

MIL-T-8973

12 September 1969

MILITARY SPECIFICATION

TUBING, STEEL, CORROSION AND HEAT RESISTANT, FOR
AEROSPACE VEHICLE HYDRAULIC SYSTEMS ASSEMBLED BY BRAZING

This specification has been approved by the Department
of the Air Force and by the Naval Air Systems Command.

1. SCOPE

1.1 Scope. This specification covers thin wall close-tolerance 1/8 hard tubing to 1-5/8 inches outside diameter suitable for use in high-pressure hydraulic or pneumatic systems assembled with brazed joints.

1.2 Classification. Tubing shall be furnished in the following compositions, as specified (see 6.2).

Composition designation

304L - Extra low carbon

316L - Extra low carbon

321 - Titanium stabilized

347 - Columbium or columbium plus tantalum stabilized.

2. APPLICABLE DOCUMENTS

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

STANDARDSFederalFed. Test Method
Std. No. 151

FED-STD-183

Metals; Test Methods

Continuous Identification
Marking of Iron and Steel
ProductsMilitary

MIL-STD-163

Steel Mill Products,
Preparation for Shipment
and Storage

FSC 4710

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MIL-STD-753

Corrosion-Resistant Steel Parts,
Sampling, Inspection and Testing
for Surface Passivation

MS33584

Tubing End, Standard Dimensions for
Flared

MS33611

Tube Bend Radii

AND10104

Tubing, Steel, Corrosion-Resistant,
Round, Standard Dimensions for

(Copies of specifications, standards, drawings, and publications required by suppliers in connection with specific procurement functions should be obtained from the procuring 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.

United States of America Standards Institute

USAS B46.1 Surface Texture (Surface Roughness, Waviness, and Lay)

(Application for copies should be addressed to the United States of America Standards Institute, 10 East 40th Street, New York, New York 10016.)

American Society for Testing and Materials.

ASTM E8

Methods of Tension Testing of
Metallic Materials

ASTM E112

Estimating the Average Grain Size
of Metals

(Application for copies of ASTM standards should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.)

3. REQUIREMENTS.

3.1 Material. The materials shall be manufactured by the electric furnace process. Heat treating shall be accomplished in air or protective atmosphere which will provide a smooth gray surface free from carburization, nitriding, or other deleterious surface conditions.

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3.1.1 Manufacturing processes. Tubing may be manufactured by any process which provides a product which complies with this specification. Tubes shall be cold drawn to the table I properties.

Table I. Limits of depth of discontinuities

Nominal wall thickness (inch)	Maximum permissible depth of discontinuities
0.020 and under	10 percent of nominal wall thickness
.021 through .030	0.002 inch
.031 through .040	.0025 inch
.041 through .074	.003 inch

3.2 Chemical composition. The chemical composition shall conform to table II.

Table II. Chemical composition limits

Element	Composition limits (percent)								Check analysis tolerance (percent)
	304L		316L		321		347		
	Min	Max	Min	Max	Min	Max	Min	Max	
Carbon		0.03		0.03		0.08		0.08	+0.005
Manganese		2.00		2.00		2.00		2.00	+0.04
Phosphorus		0.040		0.040		0.040		0.040	+0.005
Sulphur		0.030		0.030		0.030		0.030	+0.005
Chromium	18.0	20.0	16.0	18.0	17.0	20.0	17.0	20.0	±0.20
Nickel	8.0	11.0	10.0	14.0	9.0	12.0	9.0	13.0	±0.15
Silicon		1.00		1.00		1.00		1.00	+0.05
Copper		0.50		0.50		0.50		0.50	+0.05
Columbium	--	--	--	--	--	--	--	1.10 ^{1/}	+0.05
Titanium	--	--	--	--	--	0.75 ^{2/}	--	--	+0.05
Molybdenum		0.50	2.00	3.00		0.50		0.50	+0.10

1/ The sum of the columbium content plus the tantalum content shall be not less than 10 times the carbon content.

2/ The ratio of titanium to carbon shall be not less than 5 to 1.

3.3 Grain size. The average grain size of tubing shall be 6 or finer, as determined by the method cited in 4.6.

3.4 Corrosion resistance

3.4.1 Resistance to acidified copper sulfate solution. Tubes shall exhibit no evidence of intergranular embrittlement after exposure to boiling acidified copper sulfate solution at the conditions specified in 4.7. Continuous or frequent localized areas of grain delineation at the surface (more than five in a field of view at 20X magnification) shall be cause for rejection.

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3.5 Dimensions and tolerances

3.5.1 Sizes. Tubing shall be furnished in standard diameters 1/4 inch and over, and wall thicknesses indicated in AND10104, or as specified in the contract or purchase order (see 6.2).

