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FACILITIES AND ENVIRONMENTAL EFFECTS
SURFACE PREPARATION AND COATINGS
DESIGN/PRODUCTION INTEGRATION
HUMAN RESOURCE INNOVATION
MARINE INDUSTRY STANDARDS
WELDING
INDUSTRIAL ENGINEERING
EDUCATION AND TRAINING**

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Panel Line Developments**

**U.S. DEPARTMENT OF THE NAVY
CARDEROCK DIVISION,
NAVAL SURFACE WARFARE CENTER**

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Panel Line Developments

IIB-1

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PANEL LINE DEVELOPMENTS

by C. R. Turner, Member, San Diego, CA

ABSTRACT

This paper presents the joint efforts of a research and development project between an American shipyard and an independent engineering company that would resolve issues impacting panel production. The project objectives follow:

Develop an efficient means to fit full penetration joints from one side with plates of unequal thickness having the stiffener side up.

Develop an efficient one-side welding method for full penetration joints with plates of unequal thickness having the stiffener side up.

Develop a flow of material for locating and fitting longitudinal stiffening that would be balanced with the rest of the line.

Develop a multi-torch, multi-process longitudinal stiffener welding machine that one person can operate effectively.

Develop a method in which transverse stiffening could be fit and welded efficiently with minimal manpower using semi-automatic equipment.

The development of these areas would decrease facility costs and increase productivity by:

Allowing totally conveyed panel production;

Reducing edge preparations;

Reducing consumable requirements;

Automating high continuous linear footage areas of flat panels;

Reducing dimensional distortion;

Reducing operator complications; and

Lowering overall system cost.

All data are supported by production information, research and travel to domestic and foreign shipyards. Preliminary and ongoing laboratory efforts are in progress to confirm that this type of Submerged Arc Welding (SAW) will consistently meet the requirements of current standards for military and commercial ships.

INTRODUCTION

Having command of the most cost effective shipbuilding methods involves the maximum use of mechanization in production of the basic structural elements in an assembly line manner, i.e., process lanes. The process lane is defined as a series of fixed work stations with permanent production services for construction of ship components having similarities such as shape, size, and weight. However, the increased mechanization of limited purpose or interim components of the ship's structure is not a new approach to shipbuilding and in its simplest rationale can be termed efficient management of shipbuilding. Ryoji Nishijima is credited with having initiated the movement to efficient shipbuilding in Japan. The impact was such that in 1965-66 the total tonnage built in Japan near equaled that of the rest of the world and fabrication costs dropped over 70%. Nishijima's work began after reading a book by an American who is credited with having an equal impact on the automobile industry-Henry Ford.

Flexibility Increases Cost Effective Production

In today's non-series shipbuilding market, steel process lanes are still essential for efficient shipbuilding but must be established to maximize flexibility in mechanized production to minimize the impact of non-standardized contracts.

For example, SAW, patented in 1930 and imported to Japan after World War II, was primarily used for two side panel welding. It is now used in virtually all positions and its use has been expanded far beyond panel welding. Other processes typically used in steel process lanes as early as SAW was, remain inherently the same but their use is now much more

imaginative. As these processes are expanded in use and flexibility, so should the areas of their function.

Conventional mechanized SAW one side welding of flat panels has mostly been applied to panels having the same thickness or stiffener side up for panels of unequal thickness. For this reason panel production must still bear the burden of facility and equipment expense for turning some of the panels to make second side welds.

Additionally, panel production has typically bottlenecked at the stiffener attachment stations so that the maximum efficiency cannot be realized from the panel welding area. Longitudinal stiffening cannot be handled in the same manner as transverse stiffening and though different sequences exist for their attachment, both require extensive time and labor in welding. Methods for alleviating this problem range from multi-million dollar robotics to labor intensive work stations. Though automation and process lane construction methodology have decreased hours here, the most efficient mechanization must include:

Ease of setup;

Versatility; and

Minimal operator complication;

and not at only one end or the other of a process lane.

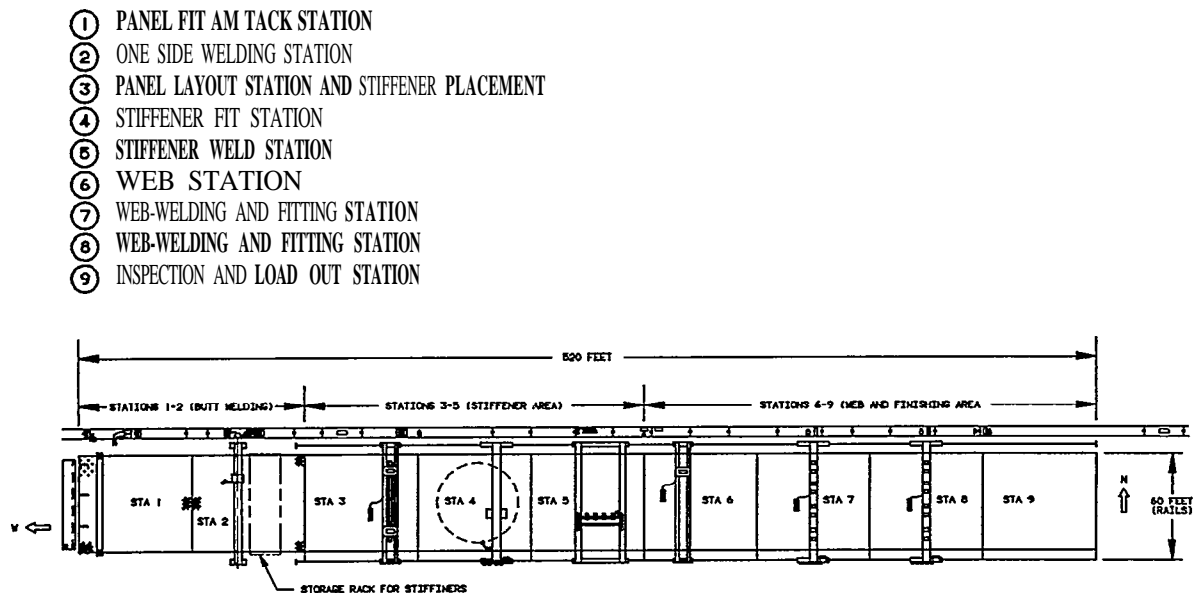
To ensure maximum efficiency from automation, a balanced workload is needed for a smooth material flow. A balanced workload can be effectively accomplished by separating the tasks into the sequences in which they are to occur in the direction of construction. It is here that automation is used to keep certain areas from becoming too labor-intensive. Hence the objective to reduce manhours can only be accomplished by the reduction of the workforce in a given area for a given budget.

