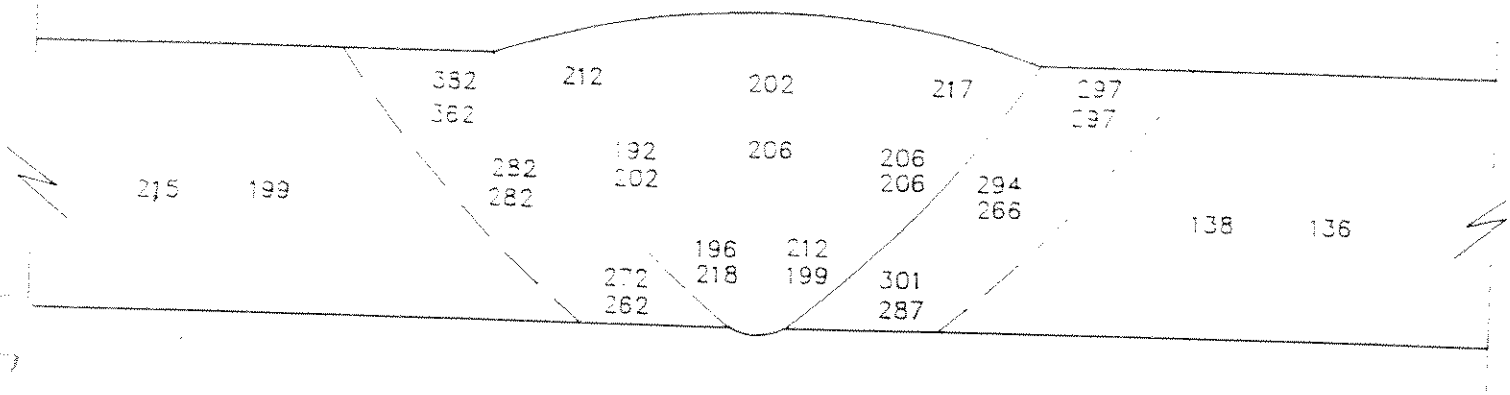
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers 10kg load hardness test on weld sample 5/8" X 8"Lg. Remake of MTB weld on A588 plate 3G-#1

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 18, 1993

SRC Job No. 92-352

Certified By: [signature] Date: 7-15-93

Reviewed By: [signature] Date: 7-15-93

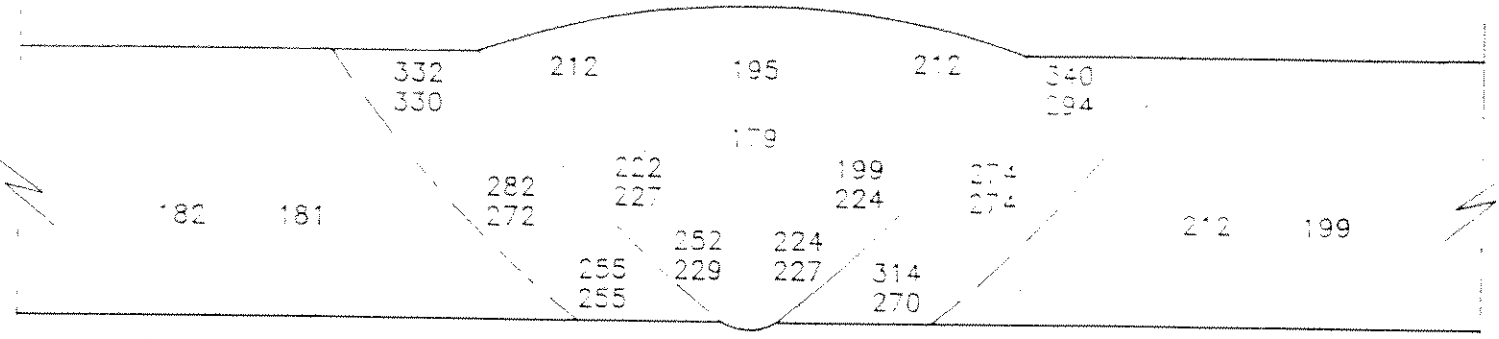
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers 10kg load hardness test on weld sample 5/8" X 8"Lg. Remake of MTB weld on A588 plate 3G-#2

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 18, 1993

SRC Job No. 92-352

Certified By: Tim Broussard Date: 7-15-93

Reviewed By: Richard Thomas Date: 7-15-93

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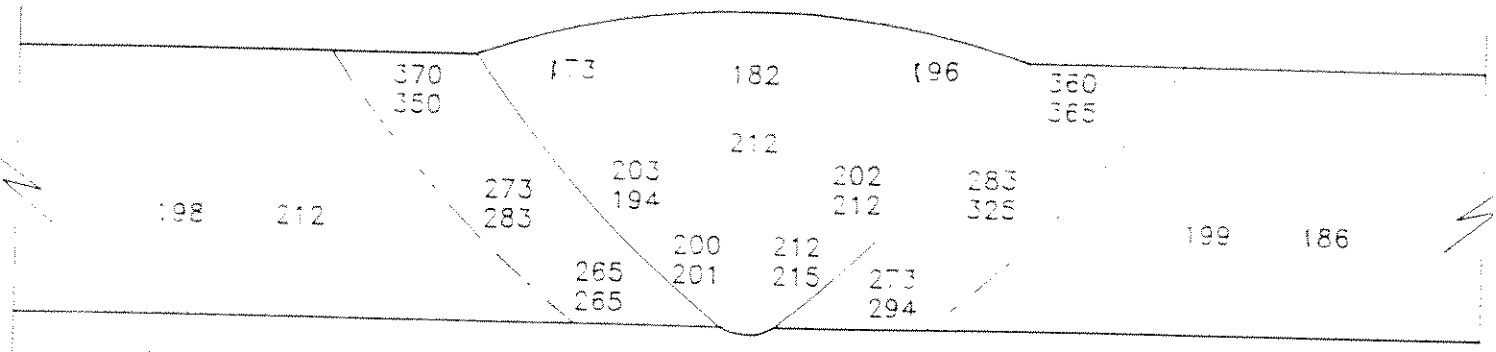
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers 10kg load hardness test on weld sample 5/8" X 8"Lg. Remake of MTB weld on A588 plate 3G-#3

