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SUPERSEDING
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MILITARY SPECIFICATION

WELDMENTS, ALUMINUM AND ALUMINUM ALLOY

This specification has been approved by the Naval Ordnance Systems Command, Department of the Navy.

1. SCOPE

1.1 Scope. This specification covers the general requirements for aluminum and aluminum alloy weldments fabricated by the inert-gas metal-arc and inert-gas tungsten-arc welding processes as defined in AWS A3.0.

1.2 Classification. Weldments shall be one of the following classes, as specified (see 6.1 and 6.2):

Class 1
Class 2
Class 3
Class 4

2. APPLICABLE DOCUMENTS

2.1 The following documents of the issue in effect on the date of invitation for bids or request for proposal form a part of this specification to the extent specified herein.

SPECIFICATIONS

Federal

QQ-R-566	Rods, Welding, Aluminum and Aluminum Alloys

Military

MIL-T-5021	Test; Aircraft Welding Operators', Qualification

FSC THJM

MIL-H-6088	Heat Treatment of Aluminum Alloys
MIL-I-6866	Inspection, Penetrant Method of
MIL-F-6939	Flux, Aluminum and Aluminum Alloy, Gas Welding
MIL-I-8950	Inspection, Ultrasonic, Wrought Metals, Process for
MIL-R-11470	Radiographic Inspection; Qualification of Equipment, Operators and Procedures
MIL-E-16053	Electrodes, Welding, Bare, Aluminum Alloys
MIL-A-18455	Argon, Technical
MIL-A-21180	Aluminum-Alloy Castings, High Strength
MIL-F-38762	Fluorescent Penetrant Inspection Units

STANDARDS

Federal

FED-STD-151	Metals, Test Methods

Military

MIL-STD-0022	Welded Joint Design
MIL-STD-105	Sampling Procedures and Tables for Inspection by Attributes
MIL-STD-129	Marking for Shipment and Storage
MIL-STD-130	Identification Marking of U.S. Military Property
MIL-STD-410	Qualification of Inspection Personnel (Magnetic Particle and Penetrant)
MIL-STD-453	Inspection, Radiographic
MIL-STD-649	Aluminum and Magnesium Products, Preparation for Shipment and Storage

PUBLICATIONS

Bureau of Ships

NAVSHIPS 0900-003-9000	Radiographic Standard for Production and Repair Welds

DRAWINGS

Such drawings as specified by the procuring activity shall form a part of this specification.

(Copies of specifications, standards, drawings, and publications required by suppliers in connection with specific procurement functions should be obtained from the procurement activity or as directed by the contracting officer.)

2.2 Other publications. The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids or request for proposal shall apply.

American National Standards

ANSI Y14.5	Dimensioning and Tolerancing for Engineering Drawings
ANSI B46.1	Surface Texture

(Application for copies should be addressed to the American National Standards Institute, 1430 Broadway, New York, N.Y. 10018.)

American Welding Society

AWS A2.0	Welding Symbols
AWS A2.2	Nondestructive Testing Symbols
AWS A3.0	Welding Terms and Definitions

(Application for copies should be addressed to the American Welding Society, 345 East 47th Street, New York, N.Y. 10017.)

3. REQUIREMENTS

3.1 Capability. When a bidder selected for award has not had previous experience in building ordnance structures as specified in the request for bids or material requiring a similar quality of workmanship, he may be required before contract award to demonstrate satisfactorily to the procuring activity that his methods of welding, his shop and equipment, and his supervision and welding procedures are such as to produce results which will comply with the provisions of this specification and permit fabrication of structures which will function satisfactorily for the purpose intended. These tests shall be conducted at the expense of the bidder. If the test results do not indicate the bidders ability to fulfill the requirements, his bid shall be rejected.

3.1.1 Weldment acceptance standards. Weldments shall meet the standards of acceptance for the applicable class as specified in 4.2.3.

3.2 Qualification of welding operators. Welding operators shall be qualified in accordance with the applicable requirements of MIL-T-5021.

3.3 Material.

3.3.1 Plates, bars, structural shapes, castings, forgings. Material for plates, castings, forgings, and other parts used in the fabrication of weldments covered by this specification shall be as specified by the applicable drawings and shall meet the standards of 4.2.3 when inspected in accordance with 4.2.2.

3.3.2 Filler metal.

3.3.2.1 Gas-shielded arc-welding.

3.3.2.1.1 Inert-gas tungsten-arc process. Filler metal for weldments fabricated by the inert-gas tungsten-arc process shall be as specified on the drawing and shall conform to the applicable class of QQ-R-566 or MIL-E-16053.

3.3.2.1.2 Inert-gas metal-arc process. Filler metal for weldments fabricated by the inert-gas metal-arc process shall be as specified on the drawing and shall conform to the applicable class of MIL-E-16053.

3.3.3 Flux. Unless otherwise specified, flux used in the fabrication of weldments covered by this specification shall conform to MIL-F-6939.

3.3.4 Inert gas. For inert-gas shielded-arc welding, either argon gas conforming to MIL-A-18455 or welding grade helium with similar limits of water vapor content or mixtures of such argon and helium may be used.

3.4 Welding process. Weldments shall be fabricated in accordance with the process specified by the procuring activity, applicable drawing, or as specified in 3.4.1.

3.4.1 Alternate welding process. Alternate processes, as defined in AWS A3.0, may be used when prior approval has been obtained from the procuring activity.

3.5 Dimensions and tolerances. Dimensions and tolerances of weldments covered by this specification shall be in accordance with the requirements of the applicable drawing and shall conform to the requirements of ANSI Y14.5 and ANSI B46.1.

