



AEROSPACE MATERIAL SPECIFICATION

AMS5561™

REV. H

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Revised 2021-10

Superseding AMS5561G

Steel, Corrosion and Heat-Resistant, Welded and Drawn or Seamless and Drawn
Tubing

9.0Mn - 20Cr - 6.5Ni - 0.28N

High-Pressure Hydraulic

(Composition similar to UNS S21900)

RATIONALE

AMS5561 has been revised and updated to comply with the SAE Five-Year Review policy. The revised document prohibits unauthorized exceptions (3.7, 4.4.1, 5.2.1, 8.5), updates composition testing (3.1), specifies passivation (3.3.1), updates cleanliness testing (3.5.2), revises NDT specification (3.5.4), adds country of origin (4.4), and allows prior revisions (8.4).

1. SCOPE

1.1 Form

This specification covers a corrosion and heat-resistant steel in the form of welded and drawn or seamless and drawn tubing.

1.2 Application

This tubing has been used typically for parts, such as fluid lines, subject to high pressures and requiring corrosion resistance, but usage is not limited to such applications. Tubing has good oxidation resistance up to 1100 °F (593 °C).

1.3 Classification

1.3.1 Tubing, covered by this specification, is classified by form of fabrication as follows:

Type 1 - Welded and drawn

Type 2 - Seamless and drawn

1.3.1.1 If no type is specified, Type 1 shall be supplied.

1.3.2 Tubing, covered by this specification, is classified by quality evaluation as follows:

Class 1 - 0.125 inch (3.18 mm) length Ultrasonic Calibration

Class 2 - 0.060 inch (1.52 mm) length Ultrasonic Calibration

Class 3 - Ultrasonic testing not required

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1.3.2.1 If no class or Class 1 is specified, Class 1 or Class 2 may be supplied. If Class 3 is specified, any of the three classes may be supplied.

2. APPLICABLE DOCUMENTS

The issue of the following documents in effect on the date of the purchase order forms a part of this specification to the extent specified herein. The supplier may work to a subsequent revision of a document unless a specific document issue is specified. When the referenced document has been cancelled and no superseding document has been specified, the last published issue of that document shall apply.

2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), or www.sae.org.

AMS2243 Tolerances, Corrosion and Heat-Resistant Steel Tubing

AMS2248 Chemical Check Analysis Limits, Corrosion and Heat-Resistant Steels and Alloys, Maraging and Other Highly-Alloyed Steels, and Iron Alloys

AMS2371 Quality Assurance Sampling and Testing, Corrosion and Heat-Resistant Steels and Alloys, Wrought Products and Forging Stock

AMS2700 Passivation of Corrosion Resistant Steels

AMS2807 Identification, Carbon and Low-Alloy Steels, Corrosion and Heat-Resistant Steels and Alloys, Sheet, Strip, Plate, and Aircraft Tubing

ARP1917 Clarification of Terms Used in Aerospace Metals Specifications

2.2 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, or www.astm.org.

ASTM A262 Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

ASTM A370 Mechanical Testing of Steel Products

ASTM A751 Chemical Analysis of Steel Products

ASTM A1016/ASTM A1016M General Requirements for Ferritic Alloy Steel, Austenitic Alloy Steel, and Stainless Steel Tubes

ASTM E112 Determining Average Grain Size

ASTM E426 Electromagnetic (Eddy-Current) Examination of Seamless and Welded Tubular Products, Titanium, Austenitic Stainless Steel and Similar Alloys

2.3 ASME Publications

Available from ASME International, 22 Law Drive, Box 2900, Fairfield, NJ 07007-2900 or www.asme.org.

ASME B46.1 Surface Texture

3. TECHNICAL REQUIREMENTS

3.1 Composition

Shall conform to the percentages by weight shown in Table 1, in accordance with ASTM A751 or by other analytical methods acceptable to purchaser.

Table 1 - Composition

Element	Min	Max
Carbon	--	0.040
Manganese	8.00	10.00
Silicon	--	1.00
Phosphorus	--	0.030
Sulfur	--	0.030
Chromium	19.00	21.50
Nickel	5.50	7.50
Nitrogen	0.15	0.40
Molybdenum	--	0.75
Copper	--	0.75

3.1.1 Check Analysis

Composition variations shall meet the applicable requirements of AMS2248.

3.2 Condition

Cold drawn and pickled as required or passivated.

