PŘÍLOHA Č. 1
Materiálový list oceli AMS 5659 [36]
Steel, Corrosion-Resistant, Bars, Wire, Forgings, Rings, and Extrusions
15Cr – 4.5Ni – 0.30Cb (Nb) – 3.5Cu
Consumable Remelted, Precipitation Hardenable

(Composition similar to UNS S15500)

RATIONALE

AMS5659M revises the reporting requirements (4.4) and is 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, extrusions, and stock for forging, flash welded rings, or extruding.

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 practice during remelting.

Type 2 - Steel multiple melted using electroslag process in the remelting cycle.

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 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, Wrought 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
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 and 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

2.2 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box 700, West Conshohocken, PA 19428-2059, Tel: 610-832-9555, www.astm.org.

ASTM A 370 Mechanical Testing of Steel Products
ASTM A 604 Macroetch Testing of Consumable Electrode Remelted Steel Bars and Billets
ASTM E 353 Chemical Analysis of Stainless, Heat-Resisting, Maraging, and Other Similar Chromium-Nickel-Iron Alloys
3. TECHNICAL REQUIREMENTS

3.1 Composition

Shall conform to the percentages by weight shown in Table 1, determined by wet chemical methods in accordance with ASTM E 353, by spectrochemical methods, or by other analytical methods acceptable to purchaser.

<table>
<thead>
<tr>
<th>Element</th>
<th>min</th>
<th>max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>-</td>
<td>0.07</td>
</tr>
<tr>
<td>Manganese</td>
<td>-</td>
<td>1.00</td>
</tr>
<tr>
<td>Silicon</td>
<td>-</td>
<td>1.00</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>-</td>
<td>0.030</td>
</tr>
<tr>
<td>Sulfur</td>
<td>-</td>
<td>0.015</td>
</tr>
<tr>
<td>Chromium</td>
<td>14.00</td>
<td>15.50</td>
</tr>
<tr>
<td>Nickel</td>
<td>3.50</td>
<td>5.50</td>
</tr>
<tr>
<td>Columbium (Niobium)</td>
<td>5%C</td>
<td>0.45</td>
</tr>
<tr>
<td>Copper</td>
<td>2.50</td>
<td>4.50</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>-</td>
<td>0.50</td>
</tr>
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</table>

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 practice during remelting for Type 1, or using electroslag practice for remelting 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 smooth turned, centerless ground, or centerless ground and polished.

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 Wire and Forgings

Solution heat treated and descaled.
3.3.1.5 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 Heat Treatment
Bars, wire, forgings, flash welded rings, and extrusions shall be solution heat treated by heating to 1900 °F ± 25 (1038 °C ± 14), holding at heat for a time commensurate with section thickness, heating equipment, and procedure used, but not less than 30 minutes, and cooling as required to below 90 °F (32 °C). Pyrometry shall be in accordance with AMS2750.

3.5 Properties
The product shall conform to the following requirements; tensile and hardness testing shall be performed in accordance with ASTM A 370:

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 A 604, shall show no pipe or cracks. Porosity, segregation, inclusions, and other imperfections for product 36 square inches (232 cm²) and under in nominal cross-sectional area shall be no worse than the macrographs of ASTM A 604 shown in Table 2.

<table>
<thead>
<tr>
<th>CLASS</th>
<th>CONDITION</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Freckles</td>
</tr>
<tr>
<td>2</td>
<td>White Spots</td>
</tr>
<tr>
<td>3</td>
<td>Radial Segregation</td>
</tr>
<tr>
<td>4</td>
<td>Ring Pattern</td>
</tr>
</tbody>
</table>

3.5.1.2 Microstructure
The product shall contain not 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 HB, 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 HB, or equivalent (See 8.2).

3.5.2.2  After Precipitation Heat Treatment

The solution heat treated product, 12 inches (305 mm) and under in nominal diameter or maximum cross-sectional dimension, 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 and 3.5.2.2.2 for that particular condition. Tensile and hardness 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

<table>
<thead>
<tr>
<th>Condition</th>
<th>Temperature</th>
<th>Time</th>
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<tbody>
<tr>
<td>H900</td>
<td>900 °F ± 10 (482 °C ± 6)</td>
<td>1 hour 0.1</td>
</tr>
<tr>
<td>H925</td>
<td>925 °F ± 10 (502 °C ± 6)</td>
<td>4 hours 0.3</td>
</tr>
<tr>
<td>H1025</td>
<td>1025 °F ± 10 (552 °C ± 6)</td>
<td>4 hours 0.3</td>
</tr>
<tr>
<td>H1075</td>
<td>1075 °F ± 10 (579 °C ± 6)</td>
<td>4 hours 0.3</td>
</tr>
<tr>
<td>H1100</td>
<td>1100 °F ± 10 (593 °C ± 6)</td>
<td>4 hours 0.3</td>
</tr>
<tr>
<td>H1150</td>
<td>1150 °F ± 10 (621 °C ± 6)</td>
<td>4 hours 0.3</td>
</tr>
</tbody>
</table>

3.5.2.2.1  Tensile Properties

Shall be as shown in Table 4.