3.5.1 Welded structures. The responsibility for furnishing welded structures that will finish to dimensions shown on the applicable drawing within functional tolerances, without additional straightening or other modifications, shall rest with the contractor. When no allowance for shrinkage is made on weldment drawings, it shall be the responsibility of the contractor to make necessary shrinkage allowances in dimensions of component parts to insure that the completed weldment complies with the applicable assembly requirements.

3.5.2 Allowance for machining. Unless otherwise specified, all parts of a welded structure where a machined finish is required shall have a minimum allowance of 1/16-inch stock for machining. Stock for finishing shall not be so great as to require excessive machining.

3.6 Component parts.

3.6.1 Shaping of parts. Unless otherwise specified on the applicable drawing, component parts may be formed, machined, sheared, or punched. Thermal cutting processes may be used when specifically authorized by the procuring activity.

3.6.1.1 Sheared, punched, or thermally cut parts. Sheared, punched, or thermally cut parts shall be smooth and free from buckles, tears, or cracks before welding.

3.6.1.2 Sharp edges. All sharp edges caused by shaping operations shall be removed from the parts before assembly for welding.

3.6.2 Heating for forming. Component parts may be heated for hot forming subject to the restrictions of 3.6.2.1 and 3.6.2.2.

3.6.2.1 Components not subsequently heat treated. Component parts to be formed from non-heat-treatable aluminum alloys, or from heat treated alloys which will not receive subsequent solution heat treatment, shall not be heated in excess of 300° Fahrenheit (F).

3.6.2.2 Components subsequently heat treated. Component parts to be formed from heat-treatable aluminum alloys which will receive a subsequent solution heat treatment may be preheated up to 600° F. Parts which are to receive only a precipitation hardening treatment shall not be heated for forming.

3.7 Direction of maximum stress. When the direction of maximum stress is indicated, the component plate parts of the welded structure shall be laid out so that the direction of rolling in the plate is parallel to the direction of maximum stress imposed on the part.

3.8 Surface preparation.

3.8.1 Surfaces. Surfaces to be welded shall be free from dirt, oil, paint, or other foreign materials. Within 24 hours of the welding operation, oxide films and other protective coatings shall be removed to the degree necessary to assure good weldability. Mechanical or chemical cleaning methods may be used.

3.8.2 Moisture. Water, snow, or ice shall be removed, and the surface completely dried before welding. No welding shall be done in locations unprotected from rain, snow, or drafts.

3.8.3 Multiple layer welds. When multiple layer welds are deposited, each layer shall be thoroughly cleaned before depositing another layer. Any gas pits or slag in or along the edge of the weld shall be removed before subsequent layers are applied.

3.9 Tack welding.

3.9.1 Welding. Tack welding shall be accomplished with the material specified in 3.3 and in accordance with 3.4. When tack welds are to be incorporated in the final weld, operators shall be qualified in accordance with 3.2.

3.9.2 Electrodes. Unless otherwise specified by the procuring activity, welding electrodes shall be as specified on the applicable drawing and MIL-E-16053.

3.9.3 Tack weld deposit. Tack welds shall be deposited in such a manner as to facilitate their incorporation into the final weld without causing a discontinuity in the deposit.

3.9.4 Additional stress. Tack welds shall be so placed that stresses in welds caused by their restricting the contraction of parts being welded will be held to a minimum.

3.10 Weld positions.

3.10.1 Flat position. Insofar as practical, all welding on structures shall be performed in the flat position as defined in AWS A3.0. Vertical welds, if necessary, should be performed using the uphand technique.

3.11 Welding assembly sequence.

3.11.1 Control of residual stresses. The actual welding of the structure and all parts entering into the assembly shall be done in such a manner that residual stresses in the welds will be reduced to a minimum. As far as practical, to reduce welding stress, the various steps in welding shall be carried out so that external restraint shall not resist the shrinking incident to the welding and add stresses to those that are unavoidable in a free joint (see 3.11.2 and 3.13.1).

3.11.2 Control of shrinking. Insofar as possible, the welding of an assembly shall begin at some central location situated so that outlying or adjacent parts may be added progressively. The unwelded sections shall be free to shrink toward the central welding location. No excessive welding, bolting, or rigid restriction shall be employed on parts at outlying points which will prevent their free movement toward the center of welding. The welding shall progress systematically so that shrinkage on both sides of the structure will be equal or balanced, insofar as practicable. Where possible, intersecting systems of framing and stiffeners shall be joined to each other before they are joined to plate or flange members.

3.12 Joints.

3.12.1 Design. Joint preparation shall be as shown on the drawing, with reference to MIL-STD-0022 and AWS A2.0 as applicable except as specified in 3.12.2 and 3.12.3.

3.12.2 Patented joints. Where joint edge preparation shown on the applicable drawing is that of a patented joint, the contractor, with prior approval from the procuring activity, may substitute other joint designs having equivalent efficiency.

3.12.3 Alternate joint designs. If so desired by the contractor and with prior approval from the procuring activity, similar and equally effective designs of joints other than specified by the applicable drawing may be used.

3.12.4 Removing root of weld. Where a through joint requiring root chipping is indicated on the drawing, the joint shall be chipped, gouged, or machined down to sound, continuous metal on the root side after sufficient welding has been done on one side and before welding on the root side is undertaken.

3.12.5 Form of chipping tool. Chipping shall be accomplished by means of a round-nosed tool having a radius of not less than one-eighth inch. No section of the chipped or machined groove shall contain an irregularity with a corner having a radius of less than one-eighth inch.

3.12.6 Gouging. Gouging may be performed by the constricted tungsten-arc method provided that the cross section profile of the gouged groove

shall comply with the specification requirements limiting the radius to one-eight inch minimum at any point.

3.12.7 Defects in root areas. In weldment classes 1, 2, and 3, the soundness of the metal remaining in the root shall be determined by the dye penetrant inspection method. All penetrant must be removed before additional welding is undertaken.

