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SUPERSEDING
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MILITARY SPECIFICATION

WELDING, FUSION; ALUMINUM ALLOYS; PROCESS AND PERFORMANCE OF

This specification is approved for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 Scope. This specification covers the requirements for eight methods of fusion welding of aluminum alloys and four quality classes of welds.

1.2 Classification. The aluminum alloys fusion welding shall be of the following methods and class, as specified (see 6.2).

1.2.1 Methods.

Gas tungsten arc welding (GTAW)
Gas metal arc welding (GMAW)
Electron beam welding (EBW)
Plasma arc welding (PAW)
Resistance spot welding (RSW)
Shielded metal arc welding (SMAW)
Oxy-acetylene welding (OAW)
Oxy-hydrogen welding (OHW)

1.2.2 Classes.

Class A - Critical application. A weldment is critical where a failure of any portion would cause loss of system, loss of major component, loss of control, unintentional release of critical stores, or endangering of personnel. 1/

Class B - Semi-critical application. A weldment is semi-critical when the failure would reduce overall efficiency of the system but loss of system or endangering of personnel would not be experienced.

Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Engineering Specifications and Standards Department (Code 93), Naval Engineering Center, Lakehurst, NJ 08733, by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

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Class C - Non-critical application. A weldment is non-critical where failure would not affect the efficiency of the system or endanger personnel.

1/ Class A (SP) - Applications such as pressure vessels, cryogenic, hypergolic and vacuum systems require special (SP) considereation.

2. APPLICABLE DOCUMENTS

2.1 Government documents.

2.1.1 Specifications, standards, and handbooks. Unless otherwise specified, the following specifications, standards, and handbooks of the issue listed in that issue of the Department of Defense Index of Specifications and Standards (DoDISS) specified in the solicitation form a part of this specification to the extent specified herein.

SPECIFICATIONS

FEDERAL

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

MILITARY

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-A-8625	-	Anodic Coatings, for Aluminum and Aluminum Alloys.
MIL-E-15597	-	Electrode, Welding, Covered, Coated, Aluminum and Aluminum Alloy.
MIL-E-16053	-	Electrode, Welding, Bare, Aluminum Alloy.
MIL-A-18455	-	Argon, Technical.
MIL-P-27407	-	Propellant Pressurizing Agent, Helium.

STANDARDS

MILITARY

MIL-STD-271	-	Nondestructive Testing Requirements for Metals.
MIL-STD-453	-	Inspection, Radiographic.
MIL-STD-1595	-	Aerospace Welder Performance Qualification.

(Copies of specifications, standards, handbooks, drawings, and publications required by manufacturers in connection with specific acquisition functions should be obtained from the contracting 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. The issues of the documents which are indicated as DoD adopted shall be the issue listed in the current DoDISS and the supplement thereto, if applicable.

AMERICAN WELDING SOCIETY (AWS)

AWS A2.4 - Symbols for Welding and Nondestructive Testing.
AWS A3.0 - Welding Terms and Definitions.
AWS A5.12 - Specification for Tungsten Arc-Welding Electrodes.

(Application for copies should be addressed to the American Welding Society, Inc., 2501 N. W. 7th Street, Miami, FL 33125.)

(Industry association specifications and standards are generally available for reference from libraries. They are also distributed among technical groups and using Federal agencies.)

2.3 Order of precedence. In the event of a conflict between the text of this specification and the references cited herein, the text of this specification shall take precedence.

3. REQUIREMENTS

3.1 Welders. Welding shall be performed only by welders who have met the requirements of MIL-STD-1595 and have been qualified for the particular alloys and types of welding involved.

3.2 Equipment.

3.2.1 General. Welding equipment, such as welding machines, welding torches, regulators and filler metal feed mechanisms shall be capable of making satisfactory welds, when operated by a certified welder using a satisfactory filler rod or electrode, where applicable.

3.2.1.1 Questionable welding apparatus capability. If, for any reason, where Government contracts are involved, the Government representative or contractor representative doubts the capability of any welding apparatus to function satisfactorily, he shall require welder's certification tests as described in MIL-STD-1595, applicable to the type of work for which the equipment is intended. The sets of specimens are to be made by a welder certified for the material and type of welding. Multiple operator sets shall be tested while the maximum number of operators are welding. If under these conditions, the applicable certification requirements can not be met, the equipment shall not be used until the necessary repairs, adjustments, replacements have been made or the work load decreased.

3.2.2 Furnaces. Furnaces and control equipment used for preheating parts prior to welding shall meet the requirements of MIL-H-6088.

3.2.2.1 Cooling ovens. Cooling ovens shall be provided with suitable means for controlling the cooling rate, in order to prevent damage to castings and other parts which are preheated prior to welding. Preheating furnaces may be used as cooling ovens.

