AEROSPACE MATERIAL SPECIFICATION

AMS2759™/2	REV. K

Issued 1984-10
Reaffirmed 2014-04
Revised 2021-07

Superseding AMS2759/2J

Heat Treatment of Low-Alloy Steel Parts Minimum Tensile Strength 220 ksi (1517 MPa) and Higher

RATIONALE

AMS2759/2K results from correcting the table reference in the ordering information, deleting “Parts with finished machined surfaces” from preheating (3.4.1) because not all finished machined require stress relief, and adding 3.4.1.1 allowing preheating in separate furnaces.

NOTICE

ORDERING INFORMATION: In addition to that listed in AMS2759, the purchaser shall supply the following information to the heat treating processor.

- AMS2759/2K
- Tensile strength and/or hardness if other than that listed in Table 3 (see 3.4.8 and 3.5.1)
- Cognizant engineering organization approval if dimensions at heat treatment exceed Table 5 size limits

1. SCOPE

This specification, in conjunction with the general requirements for steel heat treatment covered in AMS2759, establishes the requirements for heat treatment of low-alloy steel parts to minimum ultimate tensile strengths of 220 ksi (1517 MPa) and higher. Parts are defined in AMS2759. The requirements for heat treatment of alloy Aermet100 are no longer part of this specification and can be found in AMS2759/3. Due to the limited hardenability of these materials, size limits have been added to this specification.

1.1 The provisions of this specification revision shall become effective 90 days after publication.

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 processor 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.

TO PLACE A DOCUMENT ORDER: **Tel: 877-606-7323 (inside USA and Canada)**
Tel: +1 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org
SAE WEB ADDRESS: **http://www.sae.org**

For more information on this standard, visit
https://www.sae.org/standards/content/AMS2759/2K

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.

AMS2418 Plating, Copper

AMS2424 Plating, Nickel, Low-Stressed Deposit

AMS2750 Pyrometry

AMS2759 Heat Treatment of Steel Parts, General Requirements

AMS2759/11 Stress Relief of Steel Parts

AMS2769 Heat Treatment of Parts in a Vacuum

3. TECHNICAL REQUIREMENTS

3.1 Heat Treatment

Shall conform to AMS2759 and the requirements specified herein.

3.2 Equipment

Equipment shall conform to AMS2759 except that tempering furnaces shall be in accordance with AMS2750 Class 2.

3.3 Heating Environment

Parts shall be controlled by type, and heat treated in the class of atmosphere permitted in Table 1 for that type when heating above 1250 °F (677 °C). When heating parts at 1250 °F (677 °C) or below, Class A, B, or C atmosphere may be used (see 8.2). Atmosphere Class and Part Type are described in AMS2759.

Table 1 - Atmospheres

Part Type	Atmosphere Classification		
	Class A	Class B	Class C
Type 1	Permitted	Permitted	Permitted
Type 2	Permitted	Prohibited(1)	Prohibited

NOTES:
(1) Permitted provided the atmosphere is controlled to meet the surface contamination requirement in 3.5.2.

3.3.1 Protective Coatings

A supplemental coating or plating is permitted when approved by the cognizant engineering organization. Fine grain copper plating in accordance with AMS2418, or nickel plating in accordance with AMS2424, may be used without approval but the surface contamination specimens in AMS2759 shall not be plated. Failure of the unplated specimen to meet contamination requirements shall result in investigation and remedial action taken against the furnace. Additional surface contamination specimens, which include supplemental coating or plating may be processed and tested, and shall be used to represent the parts within the load.

3.4 Procedure

3.4.1 Preheating

The following parts shall be preheated in the range of 900 to 1250 °F (482 to 677 °C) before heating above 1300 °F (704 °C) until the furnace is stabilized at the required temperature:

Parts previously heat treated to a hardness of greater than HRC 35.

Parts that have been welded.

Parts that have been cold formed or straightened.

Parts that have geometries that would result in high thermally induced stresses such as: abrupt changes in section, sharp angular changes, have holes or slots, sharp or slightly rounded notches or corners.

Parts that have been normalized without tempering.

3.4.1.1 Preheating in a separate furnace is allowed provided that parts are transferred without delay into the heat treatment furnace.

3.4.2 Soaking

The start of soaking time shall be in accordance with AMS2759.

3.4.2.1 Parts coated with copper or nickel plate or similar reflective coatings that tend to reflect radiant heat shall have their soak time increased by at least 50%, for annealing, normalizing, sub-critical annealing, or austenitizing, unless load thermocouples are used. This increase does not apply to salt bath heat treating, tempering, or sub-zero processing.