3.12.8 Filler metal size. The maximum diameter of filler metal (rod or wire) used for the first pass in chipped or machined grooves shall not exceed the radius at the bottom of the groove.

3.12.9 Fillet size. Where the clearance between members to be joined by fillet welds is greater than one thirty-second of an inch, the size of the fillet to be deposited shall be the size specified plus the clearance.

3.12.10 Joint openings. Joint openings shall not be larger than those required for proper assembly. Joints with oversize root openings may be corrected by building up the basic edges or weld scarfs with weld metal and then suitably preparing such edges for welding.

3.13 Peening.

3.13.1 Uses. Peening, that is, mechanical working of the weld metal, may be done to correct distortion or to minimize residual stresses.

3.13.2 Care in peening. Peening shall be accomplished with a round- or blunt-nosed tool of circular or oblong cross section. Peening shall be performed in a manner that will not tear or burr the peened area. Care must be taken that all surface slag, residual flux, slag inclusions, gas holes, or overlaps are removed from the weld before peening so that no foreign material or unfused area shall be embodied in the weld. Peening should preferably be done in the temperature range of from 50° to 200° F using a light airhammer.

3.13.3 Restrictions.

3.13.3.1 Weldments of heat -treatable aluminum alloys. No peening shall be done unless the weldment is subsequently heat treated. Peening

will not be performed on the first or final pass. If inprocess inspection is required, no peening shall be performed until after inspection.

3.13.4 Damage to parent metal. Care shall be taken not to damage or reduce the cross sectional area adjacent to the weld with the peening tool.

3.14 Preheat.

3.14.1 Preheat temperatures. Unless prohibited on the drawings, preheat may be used as desired to avoid cracking, control distortion, and otherwise insure a sound weldment.

3.14.2 Restrictions.

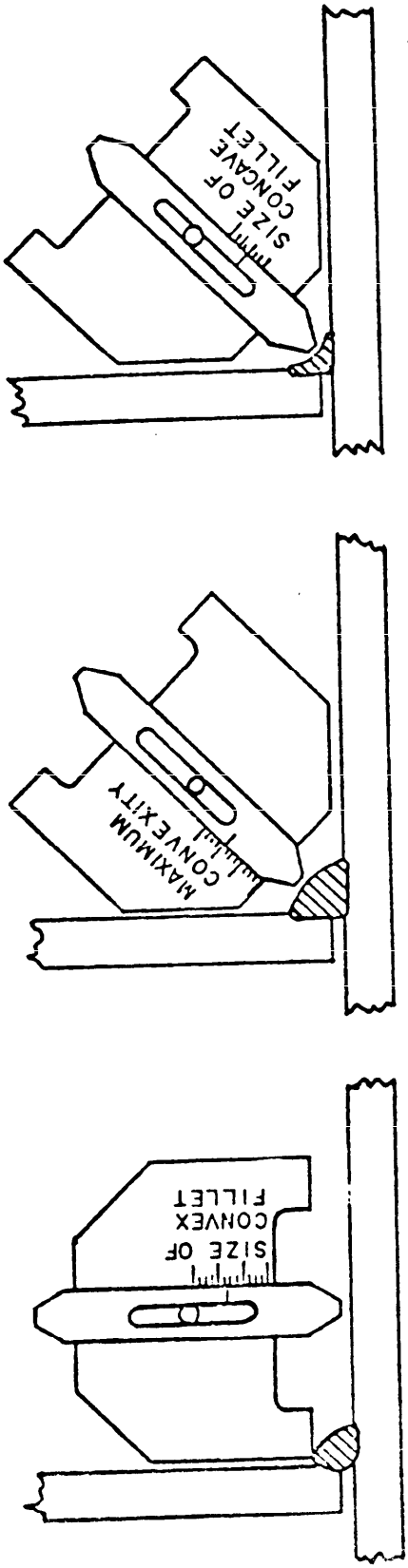
3.14.2.1 Weldments not subsequently heat treated. Weldments fabricated from non-heat-treatable aluminum alloys or weldments fabricated from heat-treated aluminum alloys which will not receive subsequent solution heat treatment after welding shall not be preheated in excess of 300° F.

3.14.2.2 Weldments subsequently heat treated. Weldments fabricated from heat-treatable aluminum alloys which will receive a subsequent solution heat treatment may be preheated up to 600° F.

3.15 Size and shape of welds.

3.15.1 Size. The form and dimensions of the welds shall be in accordance with the applicable drawings, except as provided for in 3.12.1. Weld sizes given on the drawings shall be considered the minimum size when measured as specified in AWS A3.0. Fillet weld sizes shall not exceed the next 1/16-inch larger size for welds up to three-eighths inch. For welds three-eighths inch and larger, the size shall not exceed the next 1/8-inch larger size. Fillet weld sizes may be determined by the method shown in figure 1 using the gage shown in figure 2.

3.15.2 Weld reinforcement. For plate one-half inch and greater in thickness, the reinforcement of butt welds shall not exceed one-eighth inch except as specified for individual joints on the applicable drawings. For material under one-half inch, the reinforcement shall not exceed 25 percent of the material thickness.



PLACE GAGE AGAINST STRUCTURE AND SLIDE POINTER OUT UNTIL IT TOUCHES THE FACE OF THE FILLET WELD AS SHOWN.

READ "SIZE OF CONCAVE FILLET" ON FACE OF GAGE

AFTER THE SIZE OF A CONVEX WELD HAS BEEN DETERMINED, PLACE THE GAGE AGAINST THE STRUCTURE AND SLIDE POINTER UNTIL IT TOUCHES FACE OF FILLET WELD AS SHOWN.

THE MAXIMUM CONVEXITY SHOULD NOT BE GREATER THAN THAT INDICATED BY "MAXIMUM CONVEXITY" FOR THE SIZE OF FILLET BEING CHECKED.

