



AEROSPACE MATERIAL SPECIFICATION

AMS5659™

REV. T

Issued 1965-09

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Superseding AMS5659S

Steel, Corrosion Resistant, Bars, Wire, Forgings, Rings, and Extrusions

15Cr - 4.5Ni - 0.30Cb (Nb) - 3.5Cu

Consumable Electrode Remelted

Solution Heat Treated, Precipitation Hardenable

(Composition similar to UNS S15500)

RATIONALE

AMS5659T prohibits unauthorized exceptions (3.9, 4.4.6, 5.2.1.1, 8.7), revises composition (3.1) to replace obsolete chemical analysis standards, updates condition (3.3.1.1, 8.9), introduces AMS2761 replacing legacy controls (3.4), adds strain rate control (3.5.2.2.1), deletes redundant requirements with AMS2371 (prior 3.5.2.2.1.2, 3.5.2.2.1.3), adds AS1182 (3.6.3, 8.6), updates title, allows prior revisions (8.8), and results from a Five-Year Review and update of this specification.

1. SCOPE

1.1 Form

This specification covers a corrosion resistant steel in the form of bars, wire, forgings, flash welded rings, and extrusions in the solution heat treated condition (see 8.3), 12 inches (305 mm) and under in nominal diameter, thickness or for hexagons, least distance between parallel sides, and having a maximum cross-sectional area of 144 in² (930 cm²), and stock of any size for forging, flash welded rings, or extruding.

1.1.1 For purchase of solution treated and aged product, use the applicable AMS slash specification (see 8.3). If a slash sheet description is not specified, solution annealed material shall be supplied. A specific example of a slash specification is:

AMS5659/H1025 - Precipitation Hardened to H1025 condition.

1.2 Application

These products have been used typically for parts requiring corrosion resistance and high strength up to 600 °F (316 °C) with good ductility and strength in the transverse direction in large section sizes, but usage is not limited to such applications.

1.2.1 Certain design and processing procedures may cause these products to become susceptible to stress-corrosion cracking. ARP1110 recommends practices to minimize such conditions.

1.3 Classification

Products covered by this specification are classified as follows:

Type 1 - Steel multiple melted using vacuum consumable electrode remelting.

Type 2 - Steel multiple melted using electroslag remelting.

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<https://www.sae.org/standards/content/AMS5659T>

1.3.1 Unless a specific type is ordered, either type 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), www.sae.org.

AMS2241	Tolerances, Corrosion and Heat-Resistant Steel, Iron Alloy, Titanium, and Titanium Alloy Bars and Wire
AMS2248	Chemical Check Analysis Limits, Corrosion and Heat-Resistant Steels and Alloys, Maraging and Other Highly Alloyed Steels, and Iron Alloys
AMS2300	Steel Cleanliness, Premium Aircraft-Quality, Magnetic Particle Inspection Procedure
AMS2315	Determination of Delta Ferrite Content
AMS2371	Quality Assurance Sampling and Testing, Corrosion and Heat-Resistant Steels and Alloys, Wrought Products and Forging Stock
AMS2374	Quality Assurance Sampling and Testing, Corrosion and Heat-Resistant Steel and Alloy Forgings
AMS2750	Pyrometry
AMS 2761	Heat Treatment of Steel Raw Materials
AMS2806	Identification Bars, Wire, Mechanical Tubing, and Extrusions, Carbon and Alloy Steels and Corrosion and Heat-Resistant Steels and Alloys
AMS2808	Identification Forgings
AMS7490	Rings, Flash Welded, Corrosion and Heat-Resistant Austenitic Steels, Austenitic-Type Iron, Nickel, or Cobalt Alloys, or Precipitation-Hardenable Alloys
ARP1110	Minimizing Stress Corrosion Cracking in Wrought Forms of Steels and Corrosion Resistant Steels and Alloys
ARP1917	Clarification of Terms Used in Aerospace Metals Specifications
AS1182	Standard Stock Removal Allowance Aircraft-Quality and Premium Aircraft-Quality Steel Bars and Mechanical Tubing
AS6279	Industry Standard Practices for Production, Distribution, and Procurement of Metal Stock

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, www.astm.org.