3.4.3 Annealing

3.4.3.1 When required, annealing shall be accomplished by heating to the temperature specified in Table 2, soaking for the time specified in Table 4, and cooling to below the temperature specified in Table 2 at the rate shown in Table 2, followed by air cooling to ambient temperature. Isothermal annealing treatments may be used provided equivalent hardness and microstructure are obtained.

3.4.3.2 Isothermal annealing shall be accomplished by heating to the annealing temperature specified in Table 2, soaking for the time specified in Table 4, cooling to a temperature below the critical, holding for sufficient time to complete transformation, and air cooling to ambient temperature.

3.4.4 Subcritical Annealing

When required, subcritical annealing shall be accomplished prior to hardening by heating to a set temperature between 1150 °F and 1250 °F (621 °C and 677 °C), soaking for the time specified in Table 4, and cooling to ambient temperature. Steel parts of the 9Ni-4Co type shall be subcritical annealed as specified in Table 2.

3.4.5 Pre-Hardening Stress Relief

When required, pre-hardening stress relieving shall be done in accordance with AMS2759/11.

3.4.6 Normalizing

When required, normalizing shall be accomplished by heating to the temperature specified in Table 2, soaking for the time specified in Table 4, and cooling in air or atmosphere to ambient temperature. Circulated air or atmosphere is recommended for thicknesses greater than 3 inches (76 mm). Normalizing may be followed by tempering or subcritical annealing.

3.4.7 Hardening (Austenitizing and Quenching)

3.4.7.1 All parts, except those made from H-11 (see Table 2, Note 3), 52100 (see Table 2, Note 7), or M-50 steels, shall be in one of the following conditions prior to austenitizing: normalized, normalized and tempered, or hardened and tempered. If such parts have been normalized only, without tempering, they shall be preheated per 3.4.1 before exposure to the austenitizing temperature (see Table 2, Note 2).

3.4.7.2 As steel parts hardened to this specification have limited hardenability, which varies by alloy, the size limits in Table 5 shall apply. Parts exceeding size limitations shall be machined to within 0.125 inch of the final dimensions prior to hardening. With cognizant engineering organization approval, parts may be greater than 0.125 inch (3.2 mm) of the final dimensions prior to hardening.

3.4.7.3 Welded parts and brazed parts with a brazing temperature above the normalizing temperature shall be normalized before hardening. Welded parts should be preheated in accordance with 3.4.1.

3.4.7.4 Hardening shall be done by heating to the austenitizing temperature specified in Table 2, soaking for the time specified in Table 4, and quenching as specified in Table 2. The parts shall be cooled to or below the quenchant temperature or to a temperature low enough to achieve complete transformation, before tempering. Parts made from alloys specifically noted in Table 2 as allowing inert gas quenching shall have gas quenching qualified per Appendix A or per another procedure approved by the cognizant engineering organization.

3.4.8 Tempering

When required, tempering shall be accomplished by heating to the set temperature specified in Table 3. Parts should be tempered within 2 hours from the end of quenching (see 3.4.8.1). Soaking time shall be not less than 2 hours plus 1 hour additional for each inch (25 mm) of thickness or fraction thereof greater than 1 inch (25 mm). Thickness is defined in AMS2759. When load thermocouples are used, the soaking time shall be not less than 2 hours. When multiple tempering cycles are required, parts shall be cooled to ambient temperature between tempering treatments, see Table 3. When a strength or hardness not listed in Table 3 is specified, the parts shall be processed at times and temperatures appropriate to achieve the specified properties.

3.4.8.1 When tempering cannot be started within 4 hours from the end of quenching, parts shall be snap tempered for 2 hours minimum at a temperature that is lower than the final tempering set temperature (see 8.4.1), usually 400 °F (204 °C).

3.4.9 Straightening

When approved by the cognizant engineering organization, straightening shall be accomplished as stated in an approved procedure.

3.4.10 Post-Tempering Stress Relieving

When required, post-tempering stress relieving shall be in accordance with AMS2759/11.

3.5 Properties

3.5.1 Hardness

Parts shall conform to the hardness range stated in Table 3. Hardness testing shall not be used to reject parts that meet specified tensile properties. Frequency of hardness testing shall be in accordance with AMS2759.

3.5.1.1 If tensile strength testing is specified to be performed and the hardness readings, converted to tensile strength, do not meet the specified tensile properties, the parts shall not be rejected as long as the tensile test results are conforming.

3.5.2 Surface Contamination

When heating to a temperature above 1250 °F (677 °C), surface contamination shall be in accordance with AMS2759.