3.3 Fabrication

Type 1 tubing shall be produced by drawing of welded hollows, and Type 2 tubing shall be produced by drawing of seamless hollows. Tensile properties shall be obtained by cold working and not by heat treatment (annealing). The external and internal surface finishes shall be not rougher than 32 μ in(0.8 μ m) and 63 μ in (1.6 μ m) respectively, determined in accordance with ASME B46.1, and may be produced by any method yielding the specified surface condition and which will not affect limits of wall thickness or corrosion resistance, with the exception that centerless ground finish is not acceptable. Type 1 tubing shall be processed to remove the bead and any dimensional indication of the presence of welds. A light polish to improve surface appearance or meet surface finish requirements may be employed.

3.3.1 Tubing shall be passivated in accordance with AMS2700 after any ID or OD finishing that occurs after cold drawing.

3.4 Properties

Tubing shall conform to the following requirements:

3.4.1 Tensile Properties

Shall be as shown in Table 2, except as permitted by 3.4.1.1, determined in accordance with ASTM A370.

Table 2 - Tensile Properties

Property	Value
Tensile Strength	142 to 162 ksi (979 to 1117 MPa)
Yield Strength at 0.2% Offset, Minimum	120 ksi (827 MPa)
Elongation in 2 Inches (50 mm), Minimum	20%

3.4.1.1 Tubing under 0.50 inch (12.7 mm) in nominal OD and having wall thickness of 0.020 inch (0.51 mm) or under may have elongation as low as 16%.

3.4.2 Flarability

Specimens as in 4.3.2.1 shall withstand flaring at room temperature, without formation of cracks or other visible defects, by being forced axially with steady pressure over a hardened and polished tapered steel pin having a 74-degree included angle to produce a flare having a permanent expanded OD as shown in Table 3.

Table 3A - Flarability, inch/pound units

Nominal OD Inches	Expanded OD Inches, Min	Nominal OD Inches	Expanded OD Inches, Min
0.125	0.200	0.750	0.937
0.188	0.302	1.000	1.187
0.250	0.359	1.250	1.500
0.312	0.421	1.500	1.721
0.375	0.484	1.750	2.106
0.500	0.656	2.000	2.356
0.625	0.781	2.500	2.856
		3.000	3.356

Table 3B - Flarability, SI units

Nominal OD Millimeters	Expanded OD Millimeters, Min	Nominal OD Millimeters	Expanded OD Millimeters, Min
3.18	5.08	19.05	23.80
4.78	7.67	25.40	30.15
6.35	9.12	31.75	38.10
7.92	10.69	38.10	43.71
9.52	12.29	44.45	53.49
12.70	16.66	50.80	59.84
15.88	19.84	63.50	72.54
		76.20	85.24

3.4.2.1 Tubing with nominal OD between any two standard sizes shown in Table 3 shall take the same percentage flare as shown for the larger of the two sizes.

3.4.3 Susceptibility to Intergranular Attack

A specimen as in 4.3.2.2, after being sensitized by heating to $1250^{\circ}\text{F} \pm 25^{\circ}\text{F}$ ($677^{\circ}\text{C} \pm 14^{\circ}\text{C}$), holding at heat for 60 minutes ± 5 minutes, and cooling in air, shall withstand exposure for 24 hours ± 0.25 hour to copper sulfate/sulfuric acid solution in accordance with ASTM A262.

3.4.3.1 The specimen shall be split lengthwise into two approximately equal sections. These sections shall be flattened between parallel surfaces so that the internal tube surface of one section is closed to six times the nominal wall thickness and the internal tube surface of the other section is opened as nearly flat as possible. The external surface of the closed section and the internal surface of the opened section shall show no evidence of cracks or intergranular surface attack. In case the unaided visual evidence is in doubt, the sections shall be examined microscopically.

3.4.4 Average Grain Size

Shall be ASTM No. 6 or finer, determined in accordance with ASTM E112.

3.4.5 Bending

Tubing shall withstand, without cracking, bending at room temperature through an angle of 180 degrees around a mandrel with a centerline bend radius of three times the nominal OD of the tube. An appropriate internal mandrel shall be provided to restrict flattening to not more than 5% of the minimum tubing OD.

3.5 Quality

3.5.1 Tubing, visually inspected in accordance with 4.3.1.4, shall appear uniform in quality and condition and shall have a finish conforming to the best practice for high-quality aircraft tubing. Tubing surfaces shall be smooth and free from scale, oxide, corrosion, pickling residues, carbonaceous residues, discoloration, heat colors, and other contamination removable by normal pickling. Tubing shall also be free from burrs, seams, cracks, tears, laminations, and slivers. Surface discontinuities, such as grooves, seams, scores, and mandrel marks, shall be no deeper than 5% of the nominal wall thickness. Surface imperfections, such as handling marks, straightening marks, shallow pits, and scale pattern, will be acceptable if such imperfections do not prevent assembly of liquid-pressure-tight joints after flaring.