3.2.3 Ventilation. Suitable blowers, exhausters, or other approved safety devices shall be provided to protect personnel against fumes resulting from flux, electrode coverings, etc.

3.3 Materials.

3.3.1 Storage. All materials used in the welding processes must be stored so that no degradation will result in weldment.

3.3.2 Base metal. Heat treatable wrought alloys shall not be welded without specific authorization of the acquiring agency, except that 6000 series, 2219, 7005 and 7039 alloys may be welded without such authorization. Table I is a guide to the choice of rods for welding certain combinations of base metals.

3.3.3 Filler metal. Welding rods, welding wire and electrodes used in the welding of aluminum alloys shall be capable of producing satisfactory welds when used by a certified welder with satisfactory welding apparatus, and shall have a composition suitable for producing welds conforming to the requirements specified herein. Bare welding rods shall be in accordance with QQ-R-566 or MIL-E-16053. Flux-coated electrodes shall be in accordance with MIL-E-15597.

3.3.4 Flux. Flux for the gas welding of aluminum alloys shall conform to MIL-F-6939.

3.3.5 Gases. Gases used in the welding of aluminum alloys shall be free from harmful percentages of impurities, diluent gases and moisture. All fuel and oxidizer gases shall be of a grade designated for welding. Inert gases for shielding shall be in accordance with table II.

3.3.6 Tungsten electrodes. Tungsten electrodes shall be one of any of the types covered by AWS A5.12 in the appropriate size. In addition, the surface of the rod shall be polished free of discontinuities and foreign material.

3.4 Welds.

3.4.1 Class. Unless otherwise specified, welds shall be class A.

3.4.2 Joint design. Interpretation of weld symbols shall be made in accordance with the current standard AWS A2.4. Mismatch and misalignment of fit up shall not exceed 10 percent of the thickness of the thinner member or 0.12 inch, whichever is less, unless otherwise specified on the drawing. The root opening shall be checked before depositing the first layer to ensure that it is correct. Surfaces to be welded and adjacent surfaces shall be free of all foreign matter. Any method of cleaning may be used which does not contaminate the surfaces. Edges to be fusion welded shall be essentially free of defects and finished to a surface roughness not greater than 250 micro-inches.

3.4.2.1 Accessibility. All portions of a joint or weld shall be accessible for proper cleaning especially on welds made with covered electrodes.

3.4.2.2 Joint edge preparation. Joint edges to be welded shall be prepared as follows:

a. Drawfile the edges by using a smooth single-cut mill file or wire brush the edges using a stainless steel brush. Avoid touching the cleaned edges with bare hands.

b. Store in a manner to maintain the metal in a clean, dry condition if not welded immediately.

c. Excess flux coatings, any surface contaminants or detrimental surface oxides shall be removed between passes.

3.4.3 Processes. When using the gas tungsten arc welding, the gas shield shall be argon, helium or mixtures of the two. The gas used shall flow from the welding electrode holder and trailing cup at a rate that shall satisfactorily protect the weld from oxidation. The underbead side of the weld shall also be adequately protected from oxidation when specified. Chills may be used with discretion.

3.4.4 Procedures.

3.4.4.1 Preheating. Preheating and interpass heating shall be performed at the welding engineer's discretion. Temperatures shall be measured by a calibrated surface pyrometer or other suitable temperature indicating means accurate within $\pm 20^{\circ}$F. Heating and maintaining of the proper temperature may be accomplished by a furnace (see 3.2.2), by induction, by a soot-free torch flame, by heat lamps or by any other suitable means capable of providing a uniform temperature throughout the part, unless otherwise specified herein. When a gas flame is used for preheating, the area to be welded shall be brushed clean of any soot accidentally deposited from the preheating flame before tacking or welding. Parts which have been preheated for welding may be cooled very slowly, preferably in the preheating furnace, after completion of the welding operation to avoid cracking or to improve dimensional control of complex assemblies.

3.4.4.2 Tacking. Tack welds shall be used as required. Wherever possible, the tack welds shall be spaced symmetrically along or around the joint. Tack welds shall be of sufficient size and length to permit ease of subsequent welding yet assure holding of the parts in place without cracking of the tack welds. Chipping or grinding shall be done to both ends of tack welds to fair in with base metal. Tack welds which have cracked must be removed.

3.4.4.3 Preparation of surfaces. Surfaces adjacent to the edges to be welded shall be free from grease or other foreign matter for a distance of two (2) inches and shall be as free as possible from oxide and protective coatings and any residual cleaning solvent which is harmful to the weld. (Cleaning with a wire brush or abrasive paper is a satisfactory method for removing oxides and protective coatings.)

