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PREPARED UNDER CONTRACT NO. N00024-72-C-0244
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 OTHER

DOCUMENT NO. D312-80089-1 MODEL PHM

TITLE FUSION WELDING OF 17-4PH CORROSION-RESISTANT STEEL
FOR PHM HYDROFOIL STRUCTURES

HYDROFOIL ADVANCED DEVELOPMENT PROG. NSRDC

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1 SCOPE

- a. **This specification establishes requirements for fusion welding of 17-4PH foil and strut structures for the PHM Hydrofoil Craft,**
- b. This specification requires approved welding procedures, and certified welders and welding operators.
- c. This specification meets or exceeds all relevant mandatory requirements pertaining to welding contained in NAVSHIPS 0900-000-1000, Fabrication, Welding, and Inspection of Ship Hulls.
- d. Fabrication and inspection requirements for subjects not directly related to welding are covered by documentation referenced on the engineering drawings.

2 CLASSIFICATION

Not Applicable,

3 **REFERENCES**

Except where a specific issue is indicated, the current issue of the following references shall be considered a part of this specification to the extent indicated herein.

- a. D312-80103-1, Heat Treatment of 17-4PH Foil and Strut Structures
- b. **MIL-STD-105, Sampling Procedures and Tables for Inspection by Attributes**
- c. D312-80126-1, Welding **Procedures and Performance Qualification for Corrosion Resistant Steel Hydrofoil Structures**
- d. MIL-STD-271, Nondestructive Testing Requirements for Metals
- e. NAVSHIPS 0900-003-8000, Surface Inspection Acceptance Standards for Metals
- f. **NAVSHIPS 0900-003-9000, Radiographic Standards for Production and Repair Welds**
- g. **NAVSHIPS 0900-006-3010, Ultrasonic Inspection Procedure and Acceptance Standards for Hull Structure Production and Repair Welds**
- h. **AWS A2.0, Standard Welding Symbols**
- i. **AWS A3.0, Terms and Definitions**

4 REQUIREMENTS

4.1 MATERIALS

4.1.1 FILLER METAL

4.1.1.1 SPECIFICATIONS

Unless otherwise specified on the drawing, filler metal shall be 17-4PH corrosion-resistant steel and shall conform to:

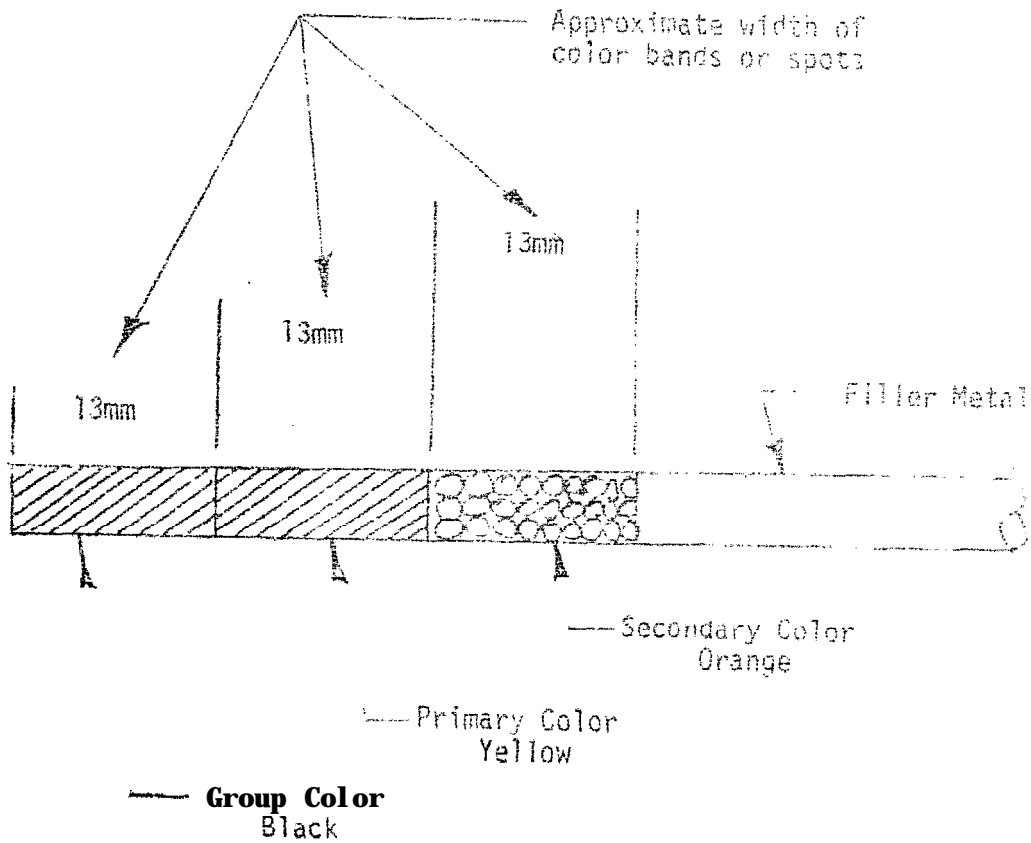
- a. BMS 7-150 Type III for bare wire.
- b. AMS 5827 for covered electrodes,