In so doing, the production process will be enhanced and, depending on the work content per station, a completed structural component will leave the process lane at intervals equal to the allotted time for the assigned tasks regardless of total hours.

PRELIMINARY WORK BEFORE INSTALLATION

Requirements and Material Specification

Ship types were studied for comparison to ensure the broadest production range that could be handled cost effectively in the allotted time per station. Light combatants as well as commercial product carriers were to be processed by the same equipment specified as a result of the study. Additionally, a study of a structural system utilizing only longitudinal members for stiffeners as opposed to the conventional approach which employs



NASSCO PANEL LINE

Fig. 1 Stationized panel production

both transverse and longitudinal stiffeners was considered. Though equipment costs and lack of immediate need prevented the requirements from being in the specifications, provisions were made for upgrades should the need arise. Table I gives the range of material types and sizes that the equipment would be required to process.

Table I
Requirements and Material Specifications

Flat Plate

Plate thickness range:	6mm-38mm (1/4" - 1-1/2")
Maximum individual plate length:	15.85 meters (52' -0")
Typical individual plate width:	3.04 meters (10' -0")
Individual plate weight density range:	.42 -2153 kg/sq mt (10-60 Lbs/Sq.Ft.)
Plate joining process:	Oscillating DC/AC SAW
Joint design:	Beveled to suit thickness
Maximum completed plate length:	15.85 meters (52' -0")
Max. completed flat plate weight:	53,712 kg (144,000 Lbs.)

Stiffeners

Stiffener length maximum:	15.85 meters (52' -0")
Flange width range:	2.54-35.56 cm (1-14")
Web (height):	10.16-76.20 cm (4" -30")
Stiffener weight:	3.67kg/lin. met (300 Lbs/Linear Ft.)

Spacing between stiffener centerlines:	50.80-76.20 cm (20 1/2" -30")
Joining process:	Two sided simultaneous multi-process arc welding
Joint design:	Horizontal fillet
No. of stiffeners welded simultaneously:	4

Cross Beam Stiffeners

Maximum length:	15.85 meters (52' -0")
Flange width range:	35.56-76.20 cm (14" -30")
Web width range (height):	15.24-243.84 cm (6" -96")
Maximum weight:	4662.5 kg (12,500 Lbs.)
Cross beam spacing:	30.48-152.40 cm (12" -60")
Joining process:	Manual flux cored Gas Metal Arc Welding (GMAW)

Completed Panel

Panel weight density range:	.84-8.4 kg/sq.mt. (20 - 200 Lbs/Sq.Ft.)
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Site Location

Site location presented a unique problem in that a 182.88 m x 19.82 m (600' x 65') envelope not already in use, with accessible crane service, that could be supplied material from the rest of the yard, seemed unavailable.

