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MILITARY SPECIFICATION

WELDING, METAL ARC AND GAS, STEELS, AND CORROSION AND HEAT RESISTANT ALLOYS; PROCESS FOR

This specification has been approved by the Department of Defense and is mandatory for use by the Departments of the Army, the Navy, and the Air Force.

1. SCOPE

1.1 Scope. This specification covers the requirements for the manual or machine welding of steels and corrosion and heat-resistant alloys for aircraft use.

1.2 Classification. This specification covers the following types of processes:

oxy-acetylene

oxy-hydrogen

atomic hydrogen

electric arc, covered electrode

submerged arc

electric arc, inert gas shielded, consumable or non-consumable electrode

2. APPLICABLE DOCUMENTS

The following specifications, standards, drawings, and publications of the issue in effect on date of invitation for bids form a part of this specification:

SPECIFICATIONS

MILITARY

MIL-T-5021 — Tests; Aircraft Welding Operators' Certification

MIL-R-5031 — Rods; Welding, Corrosion and Heat Resisting Alloys

MIL-R-5632 — Rods; Steel, Welding (for Aircraft Applications)

MIL-E-6843 — Electrodes; Welding, Mild and Alloy Steel (for Aircraft Applications)

MIL-E-6844 — Electrodes; Welding, Corrosion and Heat-Resistant Alloys

MIL-I-6865 — Inspection; Radiographic

MIL-I-6866 — Inspection; Penetrant, Method of

MIL-I-6868 — Inspection Process, Magnetic Particle

MIL-I-6850 — Inspection Requirements, Non-Destructive; for Aircraft Materials and Parts

MIL-H-6875 — Heat Treatment of Steels (Aircraft); Process for

MIL-F-7516 — Flux, Welding, Corrosion and Heat Resisting Alloys

MIL-E-8697 — Electrodes, Welding, Ferrous, Covered, Heat Treatable

STANDARDS

FEDERAL

Test Method Std. 151
Metals; Test Method

PUBLICATIONS

ANC-5 Strength of Metal Aircraft Elements

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

3. REQUIREMENTS

3.1 Welder or Welding Operator. Welding shall be performed only by welder or welding operators who have met the requirements of Specification MIL-T-5021 for the particular group of materials and types of welding involved.

3.2 Equipment.

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

3.2.1.1 If the Government representative has reason to doubt the capability of any welding apparatus to function satisfactorily he shall require welder's certification tests as described in Specification MIL-T-5021 applicable to the type of work for which the equipment is intended. The tests are to be made by a welder certified for the material and type of welding, and selected by the authorized Government representative. Multiple operator sets shall be tested while the maximum number of operators are welding. If under these conditions the applicable requirements cannot be met, the equipment shall not be used until the necessary repairs, adjustments, or replacements have been made.

3.2.2 *Heating appliances.* Furnaces used for preheating parts prior to welding or for postheating parts after welding shall have suitable pyrometric controls such that the temperature varies not more than ± 25°F. Torches or induction heating coils may be used for preheating provided the specified temperature range is maintained by using a suitable contact pyrometer, acceptable temperature-indicating sticks, or acceptable temperature-indicating liquids.

3.3 Materials.

3.3.1 *Base Metal.* Steels with a carbon equivalent greater than 0.44% and hardenability greater than that of MIL-S-5000 shall not be welded without approval of the procuring agency. For such approval the proposed welding procedure details and test results of representative specimens, examined in accordance with methods specified in Section 4, shall be submitted. Carbon Equivalents may be determined by using the following formula:

$$C.E. = C + \frac{Mn}{6} + \frac{Mo}{4} + \frac{Cr}{5} + \frac{Ni + Cu}{15} + \frac{P}{3}$$

3.3.1.2 Corrosion and heat-resistant nickel-chromium steels shall not be welded unless they are of a composition which is stabilized against sensitization to intergranular corrosion, unless the maximum carbon content is 0.03% or less, or unless they are reheat-treated in accordance with Military Specification MIL-H-6875, Table I.