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 18, 1993

SRC Job No. 92-352

Certified By: Tim Brennan Date: 7-15-93

Reviewed By: Richard Date: 7-15-93

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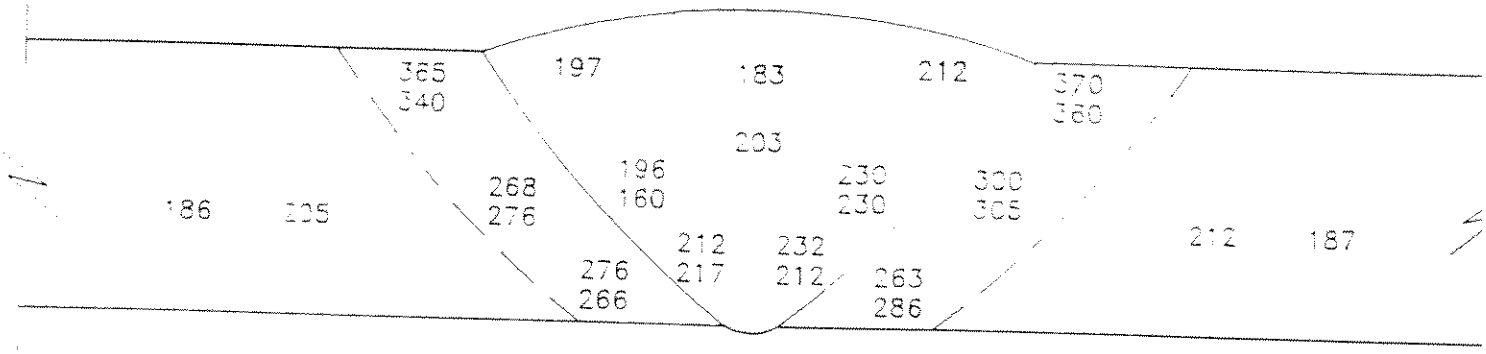
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers 10kg load hardness test on weld sample 5/8" X 8"Lg. Remake of MTB weld on A588 plate 3G-#4

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 18, 1993

SRC Job No. 92-352

Certified By: [signature] Date: 7-15-93

Reviewed By: [signature] Date: 7-15-93

GLOBAL7.VIC

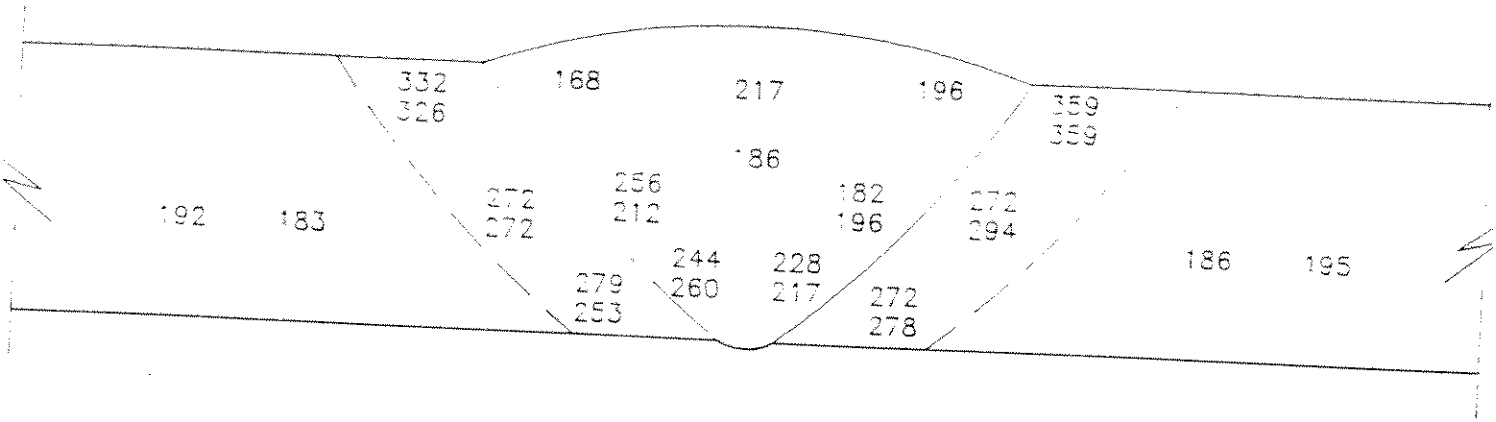
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers 10kg load hardness test on weld sample 5/8" X 8"Lg. Remake of No MTB weld on A588 plate 3G-#1

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 18, 1993

SRC Job No. 92-352

Certified By: Tim Brunard Date: 7-15-93

Reviewed By: Reginald Date: 7-[illegible]-93

GLOBAL7.VIC

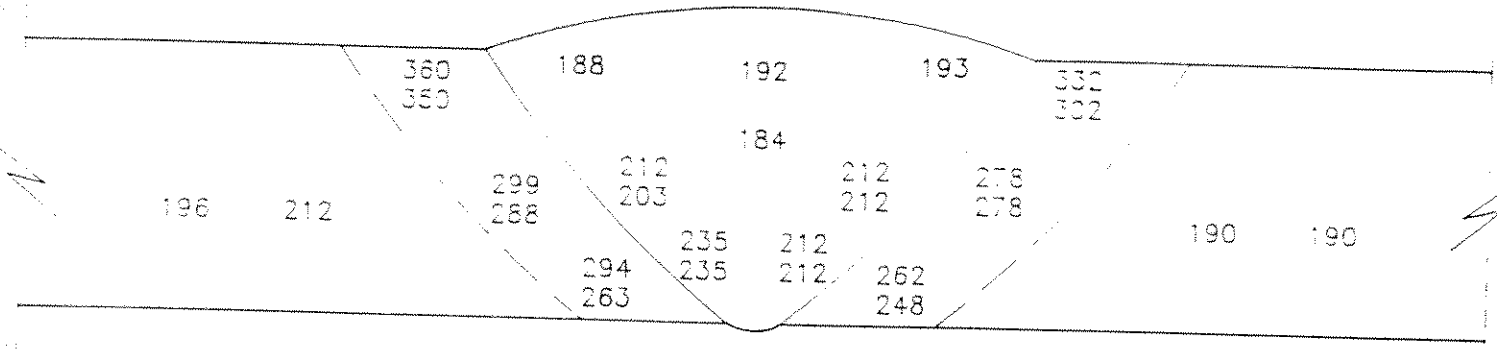
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers 10kg load hardness test on weld sample 5/8" X 8"Lg. Remake of No MTB weld on A588 plate 3G-#2