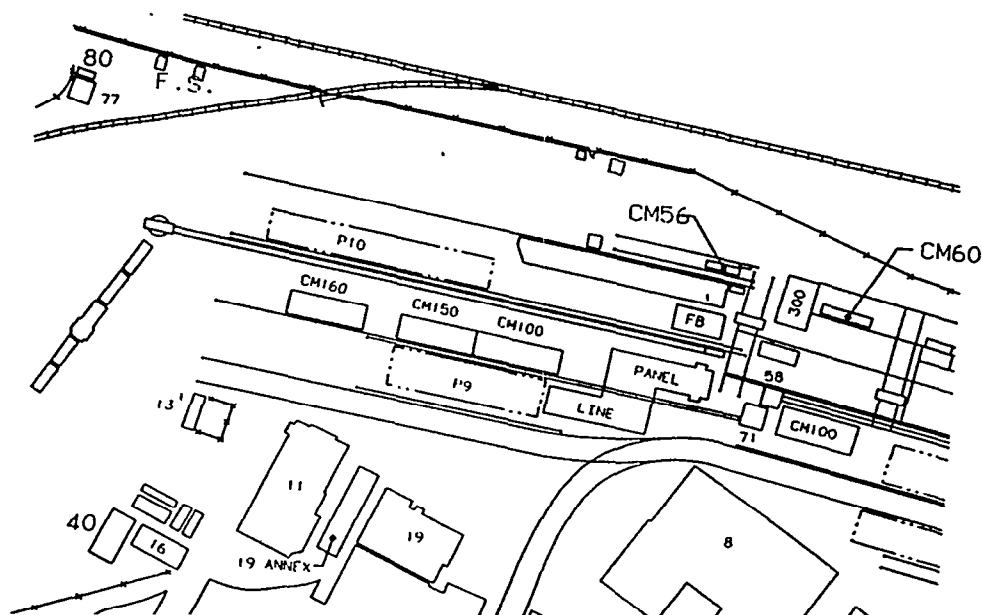


Fig. 2 Proposed site -- existing

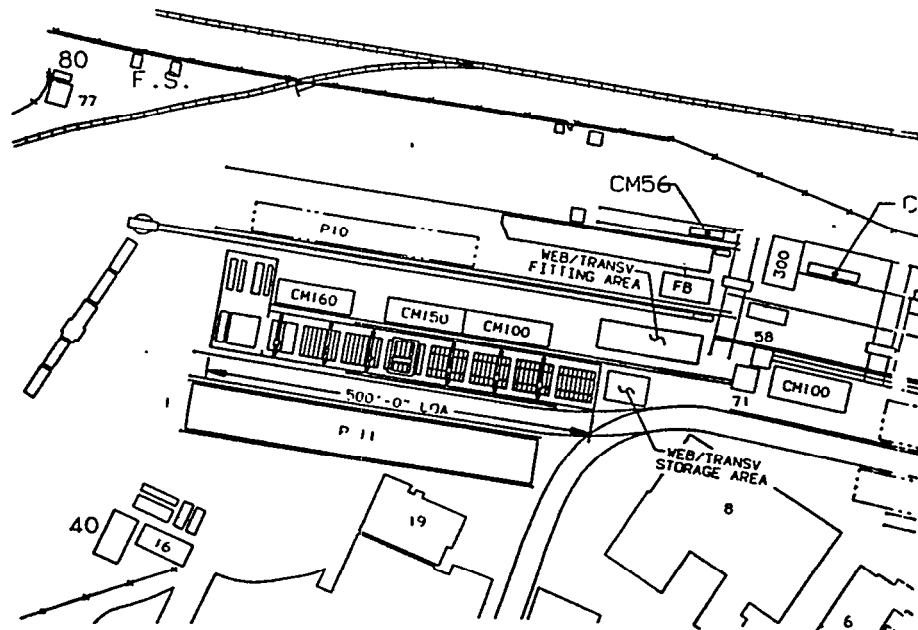


Fig. 3 Proposed site - facilities requirements

A site was chosen by eliminating alternatives that presented complicated obstacles inherent in the areas such as:

- . The need to reroute the Direct Numerical Control (DNC) for burning machines;
- . Retracking for crane service; and
- . Problems with transportation of material.

Plate Delivery

Creative thinking was required in regard to a number of other issues from a list that seemed to grow. A significant issue was how to get the plates to be paneled from the adjacent storage area to the fitting station. A transfer car, that could be loaded by an existing magnetic crane and then translated to the feed side of the panel line and convey the plate into the fitting station, resolved the problem. Additionally, the transfer car would double as a platen extension when required.

Selection of a One Side Welding (OSW) System

To compensate for the declining number of skilled welders, while continuing to reduce hours by minimizing material handling equipment, setup, and facility requirements, has been the forte of one side welding for many years. However, experience has shown that one side welding has introduced other variables that quite often counteract the original objectives, such as:

- . Joint preparations require more exactness;
- . Thinner plates not requiring a beveled preparation on two-side welds now require them;
- . Consumable quantities are increased;
- . Equipment operating parameter ranges become narrow; and
- . A highly skilled (trained by trial and error) operator is needed more so now than ever.

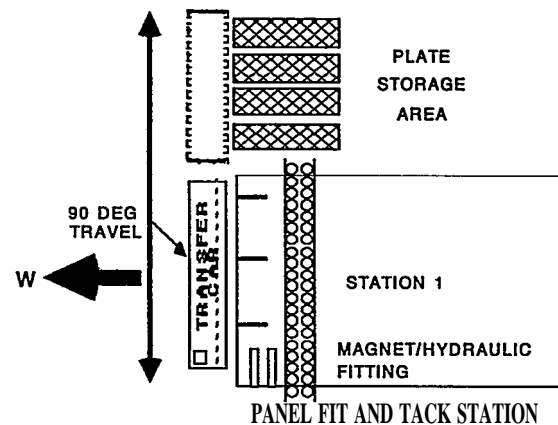


Fig. 4 Transfer car at head of panel fit and tack station

The alternatives to the aforementioned were to struggle through with an inefficient system or continue two-side welds. Support for successful OSW abounds in

foreign and domestic yards, such that acceptance of a system that is not completely cost effective could not be viewed as an alternative. Hence, the goal would be to avoid areas even marginally efficient and focus on areas that further development would enhance.

The development of NASSCO's OSW system had the ultra success of some systems, the complete failure of others and, possibly worse, the burden of those not operating efficiently, before being selected. Should cost studies be done, they would reveal that the cost of weld repair, increased joint preparation, greater care in fit-up, increased consumables, and the replacement of damaged copper bars, would exceed the cost of two-side welding.

Avoiding this would be the prime directive in developing the OSW station. The operating characteristics most sought after were determined strongly by the operation of known OSW systems as well as areas that would be enhanced by further development. The desired characteristics are:

- . One pass, OSW with conventional tandem electrodes;
- . Reduction in edge preparations;
- . Low volume of welding consumables;
- . Tolerance of joint variations;
- . Welding of pre-fitted, pre-tacked panels;
- . Reduced operator complications;
- . Minimal distortion; and
- . Consistently meeting visual Destructive Testing (DT) and Nondestructive Testing (NDT) requirements.

Typically, one pass OSW requires a multi-wire (2-3) and/or iron powder additive for most plate thicknesses. Inasmuch as mixing iron powder with conventional flux is somewhat of a black art, and obtaining some of the foreign premixed iron powder fluxes in the U.S. is difficult, many yards are using multi-wire, multi-pass, one side welding processes.

The initial decision for the OSW was the selection of either a direct current, alternating current, or series arc OSW system. After a 6-month evaluation of OSW systems, no one system, at least in its entirety, was selected. The decision was made to incorporate similarities in the three which will be referred to throughout the body of this paper as oscillating DC-AC osw.

For process approval it was first necessary to develop a full scale working prototype of the intended

system with the required features. Secondly, proof was needed that the system could consistently produce welds visually and radiographically acceptable. After these tests were confirmed, further tests were performed on high yield steels that would be sensitive to higher heat inputs from OSW.