PLACE GAGE AGAINST THE TOE OF THE SHORTEST LEG OF THE FILLET AND SLIDE POINTER OUT UNTIL IT TOUCHES STRUCTURE AS SHOWN.

READ "SIZE OF CONVEX FILLET" ON FACE OF GAGE

FIGURE 1. METHOD OF USING BUTT AND FILLET WELD GAGE

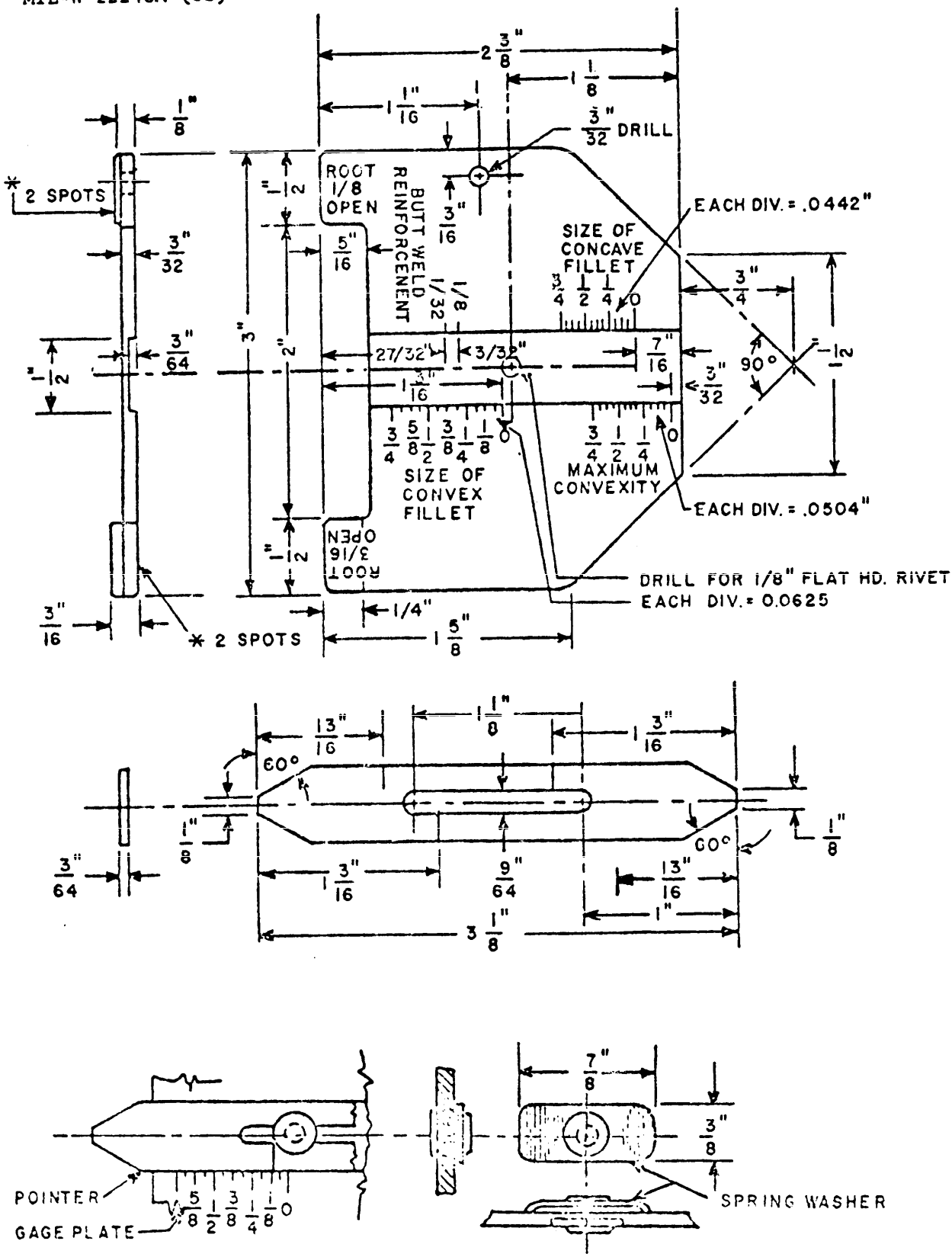


FIGURE 2. BUTT AND FILLET WELD GAGE

3.15.3 Fillet weld form. Fillet welds having a slight convex form are desirable. Excessive convexity, as determined by the gage (figure 1), may be corrected by grinding or chipping.

3.15.4 Lengths of fillet welds. When fillet welding extends for the full distance between abrupt changes in the direction of the welding, no length dimensions need be shown on the welding symbol. Specific lengths of fillet welds, excluding craters and starts, should be in accordance with the lengths specified on the drawings.

3.15.5 Extension of fillet welds. Fillet welds shall extend around the ends of abutting members when practicable.

3.16 Undercut and overlapping welds. Undercutting or overlapping will not be permitted except as specified in 4.2.3 for the applicable class of weldment.

3.17 Removal of reinforcements. Where butt welds which are to be finished flush occur on unmachined surfaces, the reinforcement shall be removed by chipping or grinding. Care shall be taken to avoid undercutting or nicking the surface of the plate in the vicinity of the welds.

3.18 Weld deposits. Welds may be built up by weave beads or stringer beads.

3.18.1 Weave beads.

3.18.1.1 Shielded metal-arc process. Weave beads made by the shielded metal-arc process shall not exceed four times the nominal diameter of the electrode.

3.18.1.2 Inert-gas metal-arc and inert-gas tungsten-arc welding processes. Weave beads made by the inert-gas metal-arc and the inert-gas tungsten-arc processes are not restricted by any maximum permissible width.