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 18, 1993

SRC Job No. 92-352

Certified By: Tim Brown Date: 7-15-93

Reviewed By: Raphael Date: 7-15-93

GLOBAL7.VIC

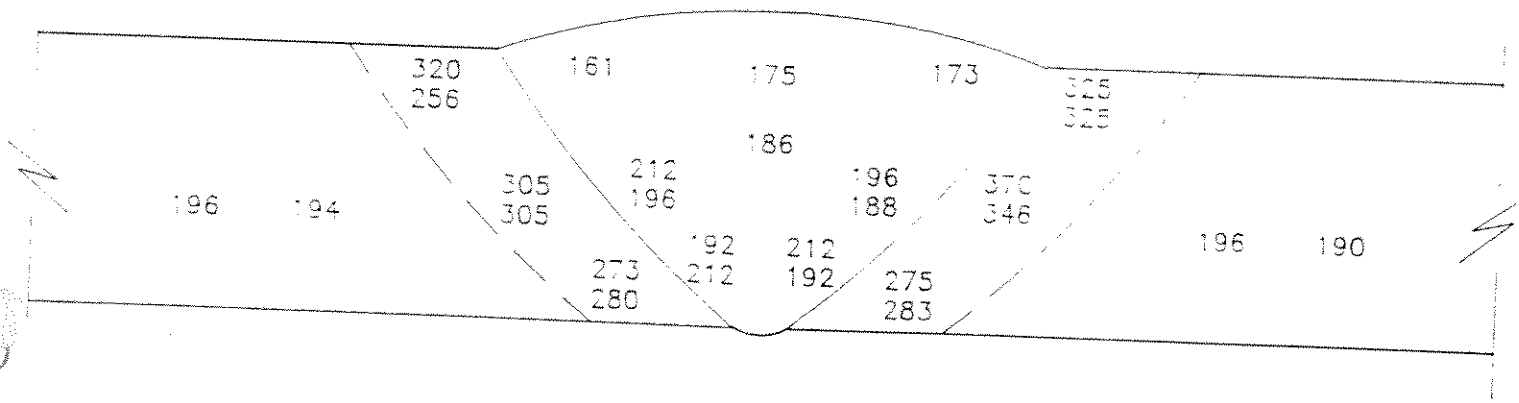
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers 10kg load hardness test on weld sample 5/8" X 8"Lg. Remake of No MTB weld on A588 plate 3G-#3

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 18, 1993

SRC Job No. 92-352

Certified By: Tim Rousseau Date: 7-15-93

Reviewed By: Reginald Landry Date: 7-15-93

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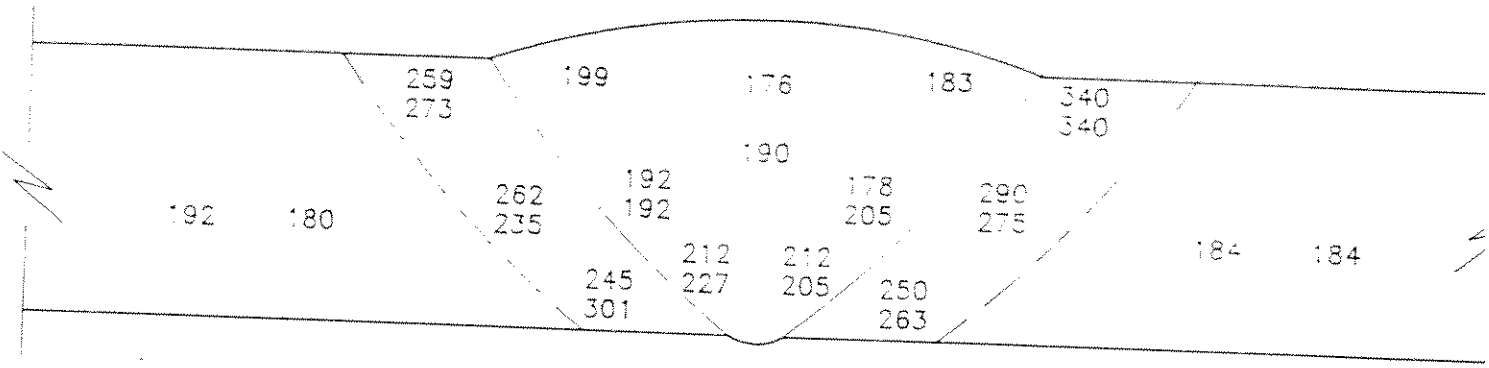
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers 10kg load hardness test on weld sample 5/8" X 8"Lg. Remake of No MTB weld on A588 plate 3G-#4

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 18, 1993

SRC Job No. 92-352

Certified By: [signature] Date: 7/5/93

Reviewed By: [signature] Date: 7-15-93

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SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch on Wet TB Groove Weld
P.O. #GD406809
1/2" A36(CE.4156) #1

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 100X Magnification.

There was no evidence of any cracking.