4.1.1.2 LOCATION AND COLOR CODING OF BARE FILLER METAL

Location of and responsibility for color coding bare filler metal for fusion welding are as follows:

- a. Identification of cut lengths of bare filler metal with a suitable lacquer or numbered flag tag is the responsibility of the using department.
- b. Apply the proper color code or numbered flag tag to bundled standard lengths, or cut lengths as follows:
 - (1) To one end or to both ends of 914mm standard lengths.
 - (2) To one end of each length cut from standard 914mm lengths.
 - (3) To one end of each length cut from spools or coils.

- c. **Typical** color code location requirements for bare filler metal are shown in **Figure 1** below:



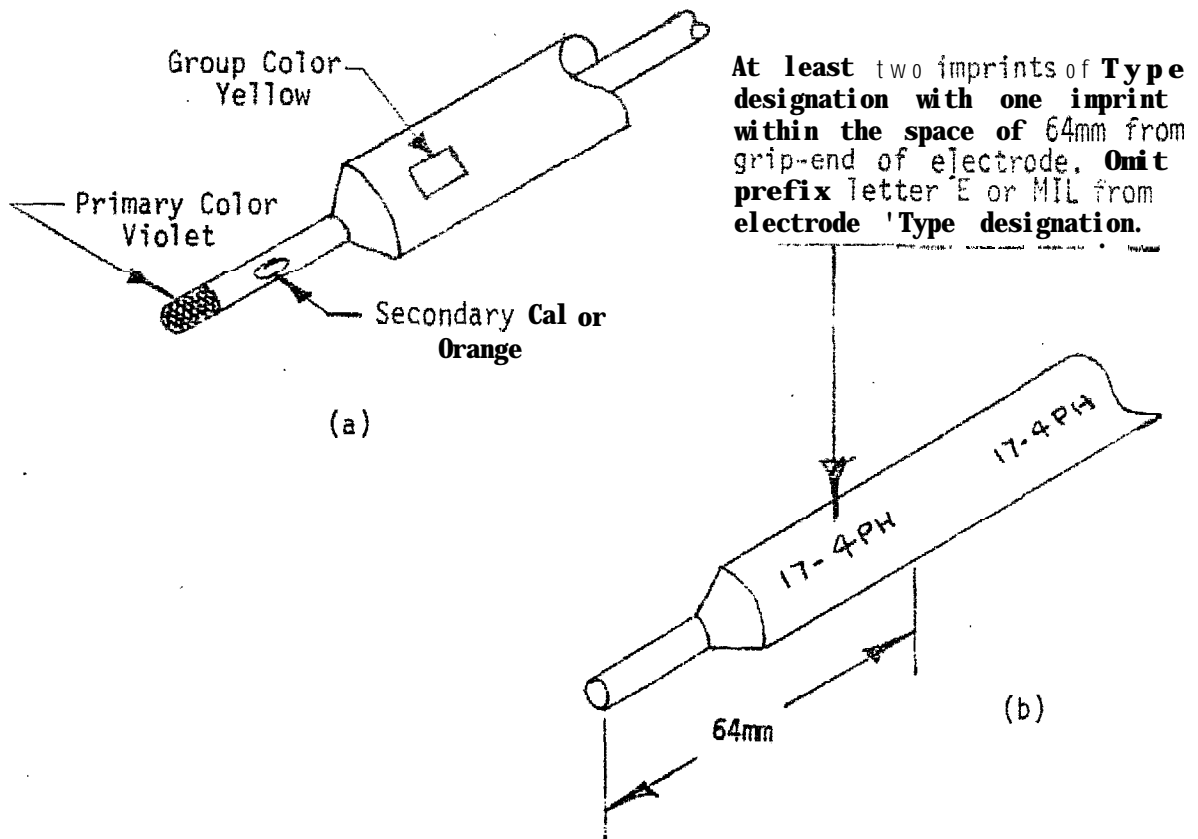
TYPICAL IDENTIFICATION OF BARE FILLER METAL

FIGURE 1

- d. Identification of bare filler metal, by applying the acceptable color code, **numbered** flag **tag** or decal to spools or coils in use on welding equipment, is the responsibility of the using department.

4.1.1.3 IDENTIFICATION OF COVERED ELECTRODES

- a. The systems of classification, location of color code, imprinting, lettering and numbering for covered arc-welding electrodes far welding described herein are those of NEMA, Identification Standards No. EW2-1959, and of AWS filler metal specifications.
- b. Covered arc-welding electrodes are identified either by color coding as set forth in Figure 2 (a), or by imprinting as set forth in Figure 2 (b).



LOCATION OF COLOR MARKING AND IMPRINTING OF COVERED ELECTRODES

FIGURE 2

4.1.1.4 STORAGE AND HANDLING OF BARE FILLER METAL

Bare filler metal in spools, coils, bundles, strips or sheets and rods in 914mm lengths or in cut lengths shall be protected from dust, shop soil and moisture at all times and shall be stored in covered containers out of direct contact with cement floors.

4.1.1.5 STORAGE OF COVERED ELECTRODES

- a. Store electrodes procured in hermetically sealed containers in a dry place and in a manner to prevent damage to the container and possibly breaking the seal.
- b. Store electrodes procured in containers not hermetically sealed in a dry place off concrete floors and in a manner to prevent damage to such containers and contents.