ASTM A370	Mechanical Testing of Steel Products
ASTM A604	Macroetch Testing of Consumable Electrode Remelted Steel Bars and Billets

ASTM A751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

ASTM E140 Hardness Conversion Tables for Metals, Relationship Among Brinell Hardness, Vickers Hardness, Rockwell Hardness, Superficial Hardness, Knoop Hardness, Scleroscope Hardness, and Leeb Hardness

3. TECHNICAL REQUIREMENTS

3.1 Composition

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

Table 1 - Composition

Element	Min	Max
Carbon	--	0.07
Manganese	--	1.00
Silicon	--	1.00
Phosphorus	--	0.030
Sulfur	--	0.015
Chromium	14.00	15.50
Nickel	3.50	5.50
Columbium (Niobium)	5xC	0.45
Copper	2.50	4.50
Molybdenum	--	0.50

3.1.1 Check Analysis

Composition variations shall meet the applicable requirements of AMS2248.

3.2 Melting Practice

Product shall be multiple melted using vacuum consumable electrode remelting for Type 1 or using electroslag remelting for Type 2.

3.3 Condition

The product shall be supplied in the following condition:

3.3.1 Bars, Wire, Forgings, and Flash Welded Rings

3.3.1.1 Rounds

Solution heat treated and descaled. Bars 2.00 inch (50.8 mm) and under in nominal diameter shall be cold finished. Bars over 2.0 inches (50.8 mm) in nominal diameter shall be hot or cold finished (see 3.6.3). When a specific finish is required, it must be ordered (see 8.8).

3.3.1.2 Hexagons

Solution heat treated, cold drawn, and descaled.

3.3.1.3 Squares and Flats

Hot finished, solution heat treated, and descaled.

3.3.1.4 Bar shall not be cut from plate (also see 4.4.5).

3.3.1.5 Wire and Forgings

Solution heat treated and descaled.

3.3.1.6 Flash Welded Rings

Solution heat treated and descaled. Flash welded rings shall not be supplied unless specified or permitted on purchaser's part drawing. When supplied, rings shall be manufactured in accordance with AMS7490.

3.3.2 Extrusions

Solution heat treated, straightened, and descaled.

3.3.3 Stock for Forging, Flash Welded Rings, or Extruding

As ordered by the forging, flash welded ring, or extrusion manufacturer.

3.4 Solution Heat Treatment

Bars, wire, forgings, flash welded rings, and extrusions shall be solution heat treated in accordance with AMS2761 by heating to 1900 °F ± 25 °F (1038 °C ± 14 °C), holding at heat for a time commensurate with section thickness, heating equipment, and procedure used, and cooling as required to below 90 °F (32 °C).

3.5 Properties

The product shall conform to the following requirements; tensile and hardness testing shall be performed in accordance with ASTM A370:

3.5.1 All Products

3.5.1.1 Macrostructure

Visual examination of transverse full cross-sections from bars, billets, and stock for forging, flash welded rings, or extrusions, etched in hot hydrochloric acid in accordance with ASTM A604, shall show no pipe or cracks. Porosity, segregation, inclusions, and other imperfections shall be no worse than the macrographs of ASTM A604 shown in Table 2.

Table 2 - Macrostructure limits

Class	Condition	Severity
1	Freckles	A
2	White Spots	A
3	Radial Segregation	A
4	Ring Pattern	B

3.5.1.2 Microstructure

The product shall contain no more than 2% free ferrite, determined in accordance with AMS2315.