EQUIPMENT UTILIZED FOR TEST
Type: Metallograph
Manufacturer: Olympus
Serial No.: 502796
Last Servicing: December, 1992

SRC Job No. 92-352

Certified By: Tim Bennett Date: 9-16 93

Reviewed By: Dept 210 Date: 09-16-93

SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch on Wet TB Groove Weld
P.O. #GD406809
1/2" A36(CE.4156) #2

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 100X Magnification.

There was no evidence of any cracking.

EQUIPMENT UTILIZED FOR TEST	
Type:	Metallograph
Manufacturer:	Olympus
Serial No.:	502796
Last Servicing:	December, 1992

SRC Job No. 92-352

Certified By: Tim Rowland Date: 9-16-93

Reviewed By: Stephen A Cobb Date: 09-10-93

GLOBAL11.MAC

SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch on Wet TB Groove Weld
P.O. #GD406809
1/2" A36(CE.4156) #3

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 100X Magnification.

There was no evidence of any cracking.

EQUIPMENT UTILIZED FOR TEST	
Type:	Metallograph
Manufacturer:	Olympus
Serial No.:	502796
Last Servicing:	December, 1992

SRC Job No. 92-352

Certified By: Tom Broussard Date: 9-16-93

Reviewed By: Stephen L. Williams Date: 09-16-93

SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch on Wet TB Groove Weld
P.O. #GD406809
1/2" A36(CE.4156) #4

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 100X Magnification.

There was no evidence of any cracking.

EQUIPMENT UTILIZED FOR TEST
Type: Metallograph
Manufacturer: Olympus
Serial No.: 502796
Last Servicing: December, 1992

SRC Job No. 92-352

Certified By: Tim Brown Date: 9-16-93

Reviewed By: Joseph A. Collins Date: 09-16-93

SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch on Wet No TB Groove Weld
P.O. #GD406809
1/2" A36(CE.4156) #1

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 100X Magnification.

There was no evidence of any cracking.

EQUIPMENT UTILIZED FOR TEST
Type: Metallograph
Manufacturer: Olympus
Serial No.: 502796
Last Servicing: December, 1992

SRC Job No. 92-352

Certified By: [signature] Date: 9-16-93

Reviewed By: [signature] Date: 09-16-93

SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch on Wet No TB Groove Weld
P.O. #GD406809
1/2" A36(CE.4156) #2

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 100X Magnification.

There was no evidence of any cracking.

EQUIPMENT UTILIZED FOR TEST
Type: Metallograph
Manufacturer: Olympus
Serial No.: 502796
Last Servicing: December, 1992

SRC Job No. 92-352

Certified By: Tim Thomas Date: 9-16-93

Reviewed By: [signature] Date: 09-10-93

GLOBAL11.MAC

SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch on Wet No TB Groove Weld
P.O. #GD406809
1/2" A36(CE.4156) #3

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 100X Magnification.

There was no evidence of any cracking.

EQUIPMENT UTILIZED FOR TEST
Type: Metallograph
Manufacturer: Olympus
Serial No.: 502796
Last Servicing: December, 1992

SRC Job No. 92-352

Certified By: Tim Smith Date: 9-16-93

Reviewed By: [signature] Date: 09-10-93

SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Macro Etch on Wet No TB Groove Weld
P.O. #GD406809
1/2" A36(CE.4156) #4

Specification: In accordance with AWS D3.6

MACRO TEST RESULTS:

HAZ Examined at 100X Magnification.

There was no evidence of any cracking.

EQUIPMENT UTILIZED FOR TEST
Type: Metallograph
Manufacturer: Olympus
Serial No.: 502796
Last Servicing: December, 1992

SRC Job No. 92-352

Certified By: Tim Brown Date: 9/16/93

Reviewed By: Dwight A. Miller Date: 09-16-93

GLOBAL10.MAC

SRC ENGINEERS, INC.
P.O. BOX 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710
(318) 837-3810, 837-3819 STEPHEN R. CALLEGARI, P.E.

CERTIFICATE OF ANALYSIS

Date: 9-16-93 P.O. No. GD406809

Company: Global Divers & Contractors, Inc.

Test: AWS D3.6-93 Side Bend Tests

Test Performed on: 1/2" A36(CE.4156) TB Groove Weld

Welders Name: Darryl Phillips

SIDE BEND TEST		
SAMPLE TYPE & NUMBER		RESULTS
Side Bend	S1 (6T,4T,3 1/3T)	Failed @ 2T
Side Bend	S2 (6T,4T,3 1/3T)	Failed @ 2T
Side Bend	S3 (6T,4T,3 1/3T)	Failed @ 2T
Side Bend	S4 (6T,4T,3 1/3T)	Failed @ 2T

EQUIPMENT UTILIZED FOR TEST
Type: Guided Bend Tester
Manufacturer: CRC

Certified By: Tim Broussard Date: 9-16-93
Tim J. Broussard
SRC Engineers, Inc.

Reviewed By: Stephen R. Callegari Date: 09-16-93

GLOBAL11.MAC

SRC ENGINEERS, INC.
P.O. BOX 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710
(318) 837-3810, 837-3819 STEPHEN R. CALLEGARI, P.E.

CERTIFICATE OF ANALYSIS

Date: 9-16-93 P.O. No. GD406809

Company: Global Divers & Contractors, Inc.

Test: AWS D3.6-93 Side Bend Tests

Test Performed on: 1/2" A36(CE.4156) No TB Groove Weld

Welders Name: Darryl Phillips

SIDE BEND TEST		
SAMPLE TYPE & NUMBER		RESULTS
Side Bend	S1 (6T,4T,3 1/3T)	Failed @ 2T
Side Bend	S2 (6T,4T,3 1/3T)	Failed @ 2T
Side Bend	S3 (6T,4T,3 1/3T)	Failed @ 2T
Side Bend	S4 (6T,4T,3 1/3T)	Failed @ 2T

EQUIPMENT UTILIZED FOR TEST
Type: Guided Bend Tester
Manufacturer: CRC

Certified By: Tim J. Broussard Date: 9-16-93
Tim J. Broussard
SRC Engineers, Inc.