3.19 Weldment condition. The final condition of the weldment (annealed, solution heat treated, aged, cold worked, or "as welded") shall be as

specified on the drawing, detail specification, or contract. If no condition is specified, the weldment shall be furnished in the "as welded" condition.

3.19.1 Heat treatment. Equipment and procedures shall comply with the requirements of MIL-H-6088.

3.19.2 Stress relief. Qualification of stress relief for large weldments shall be at the discretion of the supplier and cognizant inspection agency or as specified on the drawing.

3.20 Straightening.

3.20.1 Progressive straightening. To avoid the necessity for major straightening of weldments, check measurements shall be made at frequent intervals during the course of fabrication. Corrective measures shall be taken as required rather than permitting warpage to persist or to accumulate for a final straightening.

3.20.2 Heating for straightening. Weldments may be heated for straightening, subject to the restrictions applied to preheating for welding (see 3.14.2).

3.20.3 Stress caused by straightening. Stresses in any section of a weld or plate caused by straightening shall be held to a minimum. Buckled or stressed sections may be relieved by opening welded seams and rewelding.

3.21 Weldment finish. Weldments received from the contractor shall be free from all slag, flux, salt bath residue, weld spatter, and other foreign materials. If weldments are received in such condition that cognizant Government inspection cannot be performed because of inadequate cleaning, the contractor shall be liable for the cost of any additional cleaning deemed necessary by the inspector.

3.22 Identification marking. Weldments covered by this specification shall be legibly and permanently marked in accordance with MIL-STD-130 and the applicable drawings. In addition, weldments shall be further identified and marked as specified in 3.22.1 and 3.22.2. Weldments shall not be marked by identification stamp or other identification marking device in an area where the impression could increase the stress leading to ultimate failure of the weldment.

3.22.1 Serial numbers. Weldments required to be identified in accordance with 3.22 also shall be marked with a serial number in characters of the same size as those of the identification mark. The serial number so assigned shall be selected, in regular sequence, from a block of serial numbers furnished by the contractor or procuring activity. No two serial numbers shall be alike for the same part number unless otherwise specified, and all inspection records, reports, and correspondence shall thereafter refer to a specific weldment by its serial number.

3.22.2 Weldment drawing numbers. Where practicable, the applicable weldment drawing number (not the finish machine drawing), piece number, and revision letter shall be painted in relatively large characters on the parts.

3.23 Workmanship. Workmanship in all respects shall be such as to assure production of acceptable weldments in accordance with the requirements of the applicable drawing, detail specification, contract or order, and this specification.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified, the supplier may utilize his own facilities or any commercial laboratory acceptable to the Government. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.2 Quality conformance inspection.

4.2.1 Sampling.

4.2.1.1 Lot sizes. For sampling purposes, a lot shall consist of all like weldments of the same class and design or kind manufactured by essentially the same process and submitted for acceptance inspection at one time. As far as practical, a ratio shall be selected of each welding operator's production from each lot.

4.2.1.2 Samples. Unless otherwise specified, samples of each inspection lot shall be selected in accordance with MIL-STD-105, inspection

level I. Lot acceptance shall be based on the acceptable quality level (AQL) of 2.5 percent defectives.

4.2.2 Inspection.

4.2.2.1 General inspection. Unless otherwise specified herein, general inspection and test procedures shall be in accordance with FED-STD-151 and the requirements of this specification.

4.2.2.1.1 Nondestructive tests. Unless otherwise specified herein or on the applicable drawing, weldments shall be inspected in accordance with nondestructive testing symbols of AWS A2.2.

4.2.2.1.2 Visual and dimensional. Samples selected in accordance with 4.2.1.2 shall be visually inspected for completeness of weld and for dimensional and other requirements as set forth on applicable drawings (see table I).

4.2.2.1.3 Acceptance tests. Unless otherwise specified, weldments selected in accordance with 4.2.1.2 shall be subject to the inspection tests of 4.2.3, 4.3.1, and 4.3.2, as specified for the applicable class of weldment (see table I).

4.2.2.1.4 Finish of welds. Welds shall be inspected for smoothness, workmanship, and for conformance to the requirements of 3.15 through 3.18, and 3.23. The inspector may require chipping, grinding, or rewelding whenever necessary to obtain suitable weld surface appearance. Surface irregularities that interfere with the interpretation of radiographic or penetrant inspection, or make it questionable, shall be removed.

4.2.3 Standards of acceptance.

4.2.3.1 Welds. Welds shall be inspected to ensure compliance with the standards established for the class of weldment specified on the applicable drawing, detail specification, or by the procuring activity (see 6.2). Procedures shall be in accordance with 4.2.2, 4.3.1, and 4.3.2 as applicable per table I. Weld root areas prepared in accordance with 3.12.4 shall be inspected by the methods of 4.2.3.1.1, 4.2.3.1.2, and 4.2.3.1.3.

Table I

STANDARDS OF ACCEPTANCE

Weldment class	Inspection method		
	Radiographic (4.3.1)	Penetrant (4.3.2)	Visual (4.2.2)
1	No defects except scattered porosity not in excess of grade 1 of NAVSHIPS 0900-003-9000	No defects of any kind	No undercuts, overlap, slag, flux, or weld spatter
2	No defects except scattered porosity not in excess of class 1 or 2 of NAVSHIPS 0900-003-9000	No defects except scattered surface porosity not exceeding the pattern shown in figure 3	No undercuts, overlap, slag, flux, or weld spatter
3	Not required	No defects except scattered surface porosity not exceeding the pattern shown in figure 4	No undercuts, overlap, slag, flux, or weld spatter
4	Not required	Not required	No crack type defects permitted; permissible undercut shall not exceed 10% of plate thickness or 1/16 inch, whichever is lesser; overlap, will be permitted not to exceed 2T in any 6T length; slag or flux residue and weld spatter shall be removed; scattered surface porosity shall not exceed the pattern shown in figure 5.