3.4.4.4 Welding flux. The use of flux is mandatory in non-reducing and non-inert gas welding of all aluminum alloys and desirable in electric welding where the joint is not completely enveloped in inert gas. However, the flux should be used sparingly for most satisfactory results. The flux shall be thoroughly mixed with water (distilled water desirable but not mandatory), in the proper proportions to produce a thin paste. The paste shall be applied by dipping, or with a swab or brush. Flux which has hardened or caked shall not be used, unless it is reworked to a satisfactory consistency.

3.4.4.5 Flux removal. Residual welding flux shall be completely and promptly removed after welding, since corrosion will be accelerated if the flux is allowed to remain for any appreciable amount of time on the welded joint. Flux shall be removed by one of the following methods:

3.4.4.5.1 Acid dip method. Residual flux shall be removed by washing with water. Parts shall then be immersed in one of the following acid solutions, making sure that all surfaces are in contact with the solution, to remove all traces of flux:

a. Nitric-hydrofluoric acid cleaning. The solution shall consist of the following:

1 gallon technical nitric acid (58 - 62 percent HNO_3) (39.5° Be).

1/2 pint technical hydrofluoric acid (48 percent HF) (1.15 Sp).

9 gallons of water.

Parts shall be immersed for 3 to 5 minutes in cold acid solution.

b. Sulfuric acid cleaning. The solution shall consist of the following:

1 gallon technical sulfuric acid (93 percent H_2SO_4) (66° Be).

19 gallons of water.

Parts shall be immersed for 10 to 15 minutes in cold acid solution or 4 to 6 minutes at a temperature of 150°F.

c. Nitric acid cleaning. The solution shall consist of the following:

1 gallon technical nitric acid (58 - 62 percent HNO_3) (39.5° Be).

1 gallon of water.

Immerse parts for 5 to 10 minutes in cold acid solution.

d. Nitric-dichromate cleaning. The solution shall consist of the following:

1 pint technical nitric acid (58 - 62 percent HNO_3) (39.5° Be).

14 ounces sodium dichromate ($Na_2Cr_2O_7$).

1 gallon of water.

Immerse parts 5 to 10 minutes in hot acid solution (150°F).

3.4.4.5.1.1 Rinsing. After removal of the parts from the solution, they shall be washed in hot or cold running water, to thoroughly remove the acid. A dilute solution of chromic acid, sodium dichromate or potassium dichromate may be added to the rinse water as a corrosion inhibitor.

3.4.4.5.1.2 Treatment time. The treatment time with the above solutions depend on the age of the solution and the amount of flux remaining on the part after washing. The rinsing time depends upon the size and design of the part and the amount of water utilized. One half hour or less should be sufficient for acid removal.

3.4.4.5.2 Scrubbing method. Where the weld on castings is on a flat surface and in a readily accessible location, cleaning by vigorous scrubbing with a stiff bristle brush and running hot water shall be permissible.

3.4.4.5.3 Scrubbing and anodic treatment method. Flux shall be removed from the accessible surfaces by thoroughly scrubbing with water (preferably hot), and a scrub brush. For inaccessible locations, excess flux shall be removed as completely as possible from the surfaces by means of high pressure stream of water or by soaking in hot water for approximately fifteen (15) minutes. This shall be followed immediately by the anodic treatment specified in MIL-A-8625.

3.4.4.5.3.1 Use. The scrubbing and anodic treatment method shall be used only where frequent chemical analysis of the anodizing bath is possible. Its success over a long period of time depends largely on the effectiveness of the scrubbing methods used. The anodic treatment process will remove comparatively large amounts of flux, but this practice will soon prevent the formation of a satisfactory anodic film on any part, due to contamination of the bath. If, on analysis, the bath shows the presence of chlorides in excess of 0.02 percent, a new anodic bath shall be prepared or this cleaning method discontinued and the sulfuric acid method substituted.

3.4.4.5.4 Test for flux removal. At the discretion of the cognizant representative inspecting the operation, welds shall be tested to determine that the flux has been completely removed. The area adjacent to the weld shall be washed with distilled water to which a few drops of five (5) percent silver nitrate solution have been added. Further cleaning shall be required when a white precipitate is formed.

3.4.4.6 Welding.

3.4.4.6.1 Weld beads. Weld beads shall be terminated so as to avoid critical areas of the weld. The beads shall be smooth and shall be free of overlap, excessive undercut and excessive spatter. Sufficient metal shall be added to provide a suitable fillet or reinforcement, unless otherwise specified. The welds need not be sealed, when corrosion is not a factor, because fluxes were not used or alloys with good corrosion resistance were used. The authorized Government inspector may waive this requirement for non-critical areas not subject to possible entrapment of corrosive compounds.