3.3.2 *Filler Metal.* Welding rods, welding wire, and electrodes used in the welding of steels and corrosion and heat-resistant alloys shall be capable of producing satisfactory welds when used by a certified welding operator with satisfactory welding apparatus, and shall have a composition suitable for producing welds conforming to the requirements specified herein. Coated electrodes used for welding mild and low alloy steel shall conform to Military Specification MIL-E-6843 or MIL-E-8697 as applicable. Coated electrodes used for welding corrosion or heat-resistant alloys shall conform to Military Specification MIL-E-6844. Rods used for the welding of mild and alloy steel shall conform to Military Specification MIL-R-5632. Rods used for welding corrosion or heat-resistant alloys shall conform to Military Specification MIL-R-5031. The filler metal used in the welding of dissimilar metals shall conform to the requirements of the procuring agency. The class of filler metal employed shall be compatible with the base metal in maintaining the mechanical properties and corrosion-resistance of the base metal.

3.3.3 *Flux.* Flux for gas welding of corrosion or heat-resistant alloys shall conform to the requirements of Military Specification MIL-F-7516. Fluxes shall not increase the carbon content of the weld metal significantly.

3.3.4 *Gases.* Gases shall be of a grade designated for welding.

3.4 Weld Design.

3.4.1 *General.* Welds of material .083 inch thick or less may be of the flange, butt, lap, or fillet joint, as applicable. Welds of material thicker than .083 inch shall be of the butt or fillet type as applicable. Lap joints may be used in material thicker than 0.083 inch subject to the approval of the inspector or, in the case of critical joints, to the approval of the procuring agency.

3.4.2 *Joint Design.* Joint design should, in general, be in accordance with the latest practices recommended by the American Welding Society.

3.4.3 *Accessibility.* All portions of a weld shall be accessible to proper removal of flux residues.

3.5 Welding Procedure.

3.5.1 *Procedure Certification.* Prior to engaging in production welding, the contractor shall demonstrate to the authorized government inspector the satisfactory quality of representative welds by means of the tests specified in Section 4. Procedure certification is intended to cover a technique of operations rather than a specific application and accordingly shall not be repeated for different weld assemblies, unless recertification is warranted by a break in the continuity of production, by a substantial increase in the complexity of the work being performed, or by substantial changes in procedure. In case of doubt, the necessity for recertification shall be determined by the authorized government inspector.

3.5.2 *Preparation of Surfaces.* Surfaces to be welded shall be free from grease or other foreign matter and shall be as free as possible from rust and protective coatings. Cleaning with a wire brush or abrasive paper may be used for removing rust and protective coatings. Where a wire brush is used it is recommended that its composition, insofar as practicable, be similar to the composition of the material being welded.

3.5.3 *Smoothness and weld contour.* Where

practicable, all weld joints shall fair into the adjacent metal in gradual, smooth curves. Beads shall be smooth and shall be free of slag, excessive undercut, or excessive spatter. Sufficient metal shall be added to provide a suitable fillet or reinforcement unless otherwise specified. Welds shall be sealed to prevent the entrance of air or moisture, except that the authorized government inspector may waive this requirement for non-critical areas manufactured of corrosion-resistant material or not subject to flux residues.

3.5.4 *Burning or burn-through.* Fusion through the full thickness of the base material, in areas other than those where 100% penetration is a requirement of joint design, shall not be acceptable when welding materials above 0.050 inch in thickness or in structural or in critical areas. In no case shall the weld metal be burnt (oxidized) or contain holes or pores through the material.

3.5.6 *Marking.* Each welded assembly shall be marked by the contractor so as to positively identify it with the welding operator who made the welds, using a method of identification approved by the Government representative. Identification shall remain on the part at least until final inspection and acceptance of welds. Permanent marking, such as impression stamping, shall not be applied to critically stressed areas, but permanent marking shall be used when not injurious to the serviceability of the part.

3.6 Mechanical characteristics.

3.6.1 Plain carbon and low alloy steels: Welded assemblies in plain carbon and low alloy steels shall be classified as (a) assemblies for which a quench and temper type heat treatment after welding is specified on the applicable drawing (b) assemblies for which a normalizing or annealing heat treatment after welding is specified on the applicable drawing, and (c) other assemblies.

Type (a) assemblies, sampled as described in paragraph 4.2.1, shall conform to the prescribed mechanical strength level and to the bend test requirements of MIL-E-8697 for that strength level.

Type (b) assemblies, sampled as described in paragraph 4.2.1, shall meet the minimum strength values in ANC-5.

Type (c) assemblies, sampled as described in paragraph 4.2.1, shall meet the minimum strength values in ANC-5, shall have a hardness in the heat-affected weld zones not greater than Rockwell C-35 and shall withstand cold bending without cracking through an angle of 180 on a radius equal to twice the material thickness.