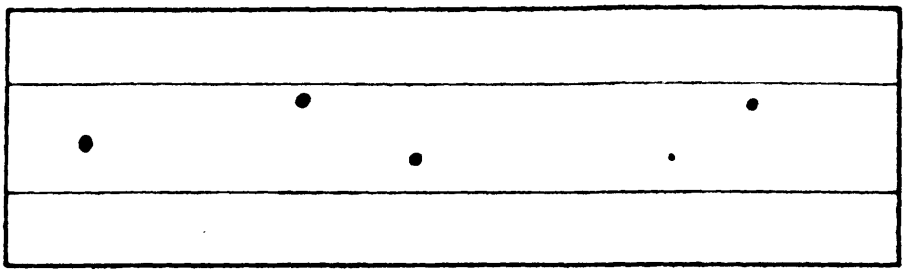


FIGURE 3. CLASS 2 PENETRANT STANDARD

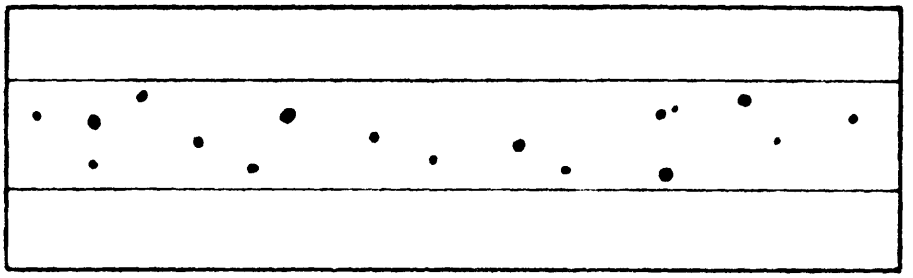


FIGURE 4. CLASS 3 PENETRANT STANDARD

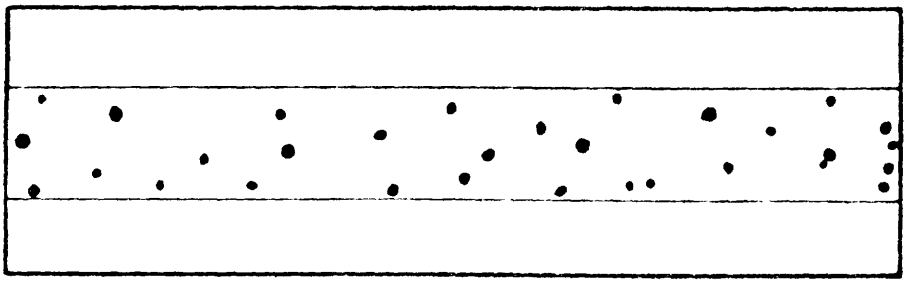


FIGURE 5. CLASS 4 PENETRANT STANDARD

4.2.3.1.1 Class 1 and class 2 weldments. Welds shall be radiographed and penetrant and visually inspected in accordance with the standards of acceptance specified in table I.

4.2.3.1.2 Class 3 weldments. Welds shall be penetrant and visually inspected in accordance with the standards of acceptance specified in table I.

4.2.3.1.3 Class 4 weldments. Welds shall be visually inspected in accordance with the standards of acceptance specified in table I.

4.2.3.2 Material. The plates, bars, structural shapes, castings, stampings, formed parts, and forgings used in the fabrication of weldments shall be inspected in accordance with 4.2.3.2.1 through 4.2.3.2.5 as applicable.

4.2.3.2.1 Bars and plates. Normal inspection of bars and plates three-eighths inch thick or less shall consist of visual inspection of the edges of prepared parts before welding and of the exposed edges of the completed weldment at final inspection. Penetrant inspection shall be required for bars and plates thicker than three-eighths inch.

4.2.3.2.2 Structural shapes, tubes, and extrusions. Normal inspection of the structural shapes shall consist of a visual inspection of the exterior surfaces and a penetrant inspection of the areas exposed by cutting.

4.2.3.2.3 Stampings and formed parts. Normal inspection of stampings and formed parts shall consist of a visual inspection of the edges of the prepared parts and the exposed edges after welding. In addition, areas of sharp bends shall be penetrant inspected by the fluorescent or nonfluorescent penetrant method.

4.2.3.2.4 Forgings. Forgings shall be inspected by the fluorescent or nonfluorescent penetrant method. In addition, ultrasonic and radiographic inspection shall be performed as shown on the drawing or as specified by the procuring activity.

4.2.3.2.5 Castings. Castings shall be inspected by the fluorescent or nonfluorescent penetrant method. In addition, castings shall be radiographed as required by the drawing or by the procuring activity. The standards of acceptance shall be as specified in MIL-A-21180.

4.3 Test methods.

4.3.1 Radiographic inspection.

4.3.1.1 General. Radiographic equipment, operators, and procedures used in radiographic inspection of weldments shall be qualified in accordance with MIL-R-11470 or MIL-STD-453.

4.3.1.1.1 Position and direction of radiation. Radiographs shall be taken in the position and directions and at the stages of assembly required by the applicable drawing. When not otherwise indicated on the drawings, the direction of radiation shall be perpendicular to the radiographic film and to the surface of the material when feasible. No deviations shall be permitted unless authorized by the procuring activity.

4.3.1.1.2 Random radiographs. On weldments requiring radiographic inspection of specific areas, additional radiographs may be made at random to demonstrate the specified quality in areas of the weldment not regularly radiographed.

4.3.1.1.2.1 Additional radiographs. Where appreciable defects are disclosed in the areas radiographed or where soundness is questioned, additional radiography may be required at the discretion of the contractor or the cognizant Government inspector.