3.5.2.1 When supplemental plating or coating, such as copper plate, is used, all atmosphere controls and surface contamination tests are required.

3.6 Test Methods

Shall be in accordance with AMS2759.

4. QUALITY ASSURANCE PROVISIONS

The responsibility for inspection, classification of tests, sampling and testing, approval, records, record retention, and report/certification shall be in accordance with AMS2759 and as follows.

4.1 Acceptance Tests

Hardness (see 3.5.1), tensile properties, when required (see 3.5.1.1), and surface contamination (see 3.5.2) are acceptance tests and shall be performed on each lot of Type 2 parts. Alternatively, if carbon potential is controlled automatically and either indicated or recorded, frequency of surface contamination tests may be in accordance with the sampling plan of 4.4.

4.2 Periodic Tests

In addition to the tests specified in AMS2759, tests for surface contamination (see 3.5.2) shall be performed monthly on each furnace in service, each kind of atmosphere to be used in each furnace, and for each Class B atmosphere at two carbon potentials, up to 0.40% and over 0.40%. Furnaces used exclusively to heat treat parts that will have all contamination removed shall not require testing.

4.3 Preproduction Tests

In addition to the tests specified in AMS2759, tests for surface contamination (see 3.5.2) shall be performed prior to any production heat treating on each furnace, each kind of atmosphere to be used in each furnace, and for each Class B atmosphere at two carbon potentials, up to 0.40% and over 0.40%. Furnaces used exclusively to heat treat parts that will have all contamination removed shall not require testing.

4.4 Alternative Sampling Plan

4.4.1 An alternative test plan to meet the requirements of 4.1 is permitted for heat treatment processes verified by statistical process control (SPC) to be stable and capable.

4.4.2 A process is considered stable when statistical evaluation of the product and process parameters show that all measured values fall within established control limits.

4.4.3 A process is considered capable when, after achieving and maintaining stability, all parts running to the process have a minimum C_{pk} of 1.33 with a confidence level of 90%.

NOTE: C_{pk} is defined as the smaller of either C_{pl} or C_{pu} as determined by Equations 1 or 2:

$$C_{pl} = \frac{\overline{X} - LSL}{3\sigma} \quad \text{(Eq. 1)}$$

$$C_{pu} = \frac{USL - \overline{X}}{3\sigma} \quad \text{(Eq. 2)}$$

where:

$\overline{X}$ = process average

LSL = lower specification limit*

USL = upper specification limit*

*Specification limits are based on target values established by the processor

σ = estimated standard deviation

4.4.4 The alternative test plan shall contain the following:

4.4.4.1 Statistical analysis of the heat treatment process parameters and the product test results of properties for control and capability (see 3.5).

4.4.4.2 Documentation of the critical process parameters and of the product test results of properties on a control plan (see 3.5). A change in these process parameters of product test results will require review to determine if the process capability requires reverification.

4.4.4.3 Periodic auditing of the heat treatment process parameters and the product test results of properties to verify continued control and capability (see 3.5).

4.4.4.4 Monthly or whenever needed by either the cognizant engineering authority or process constraints. Surface contamination shall be examined in accordance with 3.5.2.

5. PREPARATION FOR DELIVERY

Shall be in accordance with AMS2759.

6. ACKNOWLEDGMENT

Shall be in accordance with AMS2759.

7. REJECTIONS

Shall be in accordance with AMS2759.

8. NOTES

Shall be in accordance with AMS2759 and the following.

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 (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 Heating below 1400 °F (760 °C) with Class B atmospheres containing 5% or more of hydrogen (H_2), carbon monoxide (CO), or methane (CH_4) may result in explosion and fire.

8.3 Use of a chromic-caustic etch to reveal intergranular attack/oxidation has been discontinued because it is an environmental hazard, it is unnecessary for measurement of maximum depth of crevices, and light etching zones extending beyond the crevices have been misinterpreted as manifestations of intergranular oxidation.

8.4 Terms used in AMS are clarified in ARP1917 and as follows:

8.4.1 Snap Tempering

An intermediate low-temperature treatment to relieve stresses and prevent cracking prior to the next operation. Final tempering to the specified requirements is performed after snap tempering.

8.4.2 Marquenching (Martempering)

Quenching an austenitized alloy in a salt or hot oil bath at a temperature in the upper part of, or slightly above, the martensite range and holding until temperature uniformity throughout the part is obtained, usually followed by air cooling through the martensite range to ambient temperature.

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.