Strength and ductility requirements may be waived by the procuring agency upon submission of satisfactory data demonstrating that weld areas not conforming thereto will be satisfactory for the intended application.

3.7 General.

The increase in grain size of weld-affected zones over that of the base metal shall not be equivalent to more than three numbers in the ASTM scale and in no case shall the grain size be coarser than ASTM No. 3 as listed in Federal Std. 151.

In general component parts entering into weld assemblies should be normalized or annealed, in order to meet the requirements for grain size, bend, and freedom from cracking.

3.7.1 *Corrosion and heat-resistant steels.* See paragraph 3.3.1.2. The corrosion resistance of the material shall be as little affected by welding as is compatible with the best welding practice.

4. QUALITY ASSURANCE PROVISIONS

4.1 General. All parts welded in accordance with this specification shall be subject to inspection by authorized government representatives who shall be given all reasonable facilities to determine conformance with the requirements of this specification.

4.2 Procedure certification.

4.2.1 *Sampling for procedure certification.* For consideration of procedure approval, the contractor shall select sufficient samples of welded assemblies, prepared under production conditions, to establish the quality of welding. Insofar as it is practicable, he shall select samples made by different welding operators. The method of selecting samples and number of samples shall be satisfactory to the government representative.

4.2.2 *Procedure data.* The following information, as applicable, shall be furnished the government representative with all welded specimens, submitted for consideration of approval of procedure (tests conducted and data submitted for the certification of welding operators under Specification MIL-T-5021 may also be used for procedure certification):

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

(b) Brand 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.

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

(g) Welding operator's name and identification symbol.

(h) Drawings of the application.

(i) Date welded.

4.2.3 *Tests for procedure certification.* The following tests, in sufficient number to establish the quality of welding, shall be employed for certification of contractor's procedure:

Visual inspection (paragraph 4.3.2)

Magnetic particle inspection (paragraph 4.3.2)

Penetrant inspection of non-magnetic materials (paragraph 4.3.2)

Radiography (paragraph 4.3.2.1)

Tensile and bend (MIL-T-5021 or MIL-E-8697, as applicable)

4.3 Quality control of production.

4.3.1 *Sampling for inspection.* Not less than 5 per cent of the representative noncritical weldments from each welding operator's production shall be selected for inspection. All critical weldments shall be selected for inspection. Critical weldments shall be defined as one, the single failure of which during any operating condition would cause loss of the aircraft or one of its major components, loss of control, unintentional release of, or inability to release any armament store, failure of gun installation components, or which may cause significant injury to occupants of the aircraft. The method of selecting samples shall be acceptable to the government representative.

4.3.2 *Inspection for production.* Subsequent to heat treatment the welds and their adjacent areas of all samples selected as in paragraph 4.3.1 shall be subjected to detailed visual inspection and to magnetic particle or penetrant inspection. Where necessary, this examination shall be supplemented by macroscopic and microscopic inspection of representative parts 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.

4.3.2.1 In addition, at least 1 per cent of the representative critical weldments from each welding operator's production shall be spot checked by radiography for items 4.3.2 (a), (d), (e), and (f) above. Radiography may be waived by the government representative in applications where the geometry

of the joint or other considerations render radiography incapable of adding to the information obtained under paragraph 4.3.2.

4.4 **Quality control of repair welds.**

4.4.1 *Sampling repair welds.*

All repairs in critically stressed assemblies welded from wrought material, or in castings classified as class I under Military Specification MIL-C-6021, where such repairs are permitted shall be subject to inspection. Not less than ten (10) per cent of repairs in non-critically stressed assemblies welded from wrought material, or in class II castings shall be selected for inspection. The method of selecting samples shall be acceptable to the government representative.

4.4.2 *Inspection of repair welds.* All samples selected as in paragraph 4.4.1 shall be subject to the requirements of paragraph 4.3.2.

4.4.2.1 *Radiographic inspection.* One hundred (100) per cent of the repairs in class I castings or critically stressed assemblies welded from wrought material, and three (3) per cent of the repairs in class II castings or non-critically stressed assemblies welded from wrought material shall be checked by radiography for items 4.3.2 (a), (d), (e), and (f) above.