3.5.2 Tubing shall be free from grease or other foreign matter. Metallic flakes or particles shall not be collected by a clean, white cloth or plug when it is drawn through the length of the bore of a test sample. Discoloration of the cloth or plug, without the presence of flakes or particles, is acceptable. Alternate methods for evaluating tube cleanliness may be used for tubing 0.500 inch (12.7mm) and under ID.

3.5.3 Type 1 Class 1, and Class 2 tubing shall be subjected to ultrasonic inspection; ultrasonic indications shall be not greater than those from the calibration notches when the signal amplitude from the calibration notches is set at not less than 50% of full scale. The noise amplitude, during inspection of tubes, shall be not greater than 25% of full scale. Ultrasonic inspection shall be conducted as follows:

3.5.3.1 Tubing shall be inspected by ultrasonic, immersion, pulse echo methods. A calibration shall be performed at the start of operations and periodically reestablished at least once each hour of continuous operation. Separate calibration standards as in 3.5.3.2 shall be used for each tubing size. The arrangement of transducers shall be such that no cross-talk is encountered. Tube supporting equipment shall provide in-line stability throughout the complete length of each tube. For the disclosure of discontinuities, a shear mode shall be employed. The equipment shall be such that transducers functioning in a clockwise and counterclockwise direction may be separately gated and recorded. The pulse rate of the equipment shall provide 100% coverage at maximum tube rotational rates. The helix feed angle shall be such that a rejectable signal from the longitudinal calibration notch is produced on two consecutive powered turns of the tube.

3.5.3.2 Calibration Standards

Longitudinal calibration notches for the shear mode shall have a depth not greater than 0.002 inch (0.05 mm) or 5% of the nominal wall thickness, whichever is greater. The length of the calibration notches on both ID and OD surfaces parallel to the tube axis shall be as follows:

Class 1 - 0.125 inch \pm 0.002 inch (3.18 mm \pm 0.05 mm)

Class 2 - 0.060 inch \pm 0.002 inch (1.52 mm \pm 0.05 mm)

Class 3 - Not applicable

3.5.3.2.1 The placement of calibration notches in each standard shall be such that water-travel-distance, shear-angle, helix-angle, and equipment gain as established during calibration, remain identical during production applications. Calibration notches may be produced by electrodisscharge machining.

3.5.4 Type 2 tubing shall be either ultrasonically inspected as in 3.5.3 or shall be eddy current inspected in accordance with ASTM E426 using calibration notches specified in ASTM A1016/A1016M.

3.6 Tolerances

Shall conform to all applicable requirements of AMS2243 for hydraulic tubing, except as follows:

3.6.1 Outside Diameter

Shall be as shown in Table 4.

Table 4A - Diameter tolerances, inch/pound units

Nominal OD Inches	Tolerance, Inches Plus Only
0.188 to 1.250, incl	0.003
Over 1.250 to 1.500, incl	0.004
Over 1.500	0.005

Table 4B - Diameter tolerances, SI units

Nominal OD Millimeters	Tolerance, Millimeters Plus Only
4.78 to 31.75, incl	0.08
Over 31.75 to 38.10, incl	0.10
Over 38.10	0.13

3.6.2 Straightness

Maximum curvature (depth of arc) shall not exceed 0.060 inch in any 3 feet (1.67 mm in any meter).

3.6.3 Ovality

Shall be as shown in Table 5; ovality is the difference between the maximum and minimum diameters of any one section of the tubing.

Table 5A - Maximum ovality, inch/pound units

Nominal OD Inches	Ovality Inch
Up to 0.094, excl	0.001
0.094 to 0.187, incl	0.0015
Over 0.187 to 1.250, incl	0.003
Over 1.250 to 1.500, incl	0.004
Over 1.500	0.005

Table 5B - Maximum ovality, SI units

Nominal OD Millimeters	Ovality Millimeter
Up to 2.39, excl	0.03
2.39 to 4.75, incl	0.038
Over 4.75 to 31.75, incl	0.08
Over 31.75 to 38.10, incl	0.10
Over 38.10	0.13

3.7 Exceptions

Any exceptions shall be authorized by the purchaser and reported as in 4.4.1.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection

The producer of tubing shall supply all samples for producer's tests and shall be responsible for the performance of all required tests except formability. Purchaser reserves the right to sample and to perform any confirmatory testing deemed necessary to ensure that the tubing conforms to specified requirements.

4.2 Classification of Tests

4.2.1 Acceptance Tests

Composition (3.1), tensile properties (3.4.1), average grain size (3.4.4), bending (3.4.5), surface finish (3.5.1), ultrasonic quality of Class 1 or Class 2 tubing (3.5.3), and tolerances (3.6) are acceptance tests and shall be performed on each heat or lot as applicable.