3.4.4.6.2 Provisions.

a. Assemblies shall be welded in the flat position, when practical.

b. The back step and skip methods of welding shall be used to lessen warpage, when necessary.

c. Tabs, on which the arc can be struck or extinguished, shall be used, when practical, to minimize porosity at the beginning and end of the weld bead.

d. When manual welding multi-pass welds in circumferential joints in tubular sections or depositing continuous circular butt or fillet type welds, the first layer, when practical, should be deposited by welds in opposite quadrants.

e. All machine welding in circumferential or circular type joints shall be accomplished in a continuous single pass or a multiple stringer technique.

f. All groove welded joints, which are to be welded from both sides and which require one hundred percent penetration, shall be back gouged, as necessary, to ensure complete penetration of the joint. Normally, two or three passes shall be deposited on the first side prior to back gouging the back side. Back gouging shall be accomplished by chisel, grinder or other mechanical method to sound metal. Gouged areas shall be smoothed to fair in with adjacent metal.

g. The starts and stops of each weld bead shall be chipped or ground as necessary to remove cracks and visible porosity in the weld metal before depositing the subsequent weld bead.

h. The ground areas shall fair in smoothly with the adjacent metal.

i. Weld beads shall not terminate in inside corners or in other critical areas such as changes in welding direction or sudden changes in section thickness.

j. Corner welds may be a fillet weld, a butt weld, or a combination thereof.

k. Unless otherwise specified, there shall be complete penetration to the inside of the joint with a wash weld (melting of the penetrating metal with or without filler metal) permitted for contouring and blending. The outside of the joint shall blend smoothly with the adjacent metal, and unless otherwise specified, sufficient metal shall be added to provide a suitable fillet or reinforcement. In no case shall there be any evidence of holes or porosity through the metal or weld sag (drop-through).

l. When permitted by directives or proper authority, salvage of cracked castings may be accomplished by welding. The crack shall be chipped, ground or filed out when the section is heavier than 1/8 inch.

3.4.4.7 Heat treatment. Welded parts shall be reheat-treated, unless it can be ascertained that welds and weld regions of welded alloys, which depend upon heat treatment for their mechanical properties, possess the minimum design values specified on the drawing. The required pre-weld and post-weld heat treatment shall be specified on the drawing. Welded parts shall be furnished in a stress-relieved condition in all cases, except that, where severe restraint is absent and a corrosion resistant alloy (i.e. 1100, 3003, 5052, 6061) is employed, the cognizant representative may authorize omission of the stress-relieving treatment. Unless otherwise specified, heat treatment shall be in accordance with MIL-H-6088.

3.4.4.8 Post-weld cleaning. All welded assemblies shall be cleaned so as to be free of detrimental oxide, flux, scale or other foreign matter.

3.4.5 Soundness. Welds shall conform to the requirements of table IV, "Allowable Defect Limits," when inspected to 4.2.

3.4.5.1 Visual inspection. Visual inspection shall be required for all classes.

3.4.5.2 Penetrant inspection. Penetrant inspection shall be required for classes A-SP; A; and class B when specified on the drawing.

3.4.5.3 Radiographic inspection. Radiographic inspection shall be required for classes A-SP; A; and class B when specified on the drawing.

3.4.5.4 Ultrasonic inspection. Ultrasonic inspection may be substituted for radiographic inspection, 3.4.5.3, for certain applications when specified on the drawing.

3.4.6 In-process corrective action and repair of welded assemblies. All defects within the weld metal shall be corrected at the discretion of the cognizant inspector, provided the assemblies have not left the shop and before any subsequent operation is performed. The initial weld may be rewelded once, and if satisfactory assembly is not achieved, Material Review Board action shall be required as specified in 4.7.

3.4.6.1 Correction of defect-free welds. If the weld is otherwise acceptable, excessive weld underfill, undercut, low weld beads or crack-free craters shall be corrected by, laying an additional bead, joining the original weld and the base metal and filling the depression. If penetration can be obtained to the bottom of the corrected area, none of the original weld need be removed.

3.4.6.2 Correction of welds containing defects. Defects such as cracks, porosity, inclusions and surface imperfections must be removed from the original weld by machining, grinding or chipping prior to rewelding. Areas with inadequate joint penetration may have the weld deposit partially removed prior to rewelding. When one hundred percent penetration can be obtained in thin sections (up to 0.10 inch thick), cracks may be rewelded without prior removal of the weld deposit.

3.4.6.3 Correction of overlap and underbead defects. Unacceptable overlap and underbead defects shall be removed by dressing the weld deposit. Dressing of welds below the size indicated shall not be permitted.

3.4.6.4 Approval of corrective action. The cognizant inspector shall authorize the proposed corrective action specified in 3.4.6.1 through 3.4.6.3, when applicable. The area to be corrected shall be marked using the method of marking specified in 3.4.7.