- c. Upon opening containers of electrodes the following shall apply:
 - (1) If all the electrodes taken from undamaged hermetically sealed containers are to be used for production within four hours, they need not be baked prior to welding. However, if hermetically sealed containers have been damaged or opened and the time limit for use exceeds four hours, bake the entire quantity and store in accordance with item (4) below.
 - (2) When non-hermetically sealed containers are opened, no more than the quantity of electrodes that can be used within one week shall be baked and stored in accordance with item (4) below.
 - (3) The remaining electrodes in non-hermetically sealed containers shall be recovered, securely taped closed, stored in accordance with item b. above and when taken again from store, shall be baked prior to use in accordance with item (4) below.


(4) Baking of 17-4PH covered electrodes shall be in accordance with the following schedule:


- (a) Hold in oven at $115 \pm 15C$ for fifteen minutes.
- (b) Raise oven temperature to $316 \pm 6C$ and hold for two hours at temperature.
- (c) Oven cool to $66 \pm 15C$.
- (d) Maintain at $66 \pm 15C$ storage temperature until use.
- (e) Electrodes exposed to ambient temperature for more than four hours shall be rebaked in accordance with the above.

4.1.2 SHIELDING GAS

Shielding gas shall be as specified in Table 1.

TABLE 1

Gases	Description	Specification
Argon	Gaseous, 99.99% min. purity by volume Liquid, 99.99% min. purity by volume Approximate Dew Point: Gaseous, $-59C$ Liquid, $-64C$ or lower	MIL-A-18455 except that purity and dew point shall meet specified
Argon Oxygen	99% Argon - 1% Oxygen 99% Argon - 2% Oxygen 	Acceptable Source: (1) Linde Division of Union Carbide (2) Liquid Air, Inc. (3) Air Reduction Co.
Helium	Gaseous, 99.99% min. purity by volume Liquid, 99.996% min. purity by volume Approximate Dew Point: Gaseous, $-61C$ Liquid, $-69C$ or lower	Federal Specification BB-H-001168 Grade A
Helium Argon	75% Helium - 25% Argon	Acceptable Source: (1) Linde Division of Union Carbide (2) Liquid Air, inc. (3) Air Reduction Co:

 Nominal composition of cylinders, Supplier control of variation in oxygen content acceptable if obtained from the listed acceptable sources,

4.1.3 TUNGSTEN ELECTRODES

Tungsten electrodes for GTA welding shall be per AWS A5.12, EW Th-2; 2% Thoriated and also identified (red) per AWS-ASTM color code,

4.1.4 ANTI-SPATTER COMPOUNDS

The following anti-spatter compounds may be used at shop option:

- a. Protect-O-Metal No. 2; G. W. Smith & Sons, Dayton, Ohio.
- b. York #106 Compound; York Manufacturing Company, Chicago, Illinois.

4.2 FACTORY AREAS

- a. Ventilation must be adequate to protect the welder from the welding fumes.
- b. Work areas arc shielding must be adequate to protect other workers from arc flash,
- c. Areas of assembly shall be kept clean and dry.
- d. Screens shall be used as necessary during gas shielded welding to prevent deflection of the shielding gas.

4.3 WELDING EQUIPMENT

Welding equipment shall be so designed and manufactured and be in such condition as to enable qualified welders and welding operators to follow approved welding procedures and attain the results prescribed in 4.5.

4.4 PROCESSING

4.4.1 PREPARATION OF BASE METAL

- a. Surfaces and edges to be welded shall be free from burrs, tears, laminations, cracks, notches, and other defects which would adversely affect the quality or strength of the weld. Surface finish shall not

exceed 12.7 micrometers as determined from visual standards,

- b. Detail part edges which have been thermally cut shall have a minimum of 7mm of material removed from all cut faces, The 7mm dimension shall be measured from the nearest point of the cut face to the finished dimension.
- c. Detail parts shall be cleaned of dirt, oil, or other contaminants by vapor or solvent degreasing followed by chemical cleaning or wire brushing,

4.4.2 JOINT FIT-UP

- a. Manufacturing shall establish all fit-up limits necessary to insure the reproducibility of welds that satisfy the requirements of 4.5 except that:
 - (1) The maximum root opening shall not exceed the limits specified on the drawing;
 - (2) The maximum mismatch shall not exceed $1/10t$ or 1.0mm whichever is greater,
- b. Surfacing welds may be deposited on the edges of detail parts to obtain the necessary fit-up, Surfacing shall not exceed 5mm or $1/2T$ whichever is less on each joint edge.

4.4.3 PREWELD CLEANING

Weld joints and adjacent areas shall be cleaned prior to welding by means of solvent cleaning with clean shop toweling and subsequent brushing with stainless steel wire brushes. Where necessary to remove moisture, the parts may be preheated to 65C maximum prior to brushing.

4.4.4 APPLICATION OF ANTI-SPATTER COMPOUNDS

Anti-spatter compound per 4.1.4 shall be applied to surfaces adjacent to a weld by brushing. Care shall be exercised to avoid direct application of this compound on surfaces to be welded,

4.4.5 PREHEATING AND INTERPASS TEMPERATURE

- a. Preheating up to 185C may be applied at shop option.
- b. Interpass temperature shall not exceed 185C.
- c. Preheat may be applied from any heat source which does not deposit soot or other contaminant on the weld joint,
- d. Interpass temperature shall be measured by radiation thermometers or surface pyrometer.

4.4.6 UNDERBEAD SHIELDING .

The root side of all welds to be made from one side only shall be protected by argon shielding gas per 4.1.2 or backing bars. When an argon purge is used, the purging shall be continued until the shielding gas has less than 2% oxygen as measured at the outlet,

4.4.7 TACK WELDING

- a. Tack welds shall be made with GTAW only and with 17-4PH filler metal.
- b. Tack welds shall be 2 to 5mm in diameter. Tack weld length shall not exceed 1T.
- c. Tack welds shall be visually inspected prior to incorporation into the weld. Cracked tacks and those of evident poor workmanship shall be removed.