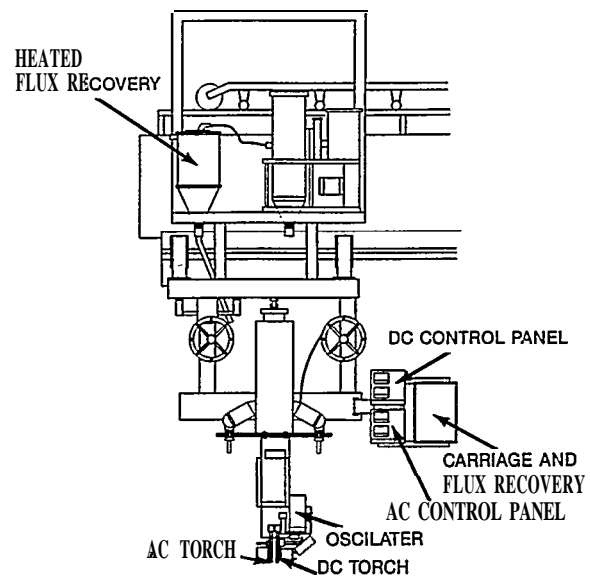


Fig. 5 Welding carriage

Procedural qualification was undertaken on the prototype manufactured in Indiana. To prove the concept, a series of tests were done simulating production conditions for plate thicknesses and joint designs. The earliest possible acceptance of these tests and the need for further training and parameter development were sufficient justification for setting up another test fixture in the shipyard. Though crude in appearance, the experience gained from these welds proved to be de cornerstone for the cause and effect operational knowledge as well as developing a level of confidence in operating the equipment.

All aspects of the acceptance criteria of both military (MIL-STD-248C) and commercial (ASME Section IX) standards were under constant scrutiny. The visual being the first level of inspection, followed by Radiographic, Ultrasonic, and mechanical tests.

The visual appearance of the welds provided information for parameter adjustments for corrections Of:

- . Reinforcement
- . Bead shape
- . Distortion.

Radiographic and ultrasonic tests were performed on all visually acceptable test welds and evaluated by a Level III Nondestructive Test Inspector. After acceptance of nondestructive testing, coupons were prepared for the various mechanical tests for ductility, tensile, and toughness. Figure 6 is the actual procedural qualification test report for the Oscillating DC-AC SAW on DH 36 material to the American Bureau of Shipping Standards.

ENGINEERING SERVICES AND INSPECTION
1165 WALNUT AVENUE, SUITE #4
CHULA VISTA, CALIFORNIA 92011
(619) 575-5012

MECHANICAL TEST REPORT
(WELDING PROCEDURE QUALIFICATION)

DATE: 28 MAY 91 EST JOB #: 1511-21 CUSTOMER: NASCO P.O.#: MC 178593-S
WELDER: WELD PROCEDURE #: NF-742.2 WELD PROCESS: SAW-PA POSITION: FLAT
BASE MATERIAL SPECIFICATION: MIL-E-21628 (1.750" A533 PLATE)
FILLER MATERIAL SPECIFICATION: MIL-C-21765/4 (LINCOLN E70/761) SIZE: 1/8" & 5/32"

TEST #	LENGTH INCHES	WIDTH INCHES	DIA-WEIDER INCHES	SQUARE AREA INCHES	TENSILE LOAD POUNDS	TENSILE STRENGTH PSI	YIELD LOAD POUNDS	YIELD STRENGTH PSI	ELONG-ACTION PERCENT	FAIL STATE	RE-SULTS
TR-1	10.06"	0.770"	N/A	0.7746	90,150	116,383	N/A	N/A	N/A	N/A	N/A
TR-2	10.995"	0.769"	N/A	0.7652	89,400	116,832	N/A	N/A	N/A	N/A	N/A
AN-1	N/A	N/A	0.507"	0.2019	23,900	118,375	21,700	107,479	22.07%	*	SAT

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MECHANICAL TEST REPORT
(WELDING PROCEDURE QUALIFICATION)

DATE: 14 SEPTEMBER 90 EST JOB #: 1497-20
CUSTOMER: NASCO P.O.#: MC 168102-S
WELDER: UNKNOWN WELDER ID:
WELD PROCEDURE #: XS-65-1 WELD PROCESS: GMAW POSITION: 1G
BASE MATERIAL SPECIFICATION: MIL-E-16216 (1.750" HY-80 PLATE)
FILLER MATERIAL SPECIFICATION: MIL-C-21765/2 (MIL-100S-1) SIZE: 5/32"

TEST #	LENGTH INCHES	WIDTH INCHES	DIA-WEIDER INCHES	SQUARE AREA INCHES	TENSILE LOAD POUNDS	TENSILE STRENGTH PSI	YIELD LOAD POUNDS	YIELD STRENGTH PSI	ELONG-ACTION PERCENT	FAIL STATE	RE-SULTS
TR-1	10.06"	0.770"	N/A	0.7746	90,150	116,383	N/A	N/A	N/A	N/A	N/A
TR-2	10.995"	0.769"	N/A	0.7652	89,400	116,832	N/A	N/A	N/A	N/A	N/A
AN-1	N/A	N/A	0.507"	0.2019	23,900	118,375	21,700	107,479	22.07%	*	SAT

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MECHANICAL TEST REPORT
(WELDING PROCEDURE QUALIFICATION)

DATE: 14 SEPTEMBER 90 EST JOB #: 1496-20
CUSTOMER: NASCO P.O.#: MC 168102-S
WELDER: UNKNOWN WELDER ID:
WELD PROCEDURE #: XS-75-1 WELD PROCESS: GMAW POSITION: 1G
BASE MATERIAL SPECIFICATION: MIL-E-16216 (1.750" HY-80 PLATE)
FILLER MATERIAL SPECIFICATION: MIL-C-21765/2 (MIL-100S-1) SIZE: 5/32"