### TABLE 4A - MINIMUM TENSILE PROPERTIES, INCH/POUND UNITS

<table>
<thead>
<tr>
<th>Condition</th>
<th>Specimen Orientation</th>
<th>Tensile Strength at 0.2% Offset ksi</th>
<th>Yield Strength ksi</th>
<th>Elongation in 2 Inches or 4D %</th>
<th>Reduction of Area %</th>
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</thead>
<tbody>
<tr>
<td>H900</td>
<td>Longitudinal</td>
<td>190</td>
<td>170</td>
<td>10</td>
<td>35</td>
</tr>
<tr>
<td>Transverse</td>
<td></td>
<td>190</td>
<td>170</td>
<td>6</td>
<td>20</td>
</tr>
<tr>
<td>H925</td>
<td>Longitudinal</td>
<td>170</td>
<td>155</td>
<td>10</td>
<td>38</td>
</tr>
<tr>
<td>Transverse</td>
<td></td>
<td>170</td>
<td>155</td>
<td>7</td>
<td>25</td>
</tr>
<tr>
<td>H1025</td>
<td>Longitudinal</td>
<td>155</td>
<td>145</td>
<td>12</td>
<td>45</td>
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<td>Transverse</td>
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<td>155</td>
<td>145</td>
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<td>32</td>
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<td>145</td>
<td>125</td>
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<tr>
<td>Transverse</td>
<td></td>
<td>145</td>
<td>125</td>
<td>9</td>
<td>33</td>
</tr>
<tr>
<td>H1100</td>
<td>Longitudinal</td>
<td>140</td>
<td>115</td>
<td>14</td>
<td>45</td>
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<tr>
<td>Transverse</td>
<td></td>
<td>140</td>
<td>115</td>
<td>10</td>
<td>34</td>
</tr>
<tr>
<td>H1150</td>
<td>Longitudinal</td>
<td>135</td>
<td>105</td>
<td>16</td>
<td>50</td>
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<tr>
<td>Transverse</td>
<td></td>
<td>135</td>
<td>105</td>
<td>11</td>
<td>35</td>
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</table>
### TABLE 4B - MINIMUM TENSILE PROPERTIES, SI UNITS

<table>
<thead>
<tr>
<th>Condition</th>
<th>Specimen Orientation</th>
<th>Tensile Strength at 0.2% Offset MPa</th>
<th>Yield Strength MPa</th>
<th>Elongation in 50.8 mm or 4D %</th>
<th>Reduction of Area %</th>
</tr>
</thead>
<tbody>
<tr>
<td>H900</td>
<td>Longitudinal</td>
<td>1310</td>
<td>1172</td>
<td>10</td>
<td>35</td>
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<td>Transverse</td>
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<td>1069</td>
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<td>38</td>
</tr>
<tr>
<td></td>
<td>Transverse</td>
<td>1172</td>
<td>1069</td>
<td>7</td>
<td>25</td>
</tr>
<tr>
<td>H1025</td>
<td>Longitudinal</td>
<td>1069</td>
<td>1000</td>
<td>12</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>Transverse</td>
<td>1069</td>
<td>1000</td>
<td>8</td>
<td>32</td>
</tr>
<tr>
<td>H1075</td>
<td>Longitudinal</td>
<td>1000</td>
<td>862</td>
<td>13</td>
<td>45</td>
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<td></td>
<td>Transverse</td>
<td>1000</td>
<td>862</td>
<td>9</td>
<td>33</td>
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<tr>
<td>H1100</td>
<td>Longitudinal</td>
<td>965</td>
<td>793</td>
<td>14</td>
<td>45</td>
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<tr>
<td></td>
<td>Transverse</td>
<td>965</td>
<td>793</td>
<td>10</td>
<td>34</td>
</tr>
<tr>
<td>H1150</td>
<td>Longitudinal</td>
<td>931</td>
<td>724</td>
<td>16</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Transverse</td>
<td>931</td>
<td>724</td>
<td>11</td>
<td>35</td>
</tr>
</tbody>
</table>

3.5.2.2.1.1 Longitudinal tensile property requirements apply to specimens taken in the longitudinal direction from bars, wire, and extrusions, to specimens taken from forgings with axis of specimen in the area of gage length varying not more than 15 degrees from parallel to the forging flow lines, and to specimens taken in the circumferential direction from flash welded rings.