3.5.2 Bars, Wire, Forgings, Flash Welded Rings, and Extrusions

3.5.2.1 As Solution Heat Treated

3.5.2.1.1 Tensile Strength

Wire shall have tensile strength not higher than 175 ksi (1207 MPa).

3.5.2.1.2 Hardness

3.5.2.1.2.1 Bars

Not higher than 363 HBW, or equivalent (see 8.2), determined at mid-radius or quarter thickness.

3.5.2.1.2.2 Forgings, Flash Welded Rings, and Extrusions

Not higher than 363 HBW, or equivalent (see 8.2).

3.5.2.2 Response to Precipitation Heat Treatment

Samples from solution heat treated product, 12 inches (305 mm) and under in nominal diameter, thickness or for hexagons, least distance between parallel sides, and having a maximum cross-sectional area of 144 in² (930 cm²), precipitation heat treated to a particular condition in accordance with the corresponding temperatures and times shown in Table 3 and cooled in air, shall have the properties specified in 3.5.2.2.1 for that particular condition. Tensile tests shall be made in only the H900 precipitation heat treated condition unless purchaser specifies another heat treated condition.

Table 3 - Precipitation heat treating parameters

Condition	Temperature	Time
H900	900 °F ± 10 °F (482 °C ± 6 °C)	1 hour + 15 minutes, -0
H925	925 °F ± 10 °F (496 °C ± 6 °C)	4 hours + 30 minutes, -0
H1025	1025 °F ± 10 °F (552 °C ± 6 °C)	4 hours + 30 minutes, -0
H1075	1075 °F ± 10 °F (579 °C ± 6 °C)	4 hours + 30 minutes, -0
H1100	1100 °F ± 10 °F (593 °C ± 6 °C)	4 hours + 30 minutes, -0
H1150	1150 °F ± 10 °F (621 °C ± 6 °C)	4 hours + 30 minutes, -0

3.5.2.2.1 Tensile Properties

Shall be as shown in Table 4.

Table 4A - Minimum tensile properties, inch/pound units

Condition	Specimen Orientation	Tensile Strength ksi	Yield Strength at 0.2% Offset ksi	Elongation in 2 Inches or 4D %	Reduction of Area %
H900	Longitudinal	190	170	10	35
	Transverse	190	170	6	20
H925	Longitudinal	170	155	10	38
	Transverse	170	155	7	25
H1025	Longitudinal	155	145	12	45
	Transverse	155	145	8	32
H1075	Longitudinal	145	125	13	45
	Transverse	145	125	9	33
H1100	Longitudinal	140	115	14	45
	Transverse	140	115	10	34
H1150	Longitudinal	135	105	16	50
	Transverse	135	105	11	35

Table 4B - Minimum tensile properties, SI units

Condition	Specimen Orientation	Tensile Strength MPa	Yield Strength at 0.2% Offset MPa	Elongation in 50 mm or 4D %	Reduction of Area %
H900	Longitudinal	1310	1172	10	35
	Transverse	1310	1172	6	20
H925	Longitudinal	1172	1069	10	38
	Transverse	1172	1069	7	25
H1025	Longitudinal	1069	1000	12	45
	Transverse	1069	1000	8	32
H1075	Longitudinal	1000	862	13	45
	Transverse	1000	862	9	33
H1100	Longitudinal	965	793	14	45
	Transverse	965	793	10	34
H1150	Longitudinal	931	724	16	50
	Transverse	931	724	11	35