Reviewed By: Stephen R. Callegari Date: 09-16-93

GLOBAL11.MAC

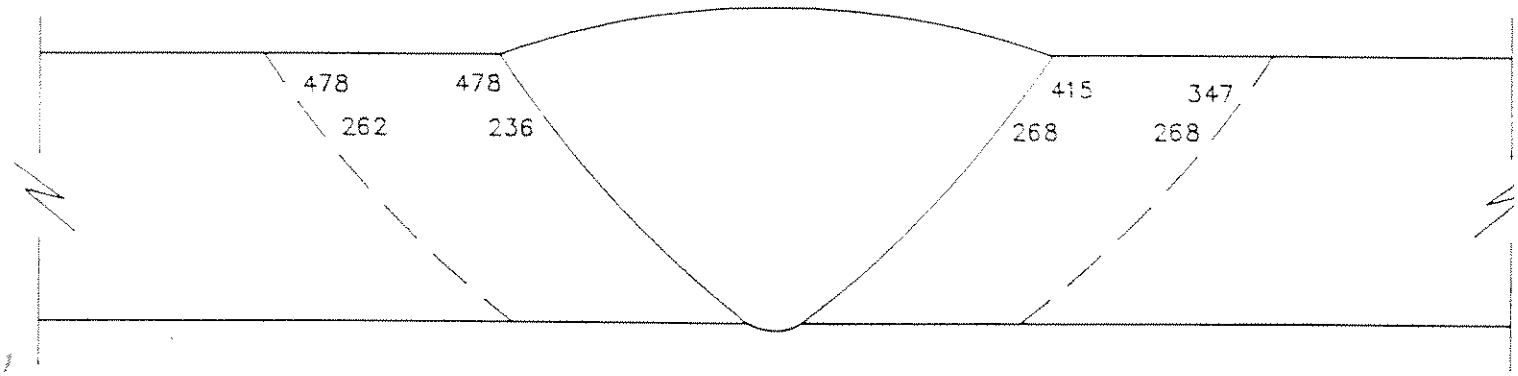
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers hardness test on Wet TB Groove Weld
1/2" A36(CE.4156) #1
P.O. #GD406809

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 18, 1993

SRC Job No. 92-352

Certified By: Tim Rossi Date: 9-17-93

GLOBAL10.VIC

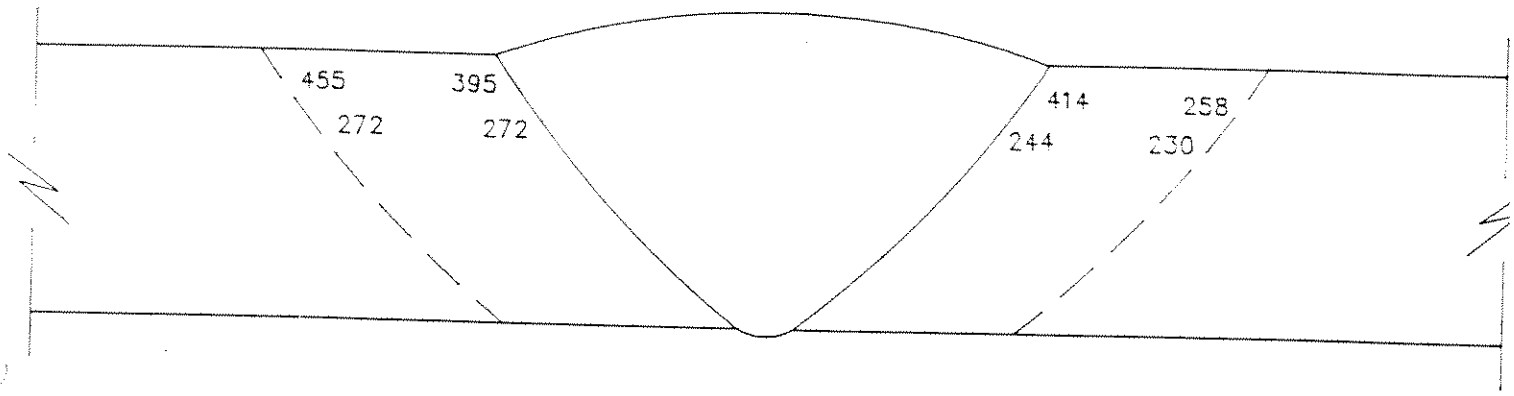
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers hardness test on Wet TB Groove Weld
1/2" A36(CE.4156) #2
P.O. #GD406809

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 18, 1993

SRC Job No. 92-352

Certified By: Tim Pierce Date: 9-17-93

GLOBAL10.VIC

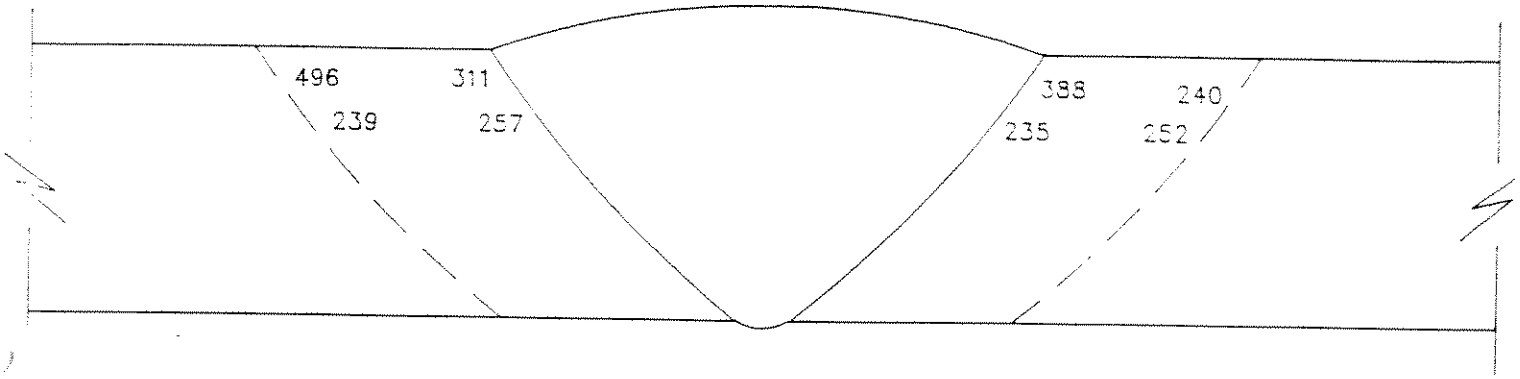
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers hardness test on Wet TB Groove Weld
1/2" A36(CE.4156) #3
P.O. #GD406809