3.4.6.5 Requirements for other types of defects. All other types of defects shall require Material Review Board action (see 4.7).

3.4.7 Marking. Each welded assembly shall be permanently marked by the contractor or his subcontractor so as to positively identify it with the welding operator who made the welds using a method of identification approved by the Government or contractor representative. This representative shall be provided with a list of the welding operators and their identifying symbols.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract or purchase order, the contractor is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract or purchase order, the contractor may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by 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.

4.1.1 Inspection records. Records, as specified herein, shall be on file at the contractor's facilities and available for review for six years.

4.2 Inspection of weldments.

4.2.1 Visual inspection. Visual inspection of all welds shall be accomplished in a well lit area using a 10X magnifier, when appropriate.

4.2.2 Penetrant inspection. Penetrant inspection shall be conducted in accordance with the requirements of MIL-I-6866.

4.2.3 Radiographic inspection. Radiographic inspection shall be conducted in accordance with the requirements of MIL-STD-453, quality level 2.

4.2.4 Ultrasonic inspection. Ultrasonic inspection shall be conducted in accordance with the requirements of MIL-STD-271.

4.3 Defect limits. Defect limits shall be in accordance with table IV.

4.4 Qualification and certification.

4.4.1 Procedure certification sampling. For consideration of procedure approval, the Government or contractor representative, when subcontracts are involved, shall select sufficient samples of welded assemblies, prepared under production conditions, to establish the quality of the welding (see 4.6.4). Insofar as it is practicable, he shall select samples made by different welders.

4.4.1.1 Procedure data. The following information, as applicable, shall be furnished with all welded specimens submitted for approval of procedure:

a. Manufacturer, type and serial number of welding machine.

b. Alloy identification of electrode or rod.

c. Nominal chemical analysis of electrode or rod.

d. Type and purity of gases used, rate of flow and flame characteristics.

e. Nominal composition or type of flux, if any.

f. Pre- and post-heat treatment, if any.

g. Welding parameters such as welding current, voltage, travel speed, shielding characteristics, position and all other significant elements required to produce a satisfactory weldment on a repetitive basis.

h. Welder's name and identification code.

i. Complete drawings of the application.

j. Date welded.

k. Requirements for determination of quality (see 4.6.4).

4.4.2 Requalification. Requalification of welders and welding procedure is required on a yearly basis within the anniversary month.

4.5 Maintenance-sampling for repair of castings. Three percent of the castings, repaired in relatively low stressed areas, shall be selected by the Government or contractor representative, when subcontracts are involved, from each welder's production for detailed radiographic inspection. Weld repairs of highly stressed areas of castings, when such repairs are permitted, shall be radiographically inspected 100 percent.

4.6 Test methods.

4.6.1 Radiographic inspection. Radiographic examination of groove welds shall be conducted as specified in 4.2.3.

4.6.2 Metallurgical examination. The preparation of microscopic and macroscopic specimens shall be in accordance with standard metallurgical practice or as specified in the contract. Microscopic examination shall be at 100X magnification or higher.

4.6.3 Other examinations. Welds shall be examined visually and, when necessary, by macroscopic and microscopic methods for the following items:

a. Fusion, including root and joint penetration.

b. Convexity, concavity and size of beads.

c. Undercutting and overlapping.

d. Cracks.

e. Porosity and inclusions.

f. Other metallic discontinuities.

In case of doubt, inspection of welds as specified in 4.2.2 through 4.2.4, inclusive, shall be required.

4.6.4 Certification destructive tests. The following tests are additional for procedure certification:

4.6.4.1 Tensile tests. Five (5) tensile specimens, 3/4 inch wide with a 1/2 inch reduced section, shall be removed from the certification groove weld test plate for tensile determination. The weld joint shall be transverse to the longitudinal axis of the specimen and with the weld joint bisecting the reduced section. These specimens shall be in the same condition as the finished production part insofar as those factors which would affect the efficiency of the weld joint are concerned (such as temper and weld reinforcement). The tensile results shall be considered satisfactory if the ultimate tensile strength exceeds the design criteria.

4.6.4.2 Bend tests. Transverse groove weld bend specimens and fillet weld bend specimens shall be removed from certification test plate and prepared as per MIL-STD-1595. The method of the bend tests and acceptance criteria of the bent samples shall conform to the requirements of MIL-STD-1595.

4.6.4.3 Chemical analysis. Two (2) samples (one from the weld metal and one from the base metal) shall be taken from the certification test plate to verify the base metal being welded and the filler metal, if used.

4.7 Material Review Board. The Material Review Board shall include a Government representative or a contractor representative when subcontracts are involved.