TEST #	LENGTH INCHES	WIDTH INCHES	DIA-WEIDER INCHES	SQUARE AREA INCHES	TENSILE LOAD POUNDS	TENSILE STRENGTH PSI	YIELD LOAD POUNDS	YIELD STRENGTH PSI	ELONG-ACTION PERCENT	FAIL STATE	RE-SULTS
TR-1	10.990"	0.757"	N/A	0.7494	87,300	116,493	N/A	N/A	N/A	N/A	N/A
TR-2	10.994"	0.760"	N/A	0.7554	88,600	117,282	N/A	N/A	N/A	N/A	N/A
AN-1	N/A	N/A	0.495"	0.1548	22,500	116,530	21,000	107,800	18.75%	*	SAT

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MECHANICAL TEST REPORT
(WELDING PROCEDURE QUALIFICATION)

DATE: 14 SEPTEMBER 90 EST JOB #: 1501-20
CUSTOMER: NASCO P.O.#: MC 168310-S
WELDER: UNKNOWN WELDER ID:
WELD PROCEDURE #: XS-82-1 WELD PROCESS: GMAW POSITION: 1G
BASE MATERIAL SPECIFICATION: MIL-E-16216 (1.750" HY-80 PLATE)
FILLER MATERIAL SPECIFICATION: MIL-C-21765/2 (MIL-100S-1) SIZE: 5/32"

TEST #	LENGTH INCHES	WIDTH INCHES	DIA-WEIDER INCHES	SQUARE AREA INCHES	TENSILE LOAD POUNDS	TENSILE STRENGTH PSI	YIELD LOAD POUNDS	YIELD STRENGTH PSI	ELONG-ACTION PERCENT	FAIL STATE	RE-SULTS
TR-1	10.997"	0.725"	N/A	0.7228	86,500	119,673	N/A	N/A	N/A	N/A	N/A
TR-2	10.994"	0.715"	N/A	0.7107	87,100	122,555	N/A	N/A	N/A	N/A	N/A
AN-1	N/A	N/A	0.501"	0.1973	22,500	114,155	19,200	97,412	22.65%	*	SAT

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MECHANICAL TEST REPORT
(WELDING PROCEDURE QUALIFICATION)

DATE: 14 SEPTEMBER 90 EST JOB #: 1511-20
CUSTOMER: NASCO P.O.#: MC 168311-S
WELDER: UNKNOWN WELDER ID:
WELD PROCEDURE #: XS-92-1 WELD PROCESS: GMAW POSITION: 1G
BASE MATERIAL SPECIFICATION: MIL-E-16216 (1.750" HY-80 PLATE)
FILLER MATERIAL SPECIFICATION: MIL-C-21765/2 (MIL-100S-1) SIZE: 5/32"

TEST #	LENGTH INCHES	WIDTH INCHES	DIA-WEIDER INCHES	SQUARE AREA INCHES	TENSILE LOAD POUNDS	TENSILE STRENGTH PSI	YIELD LOAD POUNDS	YIELD STRENGTH PSI	ELONG-ACTION PERCENT	FAIL STATE	RE-SULTS
TR-1	10.991"	0.715"	N/A	0.7086	85,400	120,519	N/A	N/A	N/A	N/A	N/A
TR-2	10.997"	0.720"	N/A	0.7178	85,800	119,532	N/A	N/A	N/A	N/A	N/A
AN-1	N/A	N/A	0.371"	0.1081	13,100	121,181	10,600	98,055	16.31%	*	SAT

GUIDED-BEND TESTS

TYPE	MINOR RADIUS	SPECIMEN WIDTH	MATERIAL THICKNESS	RESULTS
SIDE 1	.8125"	0.375"	.750"	ACCEPTABLE
SIDE 2	.8125"	0.375"	.750"	ACCEPTABLE

CHARPY IMPACT TESTS

SPECIMEN NUMBER	IMPACT STRENGTH REQUIRED	IMPACT STRENGTH ACHIEVED	TEST TEMPERATURE	RESULTS
#1	35.00 FT LBS	56.00 FT LBS	-60°F	SAT
#2	35.00 FT LBS	57.00 FT LBS	-60°F	SAT
#3	35.00 FT LBS	55.00 FT LBS	-60°F	SAT

AVERAGE IMPACT STRENGTH: 56.0 FT LBS

THE ABOVE TESTS WERE PERFORMED IN ACCORDANCE WITH ASTM A-370, ASTM E-23, ASTM E-190, MIL-STD-2480, ANSI/ASME B4.0-85, ANSI/ASME D1.1-90 & ASME BOILER & PRESSURE VESSEL CODE SECTION IX.

LAB TECHNICIAN: JIM HAN ASNT LEVEL III RM-907/ANS CH 142052041

Fig. 7 High Heat Input Procedures

Fig. 6 Procedural Qualification Report

Process Sensitive High Yield Steels

A common problem with all OSW processes for military applications is the heat input limitation of 2165 KJ/m (55KJ/in.) for 13 mm (1/2 inch) and thicker and 1772/m (45KJ/m) for less than 13 mm (1/2 inch) plates.

Anticipating the Oscillating DC-AC SAW would be no different in terms of exceeding this limitation, high heat input procedures were developed for 2558 KJ/m (65 KJ/in.), 2952 KJ/m (75 KJ/in.), 3346 KJ/m (85 KJ/in.), 3739 KJ/m (95 KJ/in.), and submitted to NAVSEA.

The results of these tests and knowledge of similar results from other shipyards causes the writer to conclude that the aforementioned heat input restrictions are no longer valid and should be modified.

CHARACTERISTICS OF OSCILLATING DC-AC ONE SIDE WELDING

One Pass One Side Welding

The characteristics of Oscillating DC-AC welding permits one side, one pass welding of plates with thicknesses up to 20 mm (3/4") with:

- . Two small diameter wires;
- . Lower heat inputs;
- . Conventional SAW wire arrangement and current;
- . Minimal edge preparations;
- . Narrow root openings; and
- . No iron powder additives for fill.