4.3.1.1.3 Identification of radiographs.

4.3.1.1.3.1 Radiographic negatives and written radiographic inspection records shall be submitted in accordance with the requirements of MIL-STD-453 unless otherwise specified by the procuring activity.

4.3.1.1.3.2 Weldment serial numbers. Each weldment radiographed shall be assigned a serial number (see 3.22.1) in accordance with MIL-STD-453.

4.3.1.1.3.3 Negative identification numbers. All radiographic negatives shall carry the image of the lead markers identifying the individual part, position number, and locating markers. These markers shall be of such size and so located as to render minimum interference with the interpretation of the radiographic image in the area of the weld.

4.3.1.1.3.4 Radiographic position number. The position number shall represent a definite area of the structure. The numbering system shall be consistent for similar parts, and the location of areas shall be readily determinable from a radiographic position chart or drawing which will be furnished by the contractor. The above requirements do not apply to additional radiographs made at random under 4.3.1.1.2 which shall be otherwise identified.

4.3.1.1.3.5 Radiographic location markers. The exact location of the markers shall be permanently stamped on the surface of the weldment so that the radiograph may be accurately located whenever desired. Generally, the markers shall be placed on the side of the metal toward the radiation, but it is permitted to place markers on the film side of the metal when it is anticipated that repairs will be made from this surface. Weldments shall not be marked in an area where the impression could increase stress leading to the ultimate failure of the weldment.

4.3.1.1.3.6 Alternate method of identifying negatives. In cases when the image of the identifying markers would interfere with proper interpretation of the radiograph, such identification may be entered on the film after exposure, but prior to development.

4.3.1.1.4 Radiographic technique. Except as otherwise noted in this specification, the technique employed shall conform to the provisions of MIL-STD-453.

4.3.1.1.4.1 Unequal thicknesses. When members being radiographed are of unequal thicknesses or when the section of a weld (such as a fillet weld) varies considerably, the density of the radiograph shall be such as to show the root of the weld or the section which is most likely to contain defects.

4.3.1.1.4.2 Examination of radiographs. Suitable facilities shall be provided for the viewing, examination, and storage of radiographs.

4.3.1.1.4.3 Surface irregularities. Any indication on radiographs that are definitely identified as the shadows of surface irregularities on the weldments shall be so indicated on the radiograph in pencil. In case of sharp indications closely resembling typical defects, the radiograph shall be rejected and the surface of the weld repaired prior to reradiographing.

4.3.2 Penetrant inspection.

4.3.2.1 General. The method used shall be either the fluorescent or nonfluorescent method conforming to the requirements of MIL-I-6866 and shall apply to rolled plates, shapes, forgings, castings, welded joints, and any necessary replacements or repair of material or welds. The final inspection shall be conducted after heat treatment, where so required, and after all machining operations have been performed. Any penetrant inspections prior to final machining shall be considered to be in-process inspection. Areas not accessible for inspection after completion of assembly shall be inspected at a suitable subassembly stage.

4.3.2.2 Additional inspection areas. In addition to the areas designated on the drawing, the Government inspector may require such additional inspections as he deems necessary for assuring a sound weldment.

4.3.2.3 Records. A complete record of final penetrant inspection of each weldment shall be submitted on an approved form when required by the procuring activity.

4.3.2.4 Qualified personnel. Inspections performed as required by this specification shall be performed only by personnel who have been certified in accordance with MIL-STD-410 or by the cognizant inspection activity.

4.3.2.5 Equipment. The penetrant inspection equipment shall conform to the requirements of MIL-I-6866 for visible penetrant methods and to MIL-F-38762 for fluorescent penetrant methods.

4.3.2.6 Procedure.

4.3.2.6.1 General. Penetrant inspection shall be performed in such a manner as to insure the detection of all surface cracks. The general inspection procedures of MIL-I-6866 shall apply.

4.3.2.6.2 Surface preparation. The surface to be inspected shall be clean, dry, and free from oil, dirt, slag, flux, salt bath residue, and all other foreign material. Surface irregularities such as shearing tears, sharp chisel marks, undercuts, overlaps, folds, gas holes, and rough welds which make interpretation of indications difficult shall be removed by grinding or chipping.

4.3.3 Ultrasonic inspection. When specified by the drawing or procuring activity, ultrasonic inspection shall be performed in accordance with the applicable classification of MIL-I-8950 in lieu of or in addition to radiographic inspection (see 6.3).

4.4 Replacement and repair criteria.

4.4.1 Material. Parts which do not meet the specified material requirements shall be repaired, discarded, or if already assembled, removed and replaced with satisfactory material. Repairs may be made under the following conditions:

(a) When the defects are confined to small areas and do not extend through an appreciable portion of the part.

(b) When the defects are in an area of low stress.

(c) When the defects are not excessive but parallel to the direction of principal stress.

(d) When it is desirable to remove all traces of defects in a highly stressed area or in a weld kerf before welding.

4.4.2 Defects. Welds and component parts containing repairable defects shall be repaired in accordance with the following applicable procedures:

(a) If the defect is detected by visual or penetrant inspection, the defect shall be removed and the underlying area shall again be penetrant tested to demonstrate compliance with the specified requirements, prior to rewelding. No section of the excavation shall contain an irregularity with a corner having a radius less than one-eighth inch. After repair, the soundness of the weld shall be demonstrated by penetrant tests. If the repair is in a radiographed area and deeper than one-fourth inch, it shall also be radiographed.

(b) If the defect is disclosed as a result of radiographic inspection, the defective area shall be excavated until the remaining metal appears to be wholly sound. No section of the excavation shall contain an irregularity with a corner having a radius less then one-eighth inch. After the defect has been removed, the area shall be repaired by welding as prescribed in 4.5. The weld reinforcement shall be removed flush with the base metal or shaped to the proper contour and the repair weld radiographed.