3.5.2.2.1.2 Transverse tensile property requirements apply to specimens taken approximately perpendicular to the longitudinal direction of bars and extrusions, to specimens taken from forgings with axis of specimen in the area of gage length varying not more than 15 degrees from perpendicular to the forging flow lines, and to specimens taken in the radial or axial direction from flash welded rings.

3.5.2.2.1.3 Transverse tensile property requirements apply only to products from which a test specimen not less than 2-1/2 inches (63.5 mm) long or 1/2 x 1/2 inch (12.7 x 12.7 mm) cross-section can be taken.

3.5.2.2.1.4 Products tested in the transverse direction need not be tested in the longitudinal direction.

3.5.2.2.2 Hardness

Shall be within the range shown in Table 5, or equivalent (See 8.2), for the corresponding precipitation heat treated condition. Product shall not be rejected on the basis of hardness if the tensile property requirements of Table 4 are acceptable, determined on specimens taken from the same sample as that with nonconforming hardness or from another sample with similar nonconforming hardness.

### TABLE 5 - HARDNESS RANGE

<table>
<thead>
<tr>
<th>Condition</th>
<th>Hardness, HB</th>
</tr>
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<tbody>
<tr>
<td>H900</td>
<td>388 to 444</td>
</tr>
<tr>
<td>H925</td>
<td>375 to 429</td>
</tr>
<tr>
<td>H1025</td>
<td>331 to 401</td>
</tr>
<tr>
<td>H1075</td>
<td>311 to 375</td>
</tr>
<tr>
<td>H1100</td>
<td>302 to 363</td>
</tr>
<tr>
<td>H1150</td>
<td>277 to 352</td>
</tr>
</tbody>
</table>
3.5.3 Forging Stock

When a sample of stock is forged to a test coupon and heat treated as in 3.4 and 3.5.2.2, specimens taken from the heat treated coupon shall conform to the requirements of 3.5.2.2.1 and 3.5.2.2.2. If specimens taken from the stock after heat treatment as in 3.4 and 3.5.2.2 conform to the requirements of 3.5.2.2.1 and 3.5.2.2.2, the tests shall be accepted as equivalent to 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 and 3.5.2.2.2.

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 and grain, shall follow the general contour of the forgings showing no evidence of reentrant grain flow.

3.7 Tolerances

Bars and wire shall conform to all applicable requirements of AMS2241.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection

The vendor of the product shall supply all samples for vendor’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) and hardness (3.5.2.2.2) 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 vendor unless frequency of testing is specified by purchaser.
4.2.2.1 Microstructure (3.5.1.2).

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

4.2.2.3 Frequency-severity cleanliness rating (3.6.1).

4.3 Sampling and Testing

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

4.4.1 The vendor of bars, wire, forgings, flash welded rings, and extrusions shall furnish with each shipment a report showing the results of tests for composition of each heat and for tensile properties and hardness of each lot, as required, both as solution heat treated and after precipitation heat treatment, and stating that the product conforms to the other technical requirements. This report shall include the purchase order number, heat number, and lot numbers, AMS5659M, type of melting practice used, product form, size, and quantity. If forgings are supplied, the size and melt source of stock used to make the forgings shall also be included.

4.4.2 The vendor of stock for forging, flash welded rings, or extrusions shall furnish with each shipment a report showing the composition of each heat. This report shall include the purchase order number, heat number, AMS5659M, product form, size, and quantity.

4.5 Resampling and Retesting

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 (18 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.

5.2.2 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 vendor.

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 vendor 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 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 E 140.

8.3 Terms used in AMS are clarified in ARP 1917.

8.4 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.

8.5 Procurement documents should specify not less than the following:

AMS 5659M

Product form and size or part number of product desired

Quantity of product desired.

PREPARED BY AMS COMMITTEE "F"
PŘÍLOHA Č. 2
Protokol o chemickém složení.
# Protokol o chemickém složení

**Materiál:** AMS 5659

**Protokol č.:** 034/2013

**Zadavatel:** Ing. Miloslav Kouřil, Csc.

**Poř. číslo knihy:** 057/2013

**Označ. vzorku:** AMS 5659

**Zkušební stroj:** Spectrumat GDS 750

## Výsledné chemické složení:

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<th>P</th>
<th>S</th>
<th>Cr</th>
<th>Ni</th>
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<td>4,1</td>
<td>0,15</td>
<td>0,11</td>
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<th>Ti</th>
<th>Co</th>
<th>B</th>
<th>Sn</th>
<th>Sb</th>
<th>Nb</th>
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<td>0,000</td>
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Zpracoval: Ing. Pavel Doležal, Ph.D.

* Informativní hodnota

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**V Brně dne 10. května 2013**

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**doc. Ing. Vít JAN, Ph.D.**