3.5.2 Tolerances. The variation between measured outside diameter (OD) (including ovality) and nominal dimensions of tubes 1 inch or less in outside diameter shall not exceed +0.003, -0.000 inch. For tubing over 1 inch OD the tolerance shall be +0.006, -0.000 inch. Wall thickness variations shall not exceed +15 percent, -0 percent of nominal wall thickness when measured as specified by 4.4.

3.5.3 Weld. In welded tubing there shall be no dimensional indication whatever of the presence of a weld at either inside or outside surfaces.

3.5.4 Surface roughness. For tubing 1/4 inch OD and over, surface roughness shall not exceed an arithmetical average roughness height rating (RHR) of 70 on inside surfaces or RHR 40 on outside surfaces as defined by USAS B46.1 (see 4.14). Individual surface defects of depth exceeding the limits of table I shall be rejected.

3.5.4.1 Discontinuities having large root radii plainly visible to the unaided eye, whose surfaces blend smoothly into the normal tubing surfaces and which do not exceed table I depth or specified wall thickness tolerances, are acceptable. Outer surface discontinuities whose depths are visually indeterminate shall be removed by light belt polishing or buffing.

3.5.5 Tube length. Tubing may be ordered to exact lengths or to lengths expressed as a multiple of a stated length, with tolerances as specified by contract or purchase order (see 6.2).

3.5.5.1 Mill lengths. When exact or multiple lengths are not specified, tubing will be accepted in mill lengths of 5 to 20 feet. Not more than 10 percent of any order shall be furnished in lengths shorter than 12 feet.

3.5.6 Straightness. Departure from straightness shall not exceed 0.060 inch in a length of 3 feet.

3.6 Passivity. Surfaces shall be passive when tested in accordance with 4.8.

3.7 Mechanical properties. Mechanical properties shall conform to table III, when tested in accordance with 4.9.

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Table III. Mechanical properties

Yield strength, 0.2 percent offset (psi)	Elongation, minimum (percent)	
	Full Section	Strip
75,000 - 110,000	20	15

3.8 Bending. Tubes shall conform to the requirements of MS33611 and shall show no evidence of cracking or splitting when bent in accordance with 4.10.

3.9 Flaring capability. One end of each piece of tubing shall be flared to 50 percent increase in diameter or to the dimensions of MS33584, whichever is less, without cracking or forming other visible defects (4.11). Tubing with intermediate nominal OD shall be flared to the same percentage increase in diameter as required for the next larger nominal size. After flaring, the inner and outer surfaces shall be smooth and sound, and capable of forming pressure-tight joints with standard fittings. Removal of the flared portion after inspection is optional.

3.10 Hydrostatic pressure capability. Tubing shall be capable of withstanding an internal hydrostatic pressure P or 15,000 psi, whichever is less, without bulging, leakage, or other defects, except that any diametric permanent set not to exceed 0.002 inch per inch of outside diameter is permissible. Hydrostatic test pressure shall be calculated according to the following formula:

$$P = \frac{S (D^2 - d^2)}{D^2 + d^2}$$

where: P = test pressure in psi
 S = specified minimum yield strength, psi
 D = maximum permissible OD (nominal OD plus tolerance), inch
 d = maximum permissible inside diameter, inch
 (computed as D less twice the minimum permissible wall thickness)

3.11 Identification of product. Tubing over 1/4 inch in outside diameter shall be marked in accordance with Federal Standard 183. The markings shall include the following items:

Specification number
 Composition designation
 Heat number of the steel
 Nominal outside diameter
 Nominal wall thickness

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3.11.1 Unless identified in accordance with 3.11, tubes 1/4 inch and less in OD shall be securely bundled and identified by metal tags stamped with the above information and securely attached at each end of the bundle.

3.12 Workmanship

3.12.1 Surface appearance. Surfaces of tubing shall be smooth, uniform, and free from defects such as seams, tears, laminations, pits, or grooves and shall have a bright or gray metallic appearance and be free from surface films, discoloration, scale, flakes, or loose or adherent particles.

3.12.2 Surface processing. All chemical bath residues shall have been removed by rinsing in flowing water, followed by thorough drying. Centerless grinding and grit blasting of outer and inner surfaces are not acceptable. Light belt polishing or buffing is permissible; however, tubing shall not be sized by metal removal methods.

3.12.3 Surface condition. When tested as specified by 4.12, differences in color and appearance between the two halves of a specimen (one of which was immersed) other than minor changes in color and texture, shall be cause for rejection.

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 in the contract or order, the supplier may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the procuring activity. The procuring activity 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 On direct procurement by the DOD, each axial (flared by methods other than spinning) flaring test specimen and five percent of the specimens subjected to surface condition tests shall be forwarded subsequent to testing by the supplier to the testing laboratory designated by the procuring activity (see 6.3). One copy of the certified test report shall accompany the specimens.