The absence of additives for joint fill, critical wire straightening requirements, extensive joint preparations, large root openings, or special welding currents does much in reducing the complications in one side welding. At the very least, the list of variables for an unforgiving process has been shortened. Production use is further enhanced with Oscillating DC-AC SAW by:

- . Greater tolerance to production joint variations;
- . Increased deposition rates;
- . A welded back-bead look; and
- . Reduced user complication.

Reductions in Edge Preparations

The joint designs for one side welding generally are double "V" preparations from 45° to 60° included angles for plate thickness greater than 6 mm (1/4 inch). Root openings vary, but range from 0 to .64 cm (1/4 inch). Two-side welding, however, is done with 16 mm (5/8 inch) square edge preparation and 20 mm (3/4 inch) is not uncommon in some foreign yards. Oscillating DC-AC was selected because there would be minimal change in the edge preparation requirement. Yard standard practice was not beveling mild steel plates 16 mm (5/8 inch) and below and double beveling plates greater than 16 mm (5/8 inch) for all two-side welds. This was altered only slightly when changing to the one side welding operation. Plates with $t \leq 15$ mm (9/16 inch) remained square edge preparation and plates $t \geq 16$ mm (5/8 inch) would require a 45° included with 6 mm (1/4 inch) land.

These two joint designs did much in keeping the changes for edge preparation requirements to a minimum when the new instructions were given to engineering.

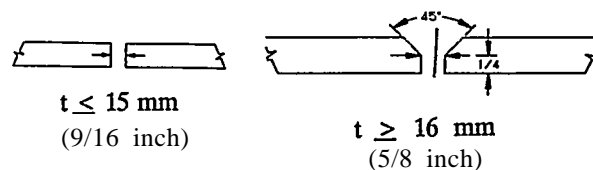


Fig. 8 Edge Preparation Requirements

Reductions in Consumable Usage

The controlling factor in welding cost is reducing the weight of weld metal required. Most of the other associated costs are related to this factor, including:

- . Less time required to deposit;
- . Fewer machines;
- . Fewer replacement parts;
- . Lower maintenance costs;
- . Less energy; and
- . Reduced consumables.

The most straightforward manner by which the volume of deposited weld metal can be reduced is to reduce the cross-sectional area of the weld area by changing the geometry of the joint design

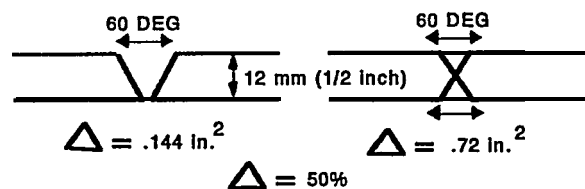


Fig. 9 Effect of cross sectional area on
fill requirements

However, the joint design for OSW is critical in all of the Flux Copper Backing (FCB) systems. Adjusting any part, i.e., root opening, including angle or land, to reduce the weld metal required would mean sacrificing the effectiveness of the system of which the joint design is a part.

Taking the extreme conditions of 16 mm (5/8 inch) plate with a 60° included angle for OSW and 16 mm (5/8 inch) plate with a square edge preparation for two side welding (1.6 mm [1/16 inch] root opening for comparison only), Figure 10 shows that there is an approximate 50% increase in weld metal over the two-side weld.

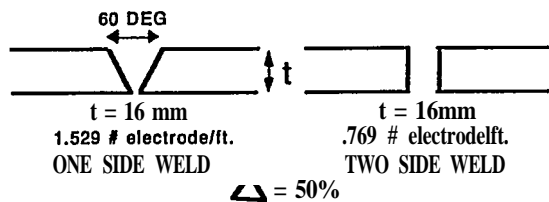


Fig. 10 Weld metal requirement for OSW compared to two-side welding

Hence, for an OSW system to be cost effective, consideration must be given to the increased volume of weld metal required. It should also be noted that plates 12 mm (1/2 inch) and below, requiring bevels for other OSW systems, were prone to heat induced distortion which increased fitting time and reduced the quality of the bevel.

The Oscillating DC-AC was chosen over other OSW systems because there was a significant reduction in the volume of weld metal as a result of joint requirement (approximately 50% less weld metal required). Should series arc rather than direct SAW be used in the comparison, the percentage would be higher because of the increased root opening.

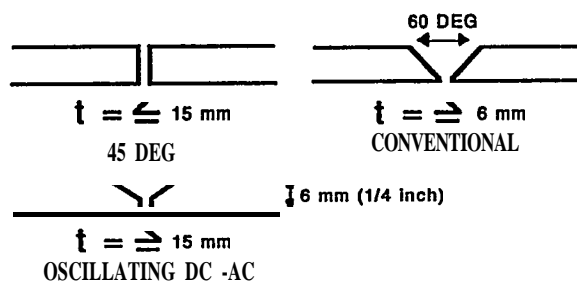


Fig 11. OSW Comparison

Joint Fit-UD Variations

Even with a number of process controls, fit-up variations are at best kept minimal. Recognized as a nuisance with any other welding operation, even minor variations in joint fit-up spell failure for OSW. If weld repair was not enough, add to this the repair or replacement cost of the copper bar with the task of separating the copper bar from the plate, and there will be strong arguments for two-side welds.

Many variables affect the amount of fit-up variation an OSW system can tolerate such as:

- . Root Opening;
- . Included Angle; and
- . Plate Fairness.

The Oscillating DC-AC OSW has proven to be more tolerable to production fit-ups. However, the tighter the controls for fit-up deviations, as with any OSW system, the better the results.

Excessively long deviations in root openings require a seal bead. If care is taken in making the seal weld, repair of the second side is generally not necessary or noticeable.