4.2.2 Periodic Tests

Surface roughness (3.3), flarability (3.4.2), and susceptibility to intergranular attack (3.4.3) are periodic tests and shall be performed at a frequency selected by the producer unless frequency of testing is specified by purchaser.

4.3 Sampling and Testing

Shall be in accordance with AMS2371 and the following; a lot shall be all tubing of one size made from one heat of steel and manufactured and presented for producer's inspection at one time:

4.3.1 For Acceptance Tests

4.3.1.1 Tensile Tests

Two tube specimens taken from each 2000 feet (610 m) or fraction thereof in each lot.

4.3.1.2 Average Grain Size and Bending

At least one section of a tube from each lot.

4.3.1.3 Ultrasonic Testing

The full length of each tube. Not required for Class 3.

4.3.1.4

Each tube shall be visually examined over the full length of the OD and bore-sighted over the full length of the ID to determine conformance to 3.3, 3.5.1, and 3.5.2. In addition, a section approximately 4 inches (102 mm) long shall be cut from the midlength of 2% of the tubes in each lot and a similar section from the end of 3% of the tubes in each lot, the sections being taken from tubes selected at random. The sections shall be split lengthwise for evaluation to the requirements of 3.3, 3.5.1, and 3.5.2. If the lot consists of 10 or fewer tubes, the center and end sections may be taken from the same tube or tubes.

4.3.2 For Periodic Tests

4.3.2.1 Flarability Test

Specimens shall be full tubes or sections cut from a tube. The end of the specimen to be flared shall be cut square, with the cut end smooth and free from burrs, but not rounded.

4.3.2.2 Susceptibility to Intergranular Attack

A specimen, approximately 3 inches (76 mm) long, cut from each of two or more tubes.

4.4 Reports

The producer of tubing shall furnish with each shipment a report showing the producer's name and the country where the metal was melted (e.g., final melt in the case of metal processed by multiple melting operations), and the results of tests for composition of each heat and the results of tests on each lot for tensile properties, average grain size, bending, and ultrasonic quality of Class 1 or Class 2 tubing, and stating that the tubing conforms to the other technical requirements. This report shall include the purchase order number, heat and lot numbers, AMS5561H, size, and quantity.

4.4.1 When material produced to this specification has exceptions taken to the technical requirements listed in Section 3, the report shall contain a statement "This material is certified as AMS5561H(EXC) because of the following exceptions:" and the specific exceptions shall be listed (also see 5.2.1).

4.5 Resampling and Retesting

Shall be in accordance with AMS2371.

5. PREPARATION FOR DELIVERY

5.1 Sizes

Except when exact lengths or multiples of exact lengths are ordered, straight tubing will be acceptable in mill lengths of 5 to 24 feet (1.5 to 7.3 m) but at least 70% of any shipment shall be supplied in lengths longer than 17 feet (5.2 m) and 90% longer than 12 feet (3.7 m).

5.2 Identification

Shall be in accordance with AMS2807 for hydraulic tubing.

5.2.1 When technical exceptions are taken (see 4.4.1), the material shall be identified with AMS5561H(EXC).

5.3 Packaging

Tubing shall be prepared for shipment in accordance with commercial practice and in compliance with applicable rules and regulations pertaining to the handling, packaging, and transportation of the tubing to ensure carrier acceptance and safe delivery.

6. ACKNOWLEDGMENT

A producer shall mention this specification number and its revision letter in all quotations and when acknowledging purchase orders.

7. REJECTIONS

Tubing not conforming to this specification, or to modifications authorized by purchaser, will be subject to rejection.

8. NOTES

NOTICE

This specification may reference the use of substances, products, or processes that are restricted or banned by local (regional) chemical substance regulations. Users of this specification should consider the implications of local legislation on the products, substances, and processes referred to within the document.

8.1 Revision Indicator

A change bar (|) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revision. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

8.2 Terms used in AMS are clarified in ARP1917.

8.3 Dimensions and properties in inch/pound units and the Fahrenheit temperatures are primary; dimensions and properties in SI units and the Celsius temperatures are shown as the approximate equivalents of the primary units and are presented only for information.

- 8.4 Unless otherwise specified, the material producer shall work to the revision of this specification (AMS5561) in effect on the date of order placement. Unless otherwise specified, material manufactured and certified to the immediately previous revision of this specification (AMS5561) may be procured and used until inventory is depleted.
- 8.5 It is the purchaser's obligation to ensure that product they procure or resell as AMS5561H has any exceptions approved by their subsequent purchaser.
- 8.6 Purchase documents should specify not less than the following:

AMS5561H

Type, class and size of tubing desired

Quantity of tubing desired

PREPARED BY SAE AMS F CORROSION HEAT RESISTANT ALLOYS COMMITTEE