- 3.5.2.2.1.1 Unless otherwise specified, the strain rate shall be set at 0.005 in/in/min (0.005 mm/mm/min) and maintained within a tolerance of ± 0.002 in/in/min (0.002 mm/mm/min) through 0.2% offset yield strain. After the yield strain, the speed of the testing machine shall be set between 0.05 in/in and 0.5 in/in (0.05 mm/mm and 0.5 mm/mm) of the length of the reduced section (or distance between the grips for specimens not having a reduced section) per minute. Alternatively, an extensometer and strain rate indicator may be used to set the strain rate between 0.05 in/in/min and 0.5 in/in/min (0.05 mm/mm/min and 0.5 mm/mm/min).
- 3.5.2.2.1.2 Transverse tensile property requirements apply only to products from which a test specimen not less than 2-1/2 inches (63.5 mm) long can be taken. If the cross-sectional dimensions of the product permit, the transverse testing shall be of the short-transverse (ST) direction; otherwise, the orientation shall be long transverse (LT).
- 3.5.2.2.1.3 Products tested in the transverse direction need not be tested in the longitudinal direction.
- 3.5.2.2.2 Mechanical property requirements for product outside of the range covered by 1.1 shall be agreed upon between purchaser and producer and reported per 4.4.6.

3.5.3 Forging Stock

Specimens extracted from a forged test coupon and heat treated as in 3.4 and 3.5.2.2 shall conform to the requirements of 3.5.2.2.1. If specimens extracted directly from the stock and heat treated as in 3.4 and 3.5.2.2 conform to the requirements of 3.5.2.2.1, the test results shall be accepted in lieu of tests of a forged coupon.

3.5.4 Stock for Flash Welded Rings or Extruding

A sample of stock heat treated as in 3.4 and 3.5.2.2 shall conform to the requirements of 3.5.2.2.1.

3.6 Quality

The product, as received by purchaser, shall be uniform in quality and condition, sound, and free from foreign materials and from imperfections detrimental to usage of the product.

- 3.6.1 Steel shall be premium aircraft-quality conforming to AMS2300.
- 3.6.2 Grain flow of die forgings, except in areas which contain flash-line end grain, shall follow the general contour of the forgings showing no evidence of reentrant grain flow.
- 3.6.3 Bars shall be free from seams, laps, tears, and cracks after removal of the standard stock removal allowance in accordance with AS1182. Superficial surface imperfections such as scratches or pits shall not exceed applicable tolerances.

3.7 Tolerances

Bars and wire shall conform to all applicable requirements of AMS2241. Tolerances for extrusions shall be as specified on the extrusion drawing.

3.8 Production, distribution, and procurement of metal stock shall comply with AS6279. After production and certification to the specified requirements, cutting in a plane perpendicular to the short transverse dimension is permitted.

3.9 Exceptions

Any exception shall be authorized by purchaser and reported as in 4.4.6.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection

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

4.2 Classification of Tests

4.2.1 Acceptance Tests

The following requirements are acceptance tests and shall be performed on each heat or lot as applicable:

4.2.1.1 Composition (3.1) and macrostructure rating (3.5.1.1) of each heat.

4.2.1.2 Tensile properties (3.5.2.1.1) of wire as solution heat treated.

4.2.1.3 Hardness (3.5.2.1.2) of bars, forgings, flash welded rings, and extrusions as solution heat treated.

4.2.1.4 Tensile properties (3.5.2.2.1) of bars, wire, forgings, flash welded rings, and extrusions after precipitation heat treatment.

4.2.1.5 Tolerances (3.7) of bars and wire.

4.2.2 Periodic Tests

The following requirements are periodic tests and shall be performed at a frequency selected by the producer unless frequency of testing is specified by purchaser.

4.2.2.1 Microstructure (3.5.1.2).

4.2.2.2 Frequency-severity cleanliness rating (3.6.1).

4.2.2.3 Ability of forging stock (3.5.3) and stock for flash welded rings or extruding (3.5.4) to develop required properties.

4.3 Sampling and Testing

Shall be as follows:

4.3.1 Bars, Wire, Flash Welded Rings, Extrusions, and Stock for Forging, Flash Welded Rings, or Extruding

In accordance with AMS2371.

4.3.2 Forgings

In accordance with AMS2374.