4.4.8 WELDING

- a. Welding may be accomplished using any of the following processes or combination of processes:

- (1) Shielded Metal Arc Welding (SMAW)
 - (2) Gas Metal Arc Welding (GMAW)
 - (3) Gas Tungsten Arc Welding (GTAW)
- b. All production welding shall be performed by welders or welding operators certified in accordance with D312-80126-1.
 - c. Interpretation of fusion welding symbols shall be in accordance with AWS A2.0 except that all dimensions shall be specified in millimeters.
 - d. Welding may be performed on 17-4PH material in Condition A, Condition H-1150 or Condition H-1150M.
 - e. Manufacturing shall establish welding procedures per D312-80126-1 to ensure the reproducibility of welds that satisfy the requirements of 4.5. Approval of welding procedures is required prior to welding production hardware,
 - f. For all double groove welds requiring complete joint penetration, sufficient material shall be removed from the back side of the root pass to insure that clean sound metal is exposed for 100% of the effective length of the weld prior to welding from the second side.
 - g. Scale, spatter, slag, or other foreign matter shall be removed from welds prior to submission for weld inspection,

4.4.9 STRESS RELIEF OF WELDED ASSEMBLIES

- a. Stress relief is required prior to cold straightening.
- b. Other stress relief may be performed as a shop option,
- c. When used, stress relief shall be accomplished as follows:
 - (1) Charge part into furnace at $260 \pm 25C$.
 - (2) Raise the temperature at a rate not exceeding 90C per hour to $620 \pm 10C$.

- (3) Hld at $620 \pm 10C$ for four (4) hours.
- (4) Cool in furnace to $475 \pm 25C$, remove from furnace and cool in still air.

4.5 WELD CHARACTERISTICS

4.5.1 SIZE OF WELD

4.5.1.1 GROOVE WELDS

Unless otherwise specified on the drawing, complete joint penetration is required for 100 percent of the effective length of weld for all groove welds,

4.5.1.2 FILLET WELDS

The minimum fillet weld size (S) shall be as specified on the drawing.

4.5.2 REINFORCEMENT

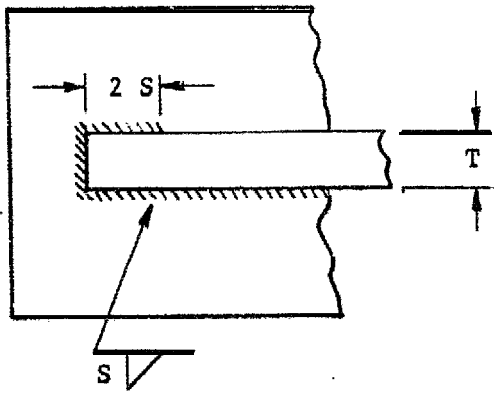
The maximum height of face or root reinforcement for groove welds shall not exceed $1/4t$ or 3.0mm, whichever is less.

4.5.3 CONCAVITY/CONVEXITY

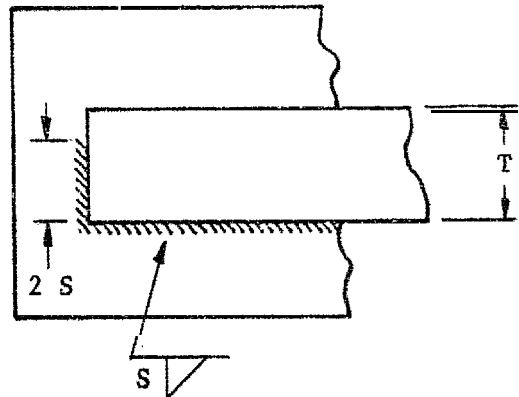
- a. The concavity of fillet welds shall not exceed $1/10S$ or 1.0mm, whichever is less.
- b. The convexity of fillet welds shall not exceed $1/5S$ or 1.5mm, whichever is less,

4.5.4 **FILLET WELD TERMINATIONS**

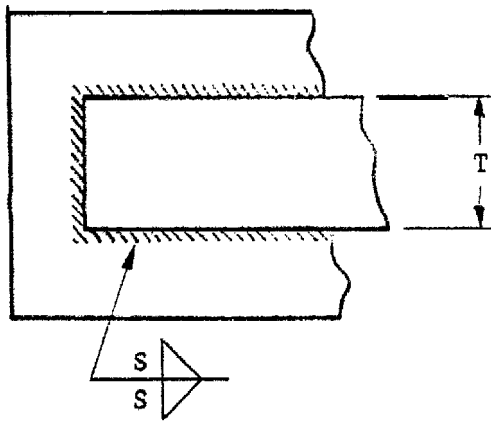
Fillet welds shall be continued full size around all accessible corners at the ends of a joint for a minimum length equal to twice the required weld size (2S). See Figure 2.