4.4.2.2 Where examination of a welder's or welding operator's production reveals unsatisfactory welding quality, additional weldments by that operator may be taken as deemed necessary by the Inspector for examination by any means to insure satisfactory weld quality.

4.5 **Test methods.**

4.5.1 Magnetic particle inspection shall be performed in accordance with the requirements of Military Specification MIL-I-6868.

4.5.2 Penetrant inspection shall be performed in accordance with the requirements of Military Specification MIL-I-6866.

4.5.3 Radiographic inspection shall be performed in accordance with Military Specification MIL-I-6865.

4.5.4 The preparation of microscopic and macroscopic specimens shall be in accordance with standard metallographic practice. Macroscopic inspection for defects should be conducted at magnifications below 40 diameters. Microscopic examination for grain size, melting, etc., shall be conducted at 100 diameters magnification or higher.

4.5.5 Hardness and tensile testing shall be in accordance with Federal Test Method Standard 151.

5. **PREPARATION FOR DELIVERY.** Not applicable.

NOTES

6.1 **General.** The provisions of this section represent recommended practice and are not mandatory.

6.2 Preheating of weldments may be employed for the following purposes:

To reduce distortion during welding.

To prevent cracking during or immediately after welding.

To prepare the weldment for postheating.

6.2.1 Preheating requirements will vary considerably with the base metal composition and the filler metal characteristics. In general, the preheating procedures necessary to prevent cracking will be furnished by the vendor of the filler metal.

6.3 Post heat treatments of weldments may be classified as follows:

Quench and temper heat treatments for maximum strength.

Normalizing to refine grain, increase ductility, and improve machineability.

Stress relieving to reduce distortion during subsequent machining.

Controlled cooling (austempering) to prevent cracking.

Carbide solution treatment of corrosion-resistant steels to minimize sensitivity to intergranular corrosion.

Stress relieving to reduce residual stresses.

6.3.1 Recommended quench and temper heat treatments are listed in MIL-E-8697.

6.3.2 Normalizing should be performed in accordance with the requirements of MIL-H-6875 after final welding of the parts.

6.3.3 Stress relieving may be accomplished as follows:

(1) The areas to be welded should be preheated to the temperature noted in Table I immediately before welding.

TABLE I

PREHEATING

Carbon Content (%)	Hardenability Equivalent to	Preheat & Interpass Temp. (°F. Min.)
0.15 or less		None required
0.16 through 0.35	Plain carbon steels	200
0.16 through 0.33	SAE 4130 and NE 8630 steels or alloy of equal or lower harenability	400
0.34 through 0.43	Steels with hardenability higher than above	475-750
0.44 and higher	(*)	(*)

(*) Steels in this carbon range should not be welded unless the welding procedure is specifically approved by the procuring agency. (See paragraph 3.3.1)

(2) After the heat-affected weld zones have cooled to room temperature, the weld and heat-affected areas should be tempered (stress-relieved) by furnace heating or by torch heating locally using a "soft" gas flame, or by induction heating, in a temperature range of 1000 — 1200°F.

(3) For each specific joint involving significantly different gauges of material, mass or joint design, the minimum time necessary within the above temperature range to insure compliance with the requirements herein should be determined and incorporated in the procedure.

6.3.4 The controlled cooling (martempering) of heat-affected zones may be performed as follows:

(1) Prior to welding, the material should be pre-heated locally or in a furnace to a temperature above the Ms point of the base metal.

(2) Immediately after welding, the heat-affected zones should be held within the above temperature range for a minimum period of 10 minutes.

6.3.5 Preheating should be accomplished by one of the following methods:

(a) In a furnace.

(b) By one or more torches so arranged as to produce and to maintain a uniform temperature. The required temperature range should be maintained by using a suitable contact pyrometer or other acceptable temperature measuring methods.

(c) Any other method providing an equivalent degree of control.

During welding the preheated part should be maintained at the preheat temperature by satisfactory methods, such as an arrangement of torches and by use of satisfactory insulating materials or an induction coil to prevent the rapid dissipation of heat.

6.4 Ventilation. Suitable blowers, exhausters, or other approved safety devices shall be provided where needed to protect personnel against fumes resulting from flux, filler rods, etc.

Custodians:
Army—Ordnance Corps
Navy—Bureau of Aeronautics

Other interests:
Army—T
Navy—Or

Preparing Activity:
Navy—Bureau of Aeronautics

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Standardization Section, Code: AIR-52021
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STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

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