4.4 Reports

The producer of bars, wire, forgings, flash welded rings, and extrusions shall furnish with each shipment a report showing the producer's name and country where the metal was melted (e.g., final melt in the case of metal processed by multiple melting operations), and the following:

4.4.1 For each Heat

Composition
Macrostructure

4.4.2 For Each Lot of bars, Wire, Flash Welded Rings, Extrusions, and Forgings

If wire, tensile strength as solution heat treated
If product form other than wire, hardness as solution treated
All product forms, tensile properties after precipitation heat treatment

4.4.3 A statement that the product is in the solution heat treated condition, and that it conforms to the other technical requirements.

4.4.4 Purchase order number
Heat and lot numbers
AMS5659T
Size
Quantity

4.4.5 If the size being shipped is different from the nominal metallurgically-worked cross-sectional size, the size of the larger product and details of how the shipped size was extracted from the larger product shall be reported.

4.4.6 When material produced to this specification is beyond the sizes allowed in the scope or tables, or other exceptions are taken to the technical requirements listed in Section 3 (see 5.2.1.1), the report shall contain a statement "This material is certified as AMS5659T(EXC) because of the following exceptions:" and the specific exceptions shall be listed.

4.4.7 If forgings are supplied, the size and melt source of stock used to make the forgings.

4.4.8 The producer of stock for forging, flash welded rings, or extrusions shall furnish with each shipment a report showing the producer's name and country where the metal was melted (e.g., final melt in the case of metal processed by multiple melting operations), composition, macrostructure of each heat. This report shall include the purchase order number, heat number, AMS5659T, product form, size, and quantity.

4.5 Resampling and Retesting

Shall be as follows:

4.5.1 Bars, Wire, Flash Welded Rings, Extrusions, and Stock for Forging, Flash Welded Rings, or Extruding

In accordance with AMS2371.

4.5.2 Forgings

In accordance with AMS2374.

5. PREPARATION FOR DELIVERY

5.1 Sizes

Except when exact lengths or multiples of exact lengths are ordered, straight bars and wire will be acceptable in mill lengths of 6 to 20 feet (1.8 to 6.1 m) but not more than 10% of any shipment shall be supplied in lengths shorter than 10 feet (3 m).

5.2 Identification

Shall be as follows:

5.2.1 Bars, Wire, and Extrusions

In accordance with AMS2806.

5.2.1.1 When technical exceptions are taken (see 4.4.6), the material shall be marked with AMS5659T(EXC).

5.2.2 Forgings

In accordance with AMS2808.

5.2.3 Flash Welded Rings and Stock for Forging, Flash Welded Rings, or Extruding

As agreed upon by purchaser and producer.

5.3 Packaging

The product 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 product 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

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

8. NOTES

8.1 Revision Indicator

A change bar (I) 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 revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

8.2 Hardness conversion tables for metals are presented in ASTM E140.

8.3 Except for forging stock (see 3.3.3), product supplied to this document will be in the solution heat treated condition. AMS slash documents (see 1.1.1) cover product in a specific solution treated and aged condition.

8.4 Terms used in AMS are clarified in ARP1917.

8.5 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.

- 8.6 Purchasers should consider stock removal requirements of 3.6.3 when selecting the appropriate size and condition including surface finish to specify in ordering information.
- 8.7 It is the Purchaser's obligation to ensure that product they procure or resell as AMS5659T has any exceptions approved by their subsequent purchaser.
- 8.8 Unless otherwise specified, the material producer shall work to the revision of this specification (AMS5659) in effect on the date of order placement. Unless otherwise specified, material manufactured and certified to the immediately previous revision of this specification (AMS5659) may be procured and used until inventory is depleted.
- 8.9 Purchase documents should specify not less than the following:

AMS5659T

Product form and size or part number of product desired

Quantity of product desired

Precipitation heat treated condition for response to heat treat test, if different from H900 (see 3.5.2.2)

Specific finish when required

PREPARED BY THE AMS F CORROSION HEAT RESISTANT ALLOYS COMMITTEE