With operator practice, travel speed adjustments prove equally beneficial. This method requires that the operator inspect the seam prior to welding for deviations greater than the allowable and mark their length. If the deviation is noticeably greater, a reduction in the travel speed will prevent the burn through; if narrower an increase will permit greater penetration. An exact increase or decrease has not been possible to determine, but even slight changes have proven to be effective.

Uniform Shrinkage Information

Reduction in the volume of weld metal required, deposited with small diameter electrodes and definitive parameter information makes weld shrinkage information very predictable because of the repeating variables. To produce neat panels this information is vital. Once installed and fully operational, the excess material plan, will be incorporated in Direct Numerical Control burning information to account for transverse weld shrinkage from the OSW station.

SPECIAL FEATURES OF THE LINE

Fitting Plates of Unequal Thickness with the Stiffener Side Up

Plates to be paneled are fed onto the line from the burning machines adjacent to the panel line by a plate transfer car. The transfer car leaves the plate staging area and is positioned at the head of the panel line. The plate is then conveyed over the variable height magnetic fitting bed. The panel fitting station is a special feature of the line which enables the automatic positioning of plates having unequal thickness with the stiffener side up.

The fitting bed includes the following features. It:

- . Ensures total conveyerized panel flow;
- . Eliminates interruptions due to panel turnover;
- . Positions with variable height magnetic beds with hydraulic lifting rams; and
- . Accommodates panel seams having unequal thicknesses with stiffener side up.

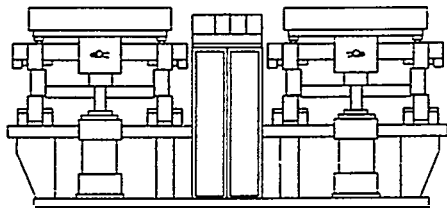


Fig. 12 Panel fitting station

Pre-Fitted (Tacked) Full Size Panels

Pre-fitting the panels prior to OSW was selected in lieu of fitting and welding at the same station. This allows a better balance of work per station. It also eliminates the interruption of panels that have to be faired and tacked because of handling or heat-induced distortion that the OSW holddown would not remove. Especially disruptive was that this work usually disturbed the flux bed so that it had to be redone or increase the risk of damaging the copper bar. It was found that the latter's disruption had no equal in causing lost time. However, pre-fitted panels would require either tie plates or tack welding, approximately 40 tie plates per seam. The additional operation of removing the tie plates, grinding the tacks, and projectiles from the abrasive wheel caused excessive rework and production interferences. To eliminate this, procedures were developed using the Oscillating DC-AC process to weld through tacks. To safeguard against the negative effects of the tacks on weld quality, measures that proved effective within the welding parameter ranges for the procedure were:

- . Reduced electrical stick-out on DC wire;
- . Lower voltage;
- . Smaller diameter lead wire;
- . The use of GMAW for the tacks; and
- . Drag angle on DC torch.

In addition, greater care was also directed toward the tacking operation which included:

- . Location plan;
- . Quality;
- . Size;
- . Number; and
- . Process used.

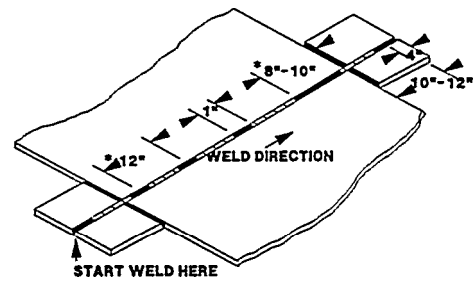


Fig. 13 Guidelines for tack location

Shipfitters that were selected to prepare panels for OSW were trained with FCAW as well as the requirements of the fitting operation. This measure should be ranked in equal standing with the aforementioned.

Weld Plates of Unequal Thickness With Stiffener Side up

The ability to weld plates of unequal thickness with the stiffener side up is a patented feature of the OSW station. The floating cradle for the FCB will uniformly adjust to back side surfaces having either a square or chamfered transition in the joining plates. This operation includes a variable pressure lift system for FCB contact to plate and weld pressure.

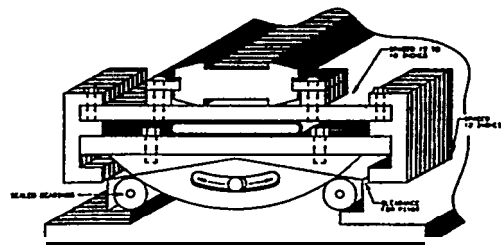


Fig. 14 Floating cradle for FCB welds with plates of unequal thickness

Longitudinal Attachment

Materials delivery problems continued with regard to how longitudinals were supplied to the welded plate panels after seam welding. Loading adjacent to the line was ruled out in favor of kitting the longitudinals at the head of the line in special racks (Figure 15) that would hold the shift's requirement for stiffeners.

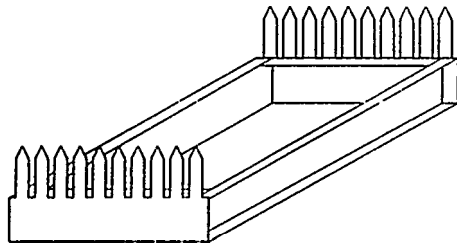


Fig. 15 Stiffener Rack

Location. The overhead crane rails were extended to enhance the panel line's independence from the yard's whirley cranes. The rack of stiffeners could be lifted from the storage area and positioned just after the welding station on a special foundation that allowed the panels to be conveyed under it into the layout station. (Figure 16) Once laid out, the stiffener would be set in place with a 10-ton magnetic crane. Roughly positioned, the panel would then be conveyed into the stiffener fitting area.