4.7.1 Action. Material Review Board action, including repair procedures, shall be required on the following types of defects:

a. Any defects extending into the base metal.

b. All cracks especially those at the fusion line between the weld deposit and the base metal.

c. Inadequate joint penetration in the first pass of a multipass weld that has been completed and submitted for final inspection.

d. Lack of fusion (see 3.4.4.6.2).

e. Excessive porosity.

f. Any defect in a welded assembly which has left the welding shop or gone through a subsequent operation.

4.7.2 Inspection of repair welds. Inspection of repair welds to the requirements of 4.2 shall be as follows:

a. Class A-SP and class A - 100 percent penetrant and radiographic inspection.

b. Class B - 100 percent penetrant inspection and radiographic inspection (minimum requirements) of the repaired area.

4.8 Certified test reports. The vendor of welded assemblies shall furnish, with each shipment containing class A-SP and class A welds, three copies of certified reports showing the results of tests of each lot to determine conformance to the requirements of this specification. The report shall include the contract or purchase order number, material specification number and revision letter, if any, this specification number, part number and quantity. Unless otherwise directed, radiographs of the welds shall be furnished with the report when applicable. Test reports of assemblies containing class B and class C welds shall be requested, if desired.

5. PACKAGING

5.1 Packaging requirements. Assemblies shall be packaged in accordance with the contract, purchase order, specification or drawing, whichever is applicable.

6. NOTES

6.1 General. The provisions of this section represent standard process definitions and intended use.

6.1.1 Methods. Descriptions of the process methods listed in 1.2.1 may be found in AWS A3.0, Welding Terms and Definitions.

6.1.2 Definitions of common defects.

a. Crack - A parting or cleft due to the fracture of solid material. Defects which have sharp corners or sharp tails shall be considered in the crack classification.

b. Incomplete fusion - The failure to fuse together adjacent layers of weld metal or adjacent weld metal and base metal.

c. Undercut - Narrow valleys or grooves parallel to the weld at the junction of the weld metal and base metal (toe of the weld).

d. Porosity - Elongated and globular voids, surface or subsurface.

e. Inclusions - Entrapped subsurface foreign particles.

f. Overlap - Protrusion of weld metal beyond the limits of fusion at the toe of the weld.

g. Arc strike - Pits or craters in the base metal caused by striking the arc outside of the area covered by the weld deposit.

h. Underfill - A depression or uniform concavity of the weld deposit in the top surface of the weld bead.

i. Penetration defects:

(1) Defects occurring on the side opposite that on which the welding was accomplished.

(2) Inadequate penetration.

(3) Melt through, underbead drop through.

6.2 Data required on purchase order or drawing.

a. Reference this specification, latest revision.

b. Class (if not class A).

c. Specify when radiographic inspection is required for class B welds (see 3.4.5.3).

d. Heat treatment, when required (see 3.4.4.7).

e. Specify when penetrant inspection is required for class B welds (see 3.4.5.2).

Custodians:
Army - MR
Navy - AS
Air Force - 11

Review activities:
Army - AV, EA, MI
Navy - MC, SH
Air Force - 79, 99

User activities:
Army - ME

Preparing activity:
Navy - AS

(Project No. THJM-0083)

TABLE I. Guide to the choice of rods for welding certain combinations of base metals.

Base metal alloy	443.0 356.0 1/	6061, 6063	5456	5086, 5356	5083	5052, 5652 2/	1100, 3003
1100, 3003	B	C	G	G	G	C	A
5052, 5652 2/	C	D	F	F	F	J	-
5083	G	F	E	F	E	-	-
5086	G	F	F	F	-	-	-
5456	G	F	I	-	-	-	-
6061, 6062, 6063, 6151	C	B, H	-	-	-	-	-
443.0, 356.0 1/	B, K	-	-	-	-	-	-

Code	Use rod
A	1100: for some applications 4043 is permissible.
B	4043.
C	4043: may use 5356, 5183 or 5556.
D	4043: may use 5183, 5356, 5554 or 5556.
E	5183: may use 5556 or 5356 (5356 is third choice).
F	5356: may use 5183 or 5556.
G	5356: may use 5183 or 5556; for some applications 4043 is permissible.
H	5356: may use 5183 or 5556; for some applications 4043 is permissible.
I	5556: may use 5183 or 5356 (5356 is third choice).
J	5652: may use 5183, 5356, 5554 or 5556; for some applications 4043 is permissible.
K	4047.

1/ Casting alloy designation:
a. 356.0 (new designation) replaces 356 (old designation).
b. 443.0 (new designation) replaces 43 (old designation).

2/ Use class 5654 filler metal for welding 5652 base metal for hydrogen peroxide service.

TABLE II. Shielding gases.