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 18, 1993

SRC Job No. 92-352

Certified By: Tim Peterson Date: 9-17-93

GLOBAL10.VIC

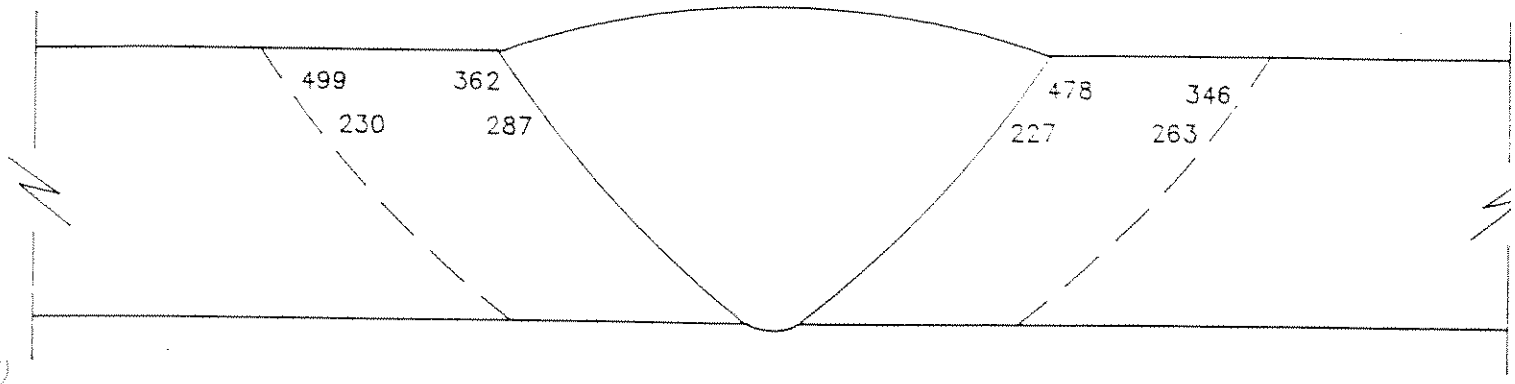
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers hardness test on Wet TB Groove Weld
1/2" A36(CE.4156) #4
P.O. #GD406809

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 18, 1993

SRC Job No. 92-352

Certified By: Tim Rousseau Date: 9-17-93

GLOBAL10.VIC

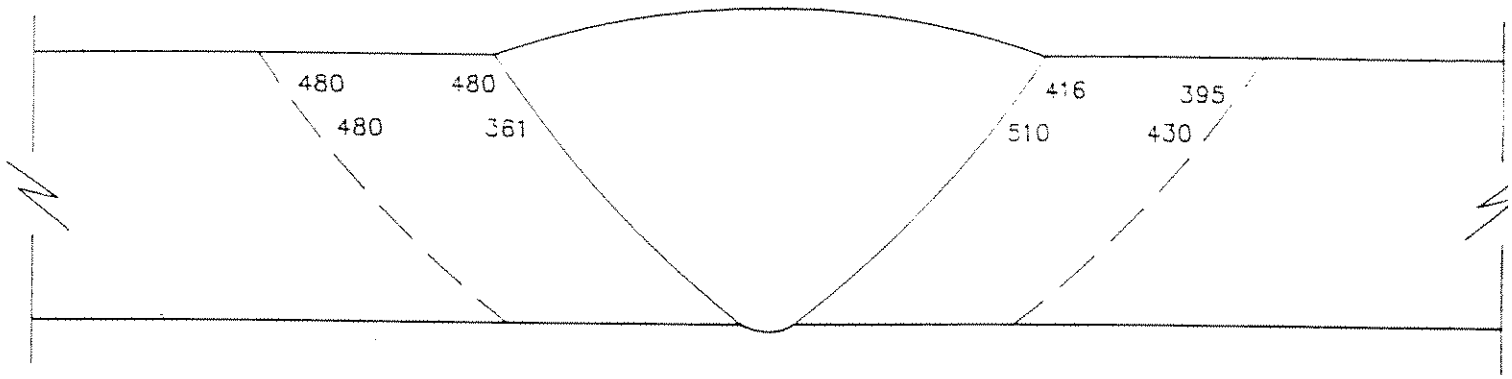
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers hardness test on Wet No TB Groove Weld
1/2" A36(CE.4156) #1
P.O. #GD406809