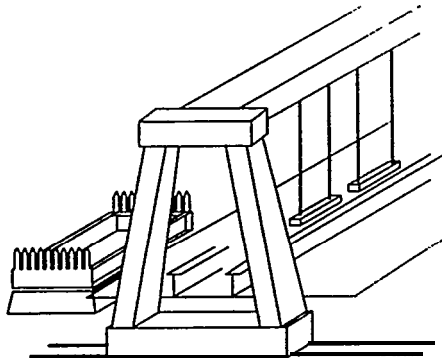


Fig. 16 Stiffener placement on panel

Stiffener Fitting

The problem of automatic fitting longitudinals that were not parallel with the panels, and the ability to fit stiffeners that were skewed on the panel, was addressed by developing a track mounted multi-hydraulic ram that could be skewed to match the stiffener.

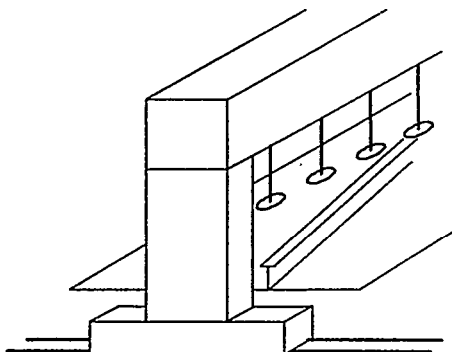


Fig. 17 Stiffener fitter

Welding

Variable stiffener spacing is common with non-series ship production and presents a problem with equipment setup for multi-torch automatic welding equipment. To minimize time lost due to equipment setup, the automatic stiffener welder was designed with floating heads that would adjust to virtually any stiffener spacing automatically with up to three feet of skew. This feature would allow different spacings from one panel to the next. It would also allow different spacing on the same panel for simultaneous welding of four longitudinals or joining smaller panels with fewer stiffeners. Thus, a greater versatility was realized while keeping the tasks repetitive without undue dependence on skilled labor for non-welding related tasks.

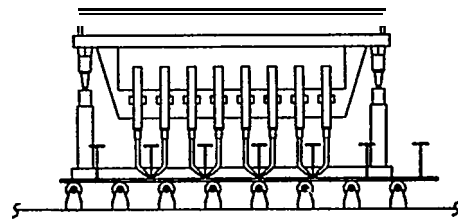


Fig. 18 Multiple head stiffener welder

SPECIAL OPERATIONAL ENHANCEMENTS

On-Site Repair of Copper Bar

Even when seemingly all precautions were taken to prevent burn through to the copper bar, it became more practical to minimize burn through rather than trying to eliminate it. Allowing that an occasional burn through is unavoidable, repair of the copper bar is a must to ensure the back bead's uniform shape. The cost of replacement bars, even on a small test bed, soon became an issue. Removing the copper bar was so time consuming that an on-site repair procedure was necessary. Though welding copper is not a feat in itself, the procedure included:

- . A semi-automatic process;
- . Minimizing distortion;
- . Avoiding excessive build-up; and
- . Ease of reshaping bar.

Though a procedure was developed to use Tungsten Inert Gas (TIG), it required too long even for minor repairs. The semi-automatic process provided favorable results as long as all oxidation was removed, and a specific preheat was reached before welding.

Welding Parameter Sheets

The need for clear and well defined welding parameters is important for any welding process; however, for OSW it was proven to be the determining factor for a successful one-side system. To ensure that repeatability would be possible, Weld Engineering first researched all seams that would be welded using the one-side system and made test welds for proper parameter ranges. These parameter sheets (Figure 19) were developed for all welds which required a change in any essential variables as a result of:

- . Plate thickness;
- . Edge preparation;
- . Unequal thickness; or
- . Chamfered plate.

Any weld with a significant change in voltage, amperage or travel speed was assigned a parameter number and given to the operator with all necessary equipment settings.

GROWTH OR EXPANSION ITEMS

Special Purpose Flux FCB Welding

During several trips to foreign shipyards, it was apparent that a great deal of research had been devoted to developing products especially formulated for FCB welding. It was noted that these products, particularly the fluxes, had better performance characteristics than those of some of the domestic fluxes available for the same purpose. The availability of these fluxes in the U.S. is marginal (some of which are not offered) and usually have long lead times with heavy import duties. It is the intent of NASSCO Weld Engineering to propose a panel project that would support a joint venture with an American welding consumable manufacturer to develop a special line of FCB-related products. The performance characteristics would be targeted to:

- . Increase tolerance to joint variations;
- . Offer greater support to the weld pool for high amperage welds;
- . Protect the copper bar from burn through; and
- . Enhance FCB welding with portable equipment in other areas.

PARAMETERS													
PASS NO.	DC-AC	EXPOSE	TENSILE	ARC	ARC	TRAVEL	TENSILE	TENSILE	TENSILE	TENSILE	TENSILE	TENSILE	TENSILE

Fig. 19 Welding parameter sheets

All products would be tested to normal shipyard building practices with similar equipment. The results would be documented as to the ability to consistently meet Radiographic Testing (RT) and mechanical requirements of regulatory bodies.

CONCLUSION

After months of feasibility studies, specifications for prototypes and revisions incorporated into the production equipment, operational enhancements are ongoing; more so in the area of OSW. To date the OSW has proved to be more cost effective in the plate thickness range of 6mm (1/4 inch) to 20 mm (3/4 inch). There has been minimal repair to underside welds and the NDT reject rate has been exceptionally low.

At this writing, further consideration is being given to the cost effectiveness of OSW in relation to plate thickness. Successive panels requiring multiple pass for fill at the OSW station interrupts material flow, which results in frequent manpower adjustments at the adjoining station. Though the welds are of equal quality, the additional time per seam (approximately 45 minutes for 15.8 m [52 feet]) is a major concern for four seam panels. A four seam panel usually requiring three

hours of arc time could require nine hours. Methods to correct this are:

1. Heavy plate to be welded on second and third Shift.
2. Additional electrodes for fill.
3. A separate OSW station.
4. Portable SAW for fill after OSW pass.
5. Eliminate OSW for panels one inch thick and greater.

The impact will vary from contract to contract but at this writing, items one and four above are proving to be effective.

ACKNOWLEDGMENT

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