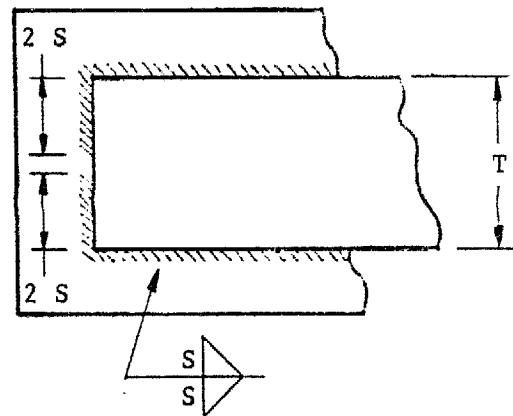
(A) T less than $2 S$



(B) T equal to or greater than $2 S$



(C) T equal to or less than $4 S$



(D) T greater than $4 S$

FILLET WELD TERMINATIONS

FIGURE 2

4.5.5 CRACKS

There shall be no cracks in the weld or in the base metal.

4.5.6 FUSION

Complete fusion is required for all welds,

4.5.7 POROSITY/INCLUSIONS

4.5.7.1 SURFACE

Acceptance criteria shall be per NAVSHIPS 0900-003-8000, Class II.

4.5.7.2 INTERNAL

Acceptance criteria shall be per NAVSHIPS 0900-003-9000, Class II if radiographically inspected, or NAVSHIPS 0900-006-3019 if ultrasonically inspected.

4.5.8 OVERLAPS

There shall be no overlaps.

4.5.9 UNDERFILL

Underfill shall not exceed $1/10t$ or 1.0mm, whichever is less, except no underfill is permitted on welds requiring grinding to achieve hydrodynamic contour.

4.5.10 CRATERS

- a. For all groove and seam welds, the depth of a crater cavity shall not extend beyond $1/10T$ or 1.0mm, whichever is less.

- b. For fillet welds, the depth of a crater shall not extend beyond $1/10t$ or 1.0mm, whichever is less.

4.5.11 UNDERCUT

- a. Sharp, notch-like undercut is not acceptable.
- b. Rounded undercut is acceptable provided the depth does not exceed $1/10t$ or 1.0mm, whichever is less.

4.5.12 CONCAVE ROOT SURFACE

Concave root surface shall not exceed $1/10t$ or 1.0mm, whichever is less.

4.5.13 ARC STRIKE

Inadvertent arc strikes shall be ground smooth and visually inspected for cracks,

4.6 IN-PROCESS CORRECTION

- a. Undersized welds, excessive face or root reinforcement, concave or convex welds, surface porosity and inclusions, overlap, underfill, craters, undercut, concave root surface, and arc strike which does not extend into the base metal beyond a depth of $1/10t$ or 1.0mm, whichever is less, may be corrected without Material Review action provided that the weldment has not gone through a subsequent operation; e.g., heat treatment, surface finishing.
- b. In-process correction of other defects not specified in 4.6.a above is prohibited and requires Material Review action.

5 **QUALITY ASSURANCE**

5 . 1 **GENERAL**

The applicable Quality organization shall ensure compliance with all requirements of this specification.

5.2 **APPROVALS**

5.2.1 **WELDING PROCEDURES**

Welding procedures shall be approved in accordance with D312-80126-1 prior to any production welding.