(c) If an undercut condition occurs, it may be corrected by depositing a small bead at the toe of the undercut portion of the weld after any adhering slag, scale, dirt, or other foreign material has been removed. Undercuts less than 5 percent of the material thickness, but not exceeding 0.020 inch, may be removed by grinding so that a smooth transition from weld to base metal results.

4.5 Weld repair procedure. Unless otherwise approved by the procuring activity, cavities caused by the removal of defects shall be repaired by welding. When the cavity extends entirely through a section, the repair shall be accomplished either by welding from one side, chipping out the first weld layers to sound metal from the opposite side, and rewelding or by welding from one side onto a backing strap of suitable dimensions and of the same material as that being welded. In the latter case, soundness of the weld root shall be demonstrated by penetrant inspection after removal of the backing strap. Repair welds may be peened in accordance with 3.13 to reduce distortion and probable cracking.

4.5.1 Weld repairs to heat-treatable alloys. When repairs involving welding are made to heat-treatable alloys after final solution heat treatment, the weldment must receive a subsequent complete heat treatment in order to comply with 3.19, unless waived by the procuring activity.

4.6 Supplementary requirements.

4.6.1 Inspection reports. All radiographic and penetrant inspection reports shall be maintained by the contractor for a period of 3 years, unless otherwise specified by the procuring activity (see 6.3).

5. PREPARATION FOR DELIVERY

5.1 Preservation and packaging. Preservation and packaging shall be level A, B, or C as specified by the procuring activity (see 6.3).

5.1.1 Level A. When level A is specified, material shall be preserved and packaged in accordance with MIL-STD-649.

5.1.2 Level B. Level B preservation and packaging is intended to provide economical but limited protection and should be specified only where it is determined that weldments will be held for a specified period of time prior to further processing. When level B preservation and packaging is specified and weldments are not used within the specified period, they shall be inspected to determine condition and represerved and repackaged as necessary.

5.1.3 Level C. When level C is specified, packaging, if required, shall be in accordance with manufacturers commercial standards.

5.2 Packing. Packing shall be level A, B, or C as specified by the procuring activity (see 6.3).

5.2.1 Levels A and B. When level A or B is specified, weldments shall be packed or crated for shipment in accordance with MIL-STD-649.

5.2.2 Level C. When level C is specified, weldments shall be packed or crated in such a manner as to insure acceptance by common or other carrier for safe and expeditious delivery to the point of destination at the lowest transportation rate. Any special packing or equipment which may be required for transportation purposes shall be provided by the contractor. Except as noted, the contractor shall be responsible for the safe delivery of weldments to the specified destination and shall replace or repair any damaged weldments to the satisfaction of the procuring activity without additional expense to the Government.

5.3 Marking. In addition to any special marking which may be required by the procuring activity (see 6.3), weldments or weldment shipping containers shall be marked for shipment in accordance with the applicable drawing and MIL-STD-129.

6. NOTES

6.1 Intended use. Weldments covered by this specification are intended for use in military equipment and as specified by the procuring activity (see 6.3). The various classes (see 1.2) are intended to be used as indicated in table II.

Table II

REQUIRED SAFETY FACTOR FOR SPECIFIC WELDMENT CLASS

Safety factor (see 6.2)	Service condition					
	Severe			Mild		
	Consequence of failure			Consequence of failure		
	Critical	Minor	Negligible	Critical	Minor	Negligible
	Class of weldment			Class of weldment		
Less than 2	1	1	2	1	2	3
2 to 3.5	1	2	3	2	3	4
3.5 to 5	2	3	4	3	4	4
5 or greater	3	4	4	4	4	4

6.2 Safety factor. The term, safety factor, as used in this specification is defined as follows:

$$\text{Safety Factor} = \frac{\text{critical stress}}{\text{service stress}} \text{ (see 6.2.1).}$$

The class of weldment and related safety factor have been established on the basis that, as the safety factor increases, certain amounts of reduction in effective cross section of the weld or material can be tolerated. However, selection of a particular class of weldment for a design should be based not only on the safety factor for the design, but also on the severity of service and the seriousness of the consequence, if failure should occur. Any weldment, the failure of which should be classed as critical or which is subjected to severe service conditions of impact or vibration, should be rated class 3 or higher (class 2 and class 1), in order to take advantage of inspection methods adequate to detect serious defects and to limit such defects to a safe level regardless of the safety factor. Conversely, if a weldment with a high safety factor is not subject to severe service conditions and its failure is not classified as critical, such a weldment should not be rated higher than class 3. This avoids unnecessarily increasing the cost by over-inspection and repair or rejection on the basis of noncritical defects. Consideration should also be given to establishing separate classes for different parts of the weldment in order to avoid overclassification of unimportant parts.

6.2.1 Critical stress. The term, critical stress, as used in this specification is relative, and the actual value will depend upon the basis of design as follows:

Basis of design	Critical stress
Fracture	Ultimate strength of material
Plastic deformation	Yield strength for specified offset
Fatigue	Endurance limit.

6.3 Ordering data. Procurement documents should specify the following as applicable:

(a) Title, number, and date of this specification

(b) Identification of weldments being ordered

(c) Quantity required

(d) Class of weldment (see 1.2 and 6.2)

(e) Whether ultrasonic inspection is required (see 4.3.3)

(f) Inspection reports required (see 4.6.1)

(g) Whether level A, B, or C preservation and packaging is required (see 5.1)

(h) Whether level A, B, or C packing is required (see 5.2)

(i) Special marking required (see 5.3)

(j) Title, number, and date of detail procurement specification, if applicable

(k) Other pertinent data peculiar to the weldments being ordered.

6.4 Manufacturing drawings. The procuring agency will supply one set of blueprints and one set of transparencies of all the applicable manufacturing drawings and sketches with the initial award of any item of the contract.

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