Gas	Description	Acquiring specification
Helium	Welding grade	MIL-P-27407
Argon	Welding grade	MIL-A-18455

TABLE III. Preheat temperatures.

Alloy designation	Condition	Maximum preheat temperature
1100, 3003	0	None
	H12, H14, H16, H18	None
5000 Series 1/	0	550°F
	H32, H34, H36, H38	550°F
2219, 6061, 6063	0	None
7005, 7039	T4, T6	None
443.0, 355.0, 356.0, 357.0 2/	All	None

1/ Avoid holding 5000 Series within temperature range of 150°F to 450°F. Use a fast heat up to temperature, not to exceed 550°F. Use fan cooling, when temperature drops to 450°F, so that minimum time is spent in 150°F to 450°F temperature range.

2/ For 355.0, 356.0 and 357.0 - time at temperature should be of very short duration.

TABLE IV. Allowable defects limits.

Defect	Class of welding			
	A-SP	A	B	C
1. Cracks	None	None	None	None
2. Mismatch	10% T or 0.06 in. 1/	10% T or 0.12 in. 1/	20% T or 0.18 in. 1/	20% T or 0.18 in. 1/
3. Porosity open to surface	None	1 per in. 2/	2 per in. 1/4 in. min. spacing 2/	3 per in. 1/4 in. min. spacing 2/
4. Undercut	None	10% T or 0.03 in. 1T max. length 1/	10% T or 0.05 in. 3T max. length 1/	20% T or 0.05 in. 5T max. length 1/
5. Incomplete penetration 3/	None	20% T or 0.03 in. depth 1/ 1T max. length	20% T or 0.05 in. depth 1/ 2T max. length	20% T or 0.05 in. depth 1/ 4T max. length
6. Cold shut 3/	None	1T 4/ or 0.1 in. 1/	1T max. length 4/	2T max length 4/
7. Overlap 3/	None	1T or 0.1 in. 1/	1T max. length	2T max. length
8. Concavity	None	20% T or 0.03 in. depth 1/ 1T max. length	20% T or 0.05 in. depth 1/ 1T max. length	20% T or 0.05 in. depth 1/ 1T max. length
9. Craters	None	20% T or 0.03 in. depth 1/ 1T max. length	20% T or 0.05 in. depth 1/ 1T max. length	20% T or 0.05 in. depth 1/ 2T max. length
10. Underbead drop through	0.04 in. maximum for T 0.04 in. 1/16 in. maximum for 0.41 T 0.100 in. 3/32 in. maximum for 0.101 T 0.250 in. 1/8 in. maximum for T 0.25 in.		Requirement only for clearance of mating parts	Requirement only for clearance of mating parts
11. Thinning	Not less than min. T	Not less than min. T	20% T or 0.05 in. 3T max. length 1/	20% T or 0.05 in. 5T max. length 1/
12. Accumulation of defects 3 to 10 inclusive	Not applicable	10T minimum between any 2 defects	6T minimum between any 2 defects	4T minimum between any 2 defects
13. Subsurface defects such as inclusions, porosity, incomplete fusion 5/	Max. dimension of any single defect shall be 25% T or 0.080 in., whichever is lesser. Accumulation shall be per curve, figure 1. Aligned defects shall be per 6/ 7/	Max. dimension of any single defect shall be 35% T or 0.10 in., whichever is lesser. Accumulation shall be per curve, figure 2. Aligned defects shall be per 6/ 7/	Same as for class A, if required	Not applicable

1/ Whichever is the lesser.

2/ Maximum size 30 percent of T or 0.10 inch, whichever is the lesser; T is plate thickness.

3/ If the defects exhibit sharp radii, sharp terminations or are crack-like, they shall be removed. If depression is not larger than permitted, they need not be rewelded.

4/ Where possible to determine, by metal removal, depth of cold shut shall not cause joint thickness to be less than thinnest material being welded.

5/ Any defect having a sharp termination or crack-like appearance shall be considered a crack. Two or more adjacent defects shall be treated as one when the space between them is less than the smallest defect.

6/ Aligned defects (4 or more) shall not be accepted when the spacing between them is less than three times the smallest defect.

7/ Aligned porosity, 1/64 inch and smaller, is acceptable in 1/4 inch length if less than 1/2 of length is composed of voids.