4.2 Classification of tests. All tests specified herein for the testing of tubing are classified as quality conformance tests.

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4.3 Lot. Except for chemical analysis (4.5), flaring test (4.11), and examination of product (4.4), a lot shall consist of tubing of one size and wall thickness from one heat of steel, and annealed in the same charge (batch anneal) or annealed at the same temperature, time, and atmosphere, without interruption in a continuous furnace, within a 24-hour period.

4.4 Examination of product. Each length of tubing shall be visually examined for compliance with workmanship requirements (3.12). Samples selected in accordance with table IV shall be examined for conformance with dimensions and tolerances (3.5), identification marking (3.11), and preparation for delivery (section 5). The OD of tubing shall be measured at three orientations, 60 degrees apart, at one end of each tube for compliance with 3.5.2.

Table IV. Sampling plan

Lot size (tubes)	Sample size	<u>1/</u> Acceptance number	<u>1/</u> Rejection number
1 to 3	all	0	1
4 to 25	4	0	1
26 to 65	6	0	1
66 to 180	13	0	1
181 to 300	20	1	2
301 to 800	32	2	3
Over 800	50	3	4

1/ The accept-reject numbers apply to the total number of defects uncovered.

4.5 Chemical tests

4.5.1 Sampling. A sample of material shall be selected from each heat of steel, and prepared as specified in Method 111 or 112 of Federal Test Method Standard No. 151.

4.5.1.1 Samples for chemical analysis may be waived, provided all the material under inspection can be identified as being made from a heat previously analyzed and found to be in conformance with the chemical composition specified herein.

4.5.2 Method. Analysis shall be by Method 111 or 112 of Federal Test Method Standard No. 151. In the event of a dispute, analysis shall be by Method 111, as applicable.

4.6 Grain size

4.6.1 Sampling. One specimen shall be selected to represent each lot of tubing.

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4.6.2 Method. Specimens shall be prepared and tested in accordance with ASTM Method E112 and the grain size evaluated using plate 2 of E112 for comparison. In the event of doubt concerning grain size as determined by comparison with plate 2, the Heyn Intercept Method of E112 shall be used. The average grain size shall be the average of five fields of view on each specimen (see 3.3).

4.7 Corrosion susceptibility (acidified copper sulfate test)

4.7.1 Sampling. This test is not normally required except when compliance with chemical composition requirements is marginal.

4.7.2 Method. Two specimens of the "as received" tubing (full sections whenever practicable) shall be treated for a period of 48 hours in a boiling copper sulfate-sulfuric acid solution of the following formula:

Copper sulfate ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$) - 10 g

Sulfuric acid (H_2SO_4) sp gr 1.84 - 10 ml

Water (distilled) - 90 ml

The specimens shall be covered with a minimum of 30 milliliters (ml) of this solution per square inch of specimen surface area. A reflux condenser or similar device shall be used to prevent change in concentration of the solution. After exposure, full-section specimens shall be flattened between parallel plates by a gradually applied load normal to the axis of the tubing until the distance between the pressure plates is not greater than four times the wall thickness. Sector specimens of tubing over 0.625 inch OD shall be subjected to reverse bending about a diameter equal to double the wall thickness. In the flattening or bending, the fold shall be along a weld zone if the specimen is of welded tubing. When examined at a magnification of 20 diameters there shall be no evidence of cracking or defects due to embrittlement of the metal.

4.8 Passivity

4.8.1 Sampling. One sample shall be selected to represent each lot of tubing.

4.8.2 Method. Specimens shall be tested in accordance with Methods 102 or 103 of MIL-STD-753.

4.9 Tensile test

4.9.1 Sampling. Two samples shall be selected to represent each 2,000 feet of tubing of each lot up to 5,000 feet, and two additional specimens from each additional 5,000 feet.

4.9.2 Method. Samples shall be tested as full-tube specimens with a test section of not less than 6 inches between plugs, as required by ASTM E8, figure 11 entitled "Metal Plugs for Testing Tubular Specimens, Proper Location of Plugs in Specimen and of Specimen in Heads of Testing Machine." In larger diameters of tubing, type T1 or T2 specimens may be used. Tests shall comply with the applicable requirements of ASTM E8.

4.10 Bending test

4.10.1 Sampling. One specimen of suitable length shall be selected from each lot.

4.10.2 Method. The specimen shall be bent cold 180 degrees around a suitable mandrel of diameter equal to three times the OD of tubing 1 inch OD and under. The bend diameter of four times the OD is required for tubing over 1 inch and to 1-3/4 inch OD. A bend diameter of five times the OD is required for tubing over 1-3/4 inch OD. At the completion of the test the specimen shall be examined for conformance to 3.8.