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 18, 1993

SRC Job No. 92-352

Certified By: Tim Powell Date: 9-17-93

GLOBAL10.VIC

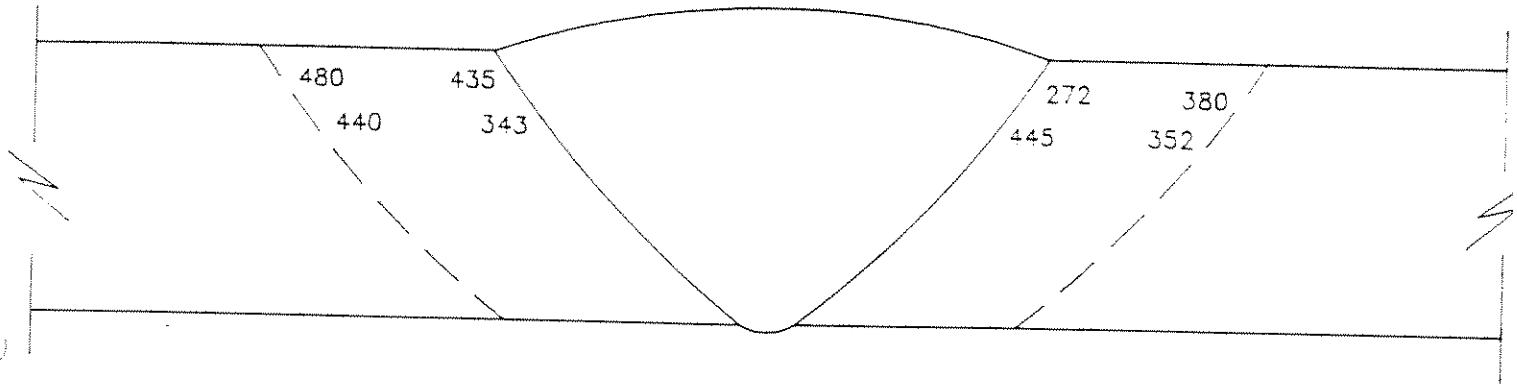
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers hardness test on Wet No TB Groove Weld
1/2" A36(CE.4156) #2
P.O. #GD406809

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 18, 1993

SRC Job No. 92-352

Certified By: Tim Green Date: 9-17-93

GLOBAL10.VIC

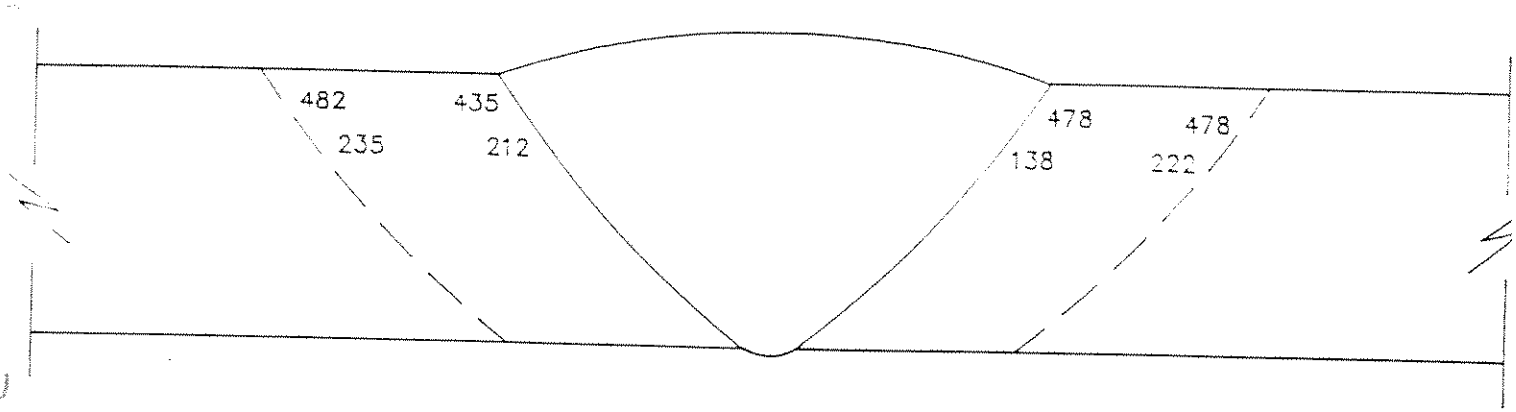
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers hardness test on Wet No TB Groove Weld
1/2" A36(CE.4156) #3
P.O. #GD406809

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 18, 1993

SRC Job No. 92-352

Certified By: Tim Bernard Date: 9-17-93

GLOBAL10.VIC

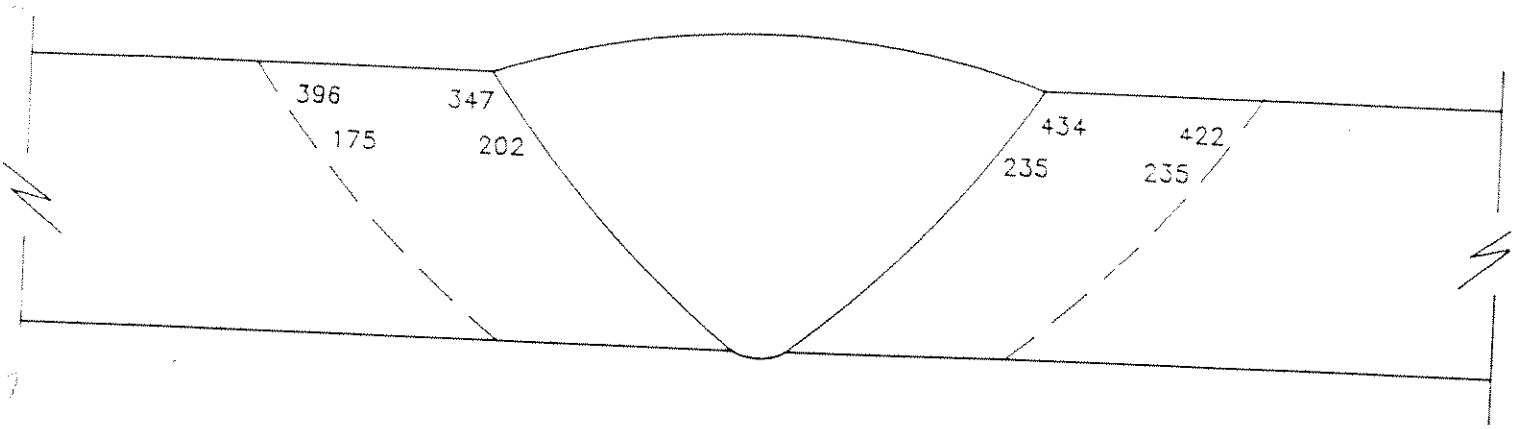
SRC ENGINEERS, INC.
837-3810, 31106 * LAFAYETTE, LA 70593-1106 * FAX (318) 837-5710

COMPANY NAME: Global Divers
New Iberia, La.