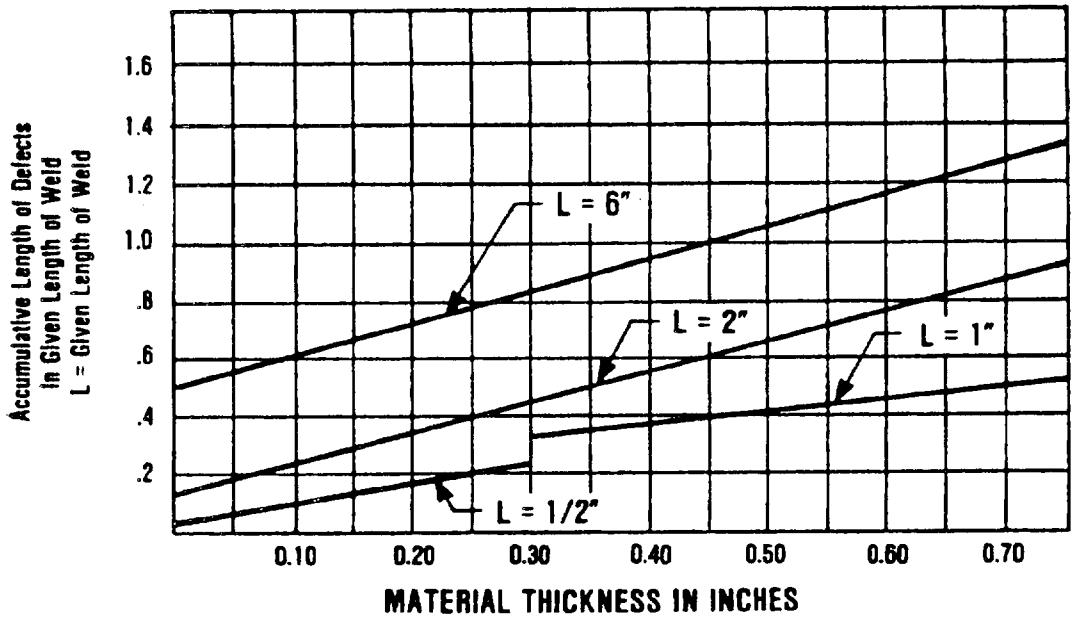

FIGURE 1. Allowable accumulation of subsurface defects for class A-SP welds.

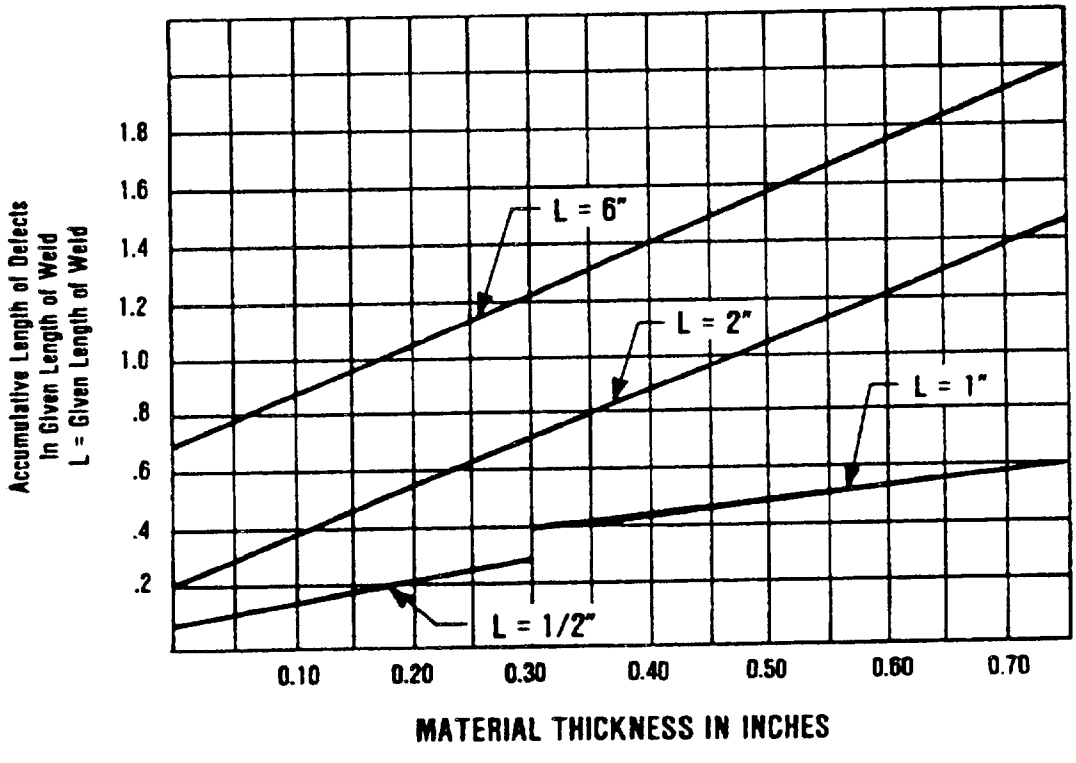

FIGURE 2. Allowable accumulation of subsurface defects for class A welds.

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