5.2.2 **CHANGES REQUIRING RE-APPROVAL**

The following changes in production welding at variance with an approved procedure shall require establishment and approval of a new welding procedure:

- (1) A change in process or combination of processes.
- (2) A change in filler metal composition,
- (3) An increase in bare filler metal diameter of more than 0.4mm.
- (4) An increase in covered electrode size by more than 0.75mm in diameter for horizontal, vertical, or overhead welding or 1.5mm in diameter for flat position welding.
- (5) A change from a single gas or any other single gas or to a mixture of gases or a change in the specified nominal percentage composition of gas mixture, or a decrease of 10% or more in the rate of flow of shielding gas or mixture.
- (6) A change in position in which welding is to be done,
- (7) In the case of vertical welding, a change from the progression specified for any pass from upward to downward or vice versa.
- (8) A change in type of welding current (ac or dc), polarity, or mode of metal transfer across the arc, or a change of more than plus or minus 20% in the welding current range.

- (9) A change in base metal thickness to a thickness outside the limits for which the procedure was qualified.

5.3 EQUIPMENT CONTROL

- a. The responsible Quality organization shall survey the calibration and accuracy of welding equipment at least once every six months.
- b. Equipment shall be certified accordingly.
- c. An equipment survey log shall be maintained.

5.4 MATERIAL CONTROL

- a. The responsible Quality organization shall ensure compliance with the requirements of 4.7.
- b. Ensure that base metal to be welded is identified and in an appropriate heat treat condition in accordance with 4.4.8.d.

5.5 WELDER AND WELDING OPERATOR CERTIFICATION

Each welder or welding operator shall be certified in accordance with D312-80126-1 prior to his performance of any production welding.

5.6 QUALITY CONFORMANCE INSPECTION

5.6.1 GENERAL

The responsible Quality organization shall provide all documentation and perform all inspections and tests necessary to ensure that the requirements of 4.4, 4.5 and 4.6 are satisfied.

5.6.2 JOINT FIT-UP

Ensure that fit-up limits in accordance with the drawing are established, documented in the welding procedure, and adhered to in the welding of production hardware.

5.6.3 WELDING PROCEDURES

Ensure that welding procedures in accordance with D312-80126-1 are established, documented and adhered to in the welding of production hardware.

5.6.4 IN-PROCESS CORRECTION

Ensure that in-process correction is performed in accordance with Section 4.6.

5.6.5 WELD CONFORMANCE

5.6.5.1 GENERAL

- a. All welds shall be inspected to ensure that requirements of 4.5 have been satisfied.
- b. Welds shall be inspected after finishing to final contour and prior to any subsequent heat treatment.
- c. Evidence of complete joint penetration shall be:
 - (1) the presence of a visible root reinforcement; or
 - (2) the absence of any visible trace of the original root or joint preparation.

5.6.5.2 VISUAL INSPECTION

All welds shall be visually examined.

5.6.5.3 PENETRANT INSPECTION

All welds shall be penetrant inspected,

5.6.5.4 RADIOGRAPHIC/ULTRASONIC INSPECTION

Unless 100% radiographic or ultrasonic inspection of specific joint is specified on the drawing, welds shall be radiographically or ultrasonically inspected to an AQL of 1.0 percent as adapted from MIL-STD-105. Sampling shall be on the basis of millimeters of weld as shown in Table II,

TABLE II

SAMPLING PLAN

RADIOGRAPHIC/ULTRASONIC INSPECTION

Millimeters of Weld Inspected	Millimeters of Weld (Total)
130	Up to 1500, inclusive
320	More than 1500

5.7 TEST METHODS

5.7.1 PENETRANT INSPECTION

Penetrant inspection shall be accomplished per MIL-STD-271.

5.7.2 **RADIOGRAPHIC INSPECTION**

Radiographic inspection shall be accomplished per ML-STD-271.

5.7.3 **ULTRASONIC INSPECTION**

Ultrasonic inspection shall be accomplished per NAVSHIPS 0900-006-3010.

6 NOTES

6.1 DEFINITIONS



- a. Arc Strike: Pits caused by touching the electrode to the surface.
- b. t: The thickness of the thinnest member to be welded.
- c. T: The thickness of the thickest member to be welded.
- d. S: , Fillet weld size as defined in AWS A3.0



Additional definitions, if required, shall be in accordance with AWS A3.0, Terms and Definitions.

ACTIVE SHEET RECORD

SHEET NO.	ADDED SHEETS				SHEET NO.	ADDED SHEETS			
	ONLY LTR	SHEET NO.	REV LTR	ONLY LTR		ONLY LTR	SHEET NO.	REV LTR	ONLY LTR