4.11 Flaring tests

4.11.1 Sampling. One end of each tube or specimen cut from each tube shall be flared by spinning or by forcing axially over a tapered pin, except that not less than 13 specimens from each lot, or 1 from each tube comprising lots of less than 13, shall be tested by the latter method. For flare test without spinning, the specimen shall be 1 inch or 1.5 diameters in length, whichever is larger.

4.11.2 Method. The end of each specimen to be flared without spinning shall be cut square, with the cut end smooth and free from burrs but the corners not rounded. The specimen shall, at room temperature, be forced axially by steady pressure over a hardened and polished tapered steel pin to produce the tubing flare configuration specified by 3.9. Both the tube and pin shall be clean and dry during the flaring operation. Surfaces of flares shall be examined at magnification of 3 to 5 diameters for freedom from cracks and other defects which would prevent sealing against mating surfaces of standard flared fittings.

4.12 Surface condition. A 1-foot section shall be selected from each lot of tubing and split lengthwise. The exposed inner surface shall be examined for surface roughness. One half shall be immersed in an aqueous solution of 15 percent nitric acid and 3 percent hydrofluoric acid by volume at 100° to 120°F for a period of 15 minutes. After immersion, the half tube shall be washed and dried. The two halves shall then be compared as to the appearance of inner and outer surfaces. Differences in color and appearance, other than minor changes in shade and texture, shall be cause for rejection.

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4.13 Cleanliness of tubing. Wads of firmly compacted clean white cloth or fibrous material shall be forced through the bore of each of two sample tubes selected from each lot, and any soiled areas examined at 10 diameter magnification for the presence of grit, metallic flakes, or other detrimental materials. The presence of such particles shall be cause for rejection.

4.14 Surface roughness. Surface roughness shall be determined on the surface condition test sample (4.12) in conformance with USAS B46.1.

4.15 Hydrostatic pressure resistance.

4.15.1 Sampling. Two tubes shall be selected to represent each lot.

4.15.2 Method. Each specimen, not less than 2 feet in length, shall be subjected to internal hydrostatic pressure calculated in accordance with 3.10. Each specimen shall be subjected to two pressure applications, with the calculated pressure to be maintained at least 2 minutes during each cycle. The rate of pressure change shall not exceed 25,000 psi per minute.

4.16 Rejection and retest. The failure of any sample to conform to any requirement considered a lot characteristic (chemical composition, mechanical properties, grain size, weld quality, or corrosion susceptibility) shall cause rejection of the lot with no retest permitted. Failure of a sample to conform to requirements not lot characteristics (surface condition, cleanliness, dimensions, bending, etc) shall cause rejection of the individual tubes from which the specimens were obtained. The remainder of the lot shall, at the option of the supplier, be rejected or reprocessed to assure compliance with the specification, and the tubes individually inspected.

5. PREPARATION FOR DELIVERY

5.1 Preparation for shipment. Unless otherwise specified, tubing for direct shipment to the Government shall be prepared for shipment in accordance with level A of MIL-STD-163 (see 3.11). The ends of each tube shall be sealed with plastic plugs.

5.2 Marking of shipments. Shipping containers shall be marked in accordance with MIL-STD-163.

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6. NOTES

6.1 Intended use. Tubing procurable to this specification is intended for use in high-pressure hydraulic and pneumatic systems assembled with brazed sleeve joints between tubes and fittings, and operating over a temperature range whose maximum does not exceed 1200°F (at low stress levels). The tubing is suitable for use in moderately corrosive or oxidizing environments. The steels represented are weldable; however, for reasons of economy, tubing for use with welded fittings and tubings less than 1/4 inch OD should be procured to MIL-T-8808.

6.2 Ordering data. Procurement documents should specify the following:

- a. Title, number, and date of this specification
- b. Composition designation (see 1.2)
- c. Length (when exact lengths are required)
- d. Outside diameter, wall thickness (3.5.1)
- e. Level of packaging required (see 5.1)
- f. A warranty clause pursuant to paragraph 1.324.7 of the Armed Service Procurement Regulation, applicable to such time as the tubes are installed in an air vehicle, should be included in all contracts.

6.3 Procuring activity testing laboratory. Specimens to be examined by the Government subsequent to testing (see 4.1.1) shall be forwarded to the Aeronautical Materials Department, Naval Air Development Center, Johnsville, Pa. 18974. Specimens shall be identified with the contract or order number, name of manufacturer, heat number(s), and wall thickness(es).

Custodians: -
Air Force - 11
Navy - AS

Preparing activity:
Air Force - 11

Project No. 4710-F0224

Review activity:
Air Force - 82

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