TEST PERFORMED: Vickers hardness test on Wet No TB Groove Weld
1/2" A36(CE.4156) #4
P.O. #GD406809

Specification: In accordance with AWS D3.6

HARDNESS TEST DATA: Vickers 10kg



EQUIPMENT UTILIZED FOR TEST
Type: Tukon Model LR Microhardness Tester
Manufacturer: Wilson
Serial No.: LR-997
Last Calibration: January 18, 1993

SRC Job No. 92-352

Certified By: Tim Brown Date: 9-17-93

GLOBAL10.VIC

Appendix XXII

SCIENTIFIC TESTING LABORATORIES , INC.

one 504/356-2759 2703 Weller Avenue Fax 504/358-0648
Baton Rouge, Louisiana 70805

CHARPY IMPACT TEST [Using a Vee type notch]

Specimen ID	Individual Size	Notch Location	Test Temp(°F)	Energy (FT-LBS)	Percent Shear	Mils Exp.
A1	10mm x 10mm	WELD METAL	+60	31	100	30
A2	10mm x 10mm	WELD METAL	+60	29	100	32
B1	10mm x 10mm	WELD METAL	+40	30	100	30
B2	10mm x 10mm	WELD METAL	+40	30	100	31
C1	10mm x 10mm	WELD METAL	+28	29	100	29
C2	10mm x 10mm	WELD METAL	+28	29	100	28
C3	10mm x 10mm	WELD METAL	+10	28	95	28
D1	10mm x 10mm	WELD METAL	0	25	90	24
D2	10mm x 10mm	WELD METAL	0	30	90	35
D3	10mm x 10mm	WELD METAL	0	29 1/2	90	30
E3	10mm x 10mm	WELD METAL	-10	23	90	26
F3	10mm x 10mm	WELD METAL	-10	17 1/2	80	19
G3	10mm x 10mm	WELD METAL	-10	16 1/2	70	20
E1	10mm x 10mm	WELD METAL	-20	18	60	17
[illegible]2	10mm x 10mm	WELD METAL	-20	18	60	15
[illegible]3	10mm x 10mm	WELD METAL	-25	13	30	14
F1	10mm x 10mm	WELD METAL	-30	13	30	10
F2	10mm x 10mm	WELD METAL	-30	14	30	10
A3	10mm x 10mm	WELD METAL	-35	15	10	14
G1	10mm x 10mm	WELD METAL	-40	13	20	12
G2	10mm x 10mm	WELD METAL	-40	16	20	13

Notes: T=3/4" PLATE WELDED WITH AN EX7 ELECTRODE AT -33 FT.
JOB#91-M-4346

Test No.: 15137 Welded by:
Test Date: 11/04/93 SSN:
Conducted by: STL NB ML DD Approved by: Dale Delaville
Per: ASTM E 23 DALE DELAVILLE

DALE A. DELAVILLE CERTIFICATE NO. 820063

We certify that the statements in this record are correct. The weldments were prepared, welded, and tested in accordance with the requirements of AWS D3.6

Organization: GLOBAL DIVERS
Date: November 8, 1993 By: [signature]

SCIENTIFIC TESTING LABORATORIES, INC.
2703 Weller Avenue
Baton Rouge, Louisiana 70805

CHARPY IMPACT TEST (METRIC)

Specimen ID	Individual Size	Notch Location	Test Temp (°C)	Energy (Jules)	Percent Shear	MM Exp.
A1	10mm x 10mm	WELD METAL	15.5	42.0	100	0.76
A2	10mm x 10mm	WELD METAL	15.5	39.3	100	0.81
B1	10mm x 10mm	WELD METAL	4.4	40.7	100	0.76
B2	10mm x 10mm	WELD METAL	4.4	40.7	100	0.79
C1	10mm x 10mm	WELD METAL	-2.2	39.3	100	0.74
C2	10mm x 10mm	WELD METAL	-2.2	39.3	100	0.71
C3	10mm x 10mm	WELD METAL	-12.2	38.0	95	0.71
D1	10mm x 10mm	WELD METAL	-17.8	33.9	90	0.61
D2	10mm x 10mm	WELD METAL	-17.8	40.7	90	0.89
D3	10mm x 10mm	WELD METAL	-17.8	40.0	90	0.76
E3	10mm x 10mm	WELD METAL	-23.3	31.2	90	0.66
F3	10mm x 10mm	WELD METAL	-23.3	23.7	80	0.48
G3	10mm x 10mm	WELD METAL	-23.3	22.4	70	0.51
E1	10mm x 10mm	WELD METAL	-28.9	24.4	60	0.43
E2	10mm x 10mm	WELD METAL	-28.9	24.4	60	0.38
B3	10mm x 10mm	WELD METAL	-31.7	17.6	30	0.36
F1	10mm x 10mm	WELD METAL	-34.4	17.6	30	0.25
F2	10mm x 10mm	WELD METAL	-34.4	19.0	30	0.25
A3	10mm x 10mm	WELD METAL	-37.2	20.3	10	0.36
G1	10mm x 10mm	WELD METAL	-40.0	17.6	20	0.30
G2	10mm x 10mm	WELD METAL	-40.0	21.7	20	0.33

NOTES: 3/4" PLATE WET WELDED WITH EX7 ELECTRODE AT -33 FT. JOB# 91-M-4346
V TYPE NOTCH WAS USED FOR TESTING

Test No.: 15137
Test Date: 11/04/93
Conducted by: STL NB ML DD
Per: ASTM E 23

Welded by: Darryl R. Phillips
SS#: 262-19-9555

We certify that the statements in this record are correct. The weldments were prepared, welded, and tested in accordance with the requirements of AWS D3.6.

Organization: GLOBAL DIVERS & CONTRACTORS, INC.
Date: November 8, 1993

Metric Conversion By: C.E. Grubbs