PREPARED BY AMS COMMITTEE “E” AND AMEC

Table 2A - Annealing, normalizing, and austenitizing temperatures and quenchants (inch/pound units)

Material Designation	Annealing[1] Set Temperature, °F	Normalizing Set Temperature, °F	Austenitizing Set Temperature, °F	Hardening Quenchant
4330V, 4330Mod[2]	1550-1575	1650	1600	oil, polymer, inert gas[13][14]
4335V, 4335Mod[2]	1550	1650	1600	oil, polymer, inert gas[14]
4340[2]	1550	1650	1500-1550	oil, polymer, inert gas[13][14]
Hy-Tuf[2]	1400	1725	1600	oil, polymer
300M[2]	1550	1700	1600	oil, polymer, inert gas[13][14]
4340 Mod[2]	1550	1700	1600	oil, polymer, inert gas[13][14]
H-11[3]	1575-1625	[18]	1850	air, oil, polymer, inert gas
98BV40 Modified[2]	1550	1600	1550	oil, polymer
D6AC[2]	1550	1725	1625[4]	oil, polymer
52100	[6]	1625-1675	1525-1550[7]	oil, polymer[5][13]
9Ni-4Co-0.30C[2]	[8]	1650-1700	1550	oil, polymer[5]
M-50	[18]	[9]	2000-2025[10]	salt[11], oil, inert gas[13][14]
NC310YW (AMS6499)[2]	[15]	1787[16]	1724[12][17]	oil, polymer, inert gas[14]

NOTES:

1 Cool at a rate not to exceed 200 °F per hour to below 1000 °F, except cool 4330V, 4335V, and 4340 to below 800 °F, and 300M to below 600 °F.

2 All parts, except those made from H-11, 52100, or M-50 steels, shall be in one of the following conditions prior to austenitizing: normalized, normalized and tempered, or hardened. If such parts have been normalized only, without tempering or overaging, they shall be preheated per 3.4.1 before exposure to the austenitizing temperature.

3 H-11 parts shall be in the annealed condition prior to the initial austenitizing treatment.

4 1700 °F permitted for D6AC parts, when approved by the cognizant engineering organization.

5 Immediately after quenching sub-zero cool parts made from 52100 and 9Ni-4Co-0.30C at -90 °F or lower, hold 1 hour minimum, and air warm to room temperature. For parts made from 52100 with a geometry that is susceptible to cracking during sub-zero cooling, a snap temper before sub-zero cooling is allowed (see 8.4.1).

6 Anneal parts made from 52100 at 1430 °F for 20 minutes, cool to 1370 °F at a rate not faster than 20 °F per hour, cool to 1320 °F at a rate not to exceed 10 °F per hour, cool to 1250 °F at a rate not faster than 20 °F per hour, and air cool to ambient temperature.

7 1500 °F permissible for parts made from 52100 requiring distortion control. Parts shall be hardened from the spheroidize annealed condition or the normalized condition.

8 9Ni-4Co-0.30C parts shall be duplex subcritical annealed by heating at 1250 °F ± 25 °F for 4 hours ± 1/4 hour, air cooling to ambient temperature, reheating at 1150 °F ± 25 °F for 4 hours ± 1/4 hour, and air cooling to ambient temperature or shall be annealed by heating at 1150 °F ± 25 °F for not less than 23 hours minimum and air cooling to ambient temperature.

9 Normalizing of M-50 parts should be avoided due to grain growth.

10 M-50 parts shall be preheated to 1550 °F prior to austenitizing.

11 For M-50, use 1125 °F followed by air cool to ambient temperature or air cool directly to ambient temperature.

12 Sub-zero no more than -94 °F is required for obtaining the maximum hardness.

13 Marquenching in a nitrate/nitrite salt bath, oil bath, or alternate quenchant operated at a set temperature applicable to the alloys processed is permitted. The parts shall be in the marquenching bath only for sufficient time to stabilize the parts at the bath temperature, but not less than 2 minutes, followed by cooling to approximately ambient temperature. Salt residues shall be removed by a hot water rinse before air tempering (see 8.4.2).

14 Parts may be gas quenched as required in 3.4.7.4.

15 For NC310YW, anneal by heating at 1688 °F ± 25 °F for 1 hour, cool to 1292 °F ± 25 °F and maintain at 1292 °F ± 25 °F for 24 hours.

16 For NC310YW, normalizing temperature can be set between 1742 °F and 1814 °F.

17 For NC310YW, austenitizing temperature can be set between 1670 °F and 1742 °F.

18 These operations are not recommended.

Table 2B - Annealing, normalizing, and austenitizing temperatures and quenchants (SI units)

Material Designation	Annealing[1] Set Temperature, °C	Normalizing Set Temperature, °C	Austenitizing Set Temperature, °C	Hardening Quenchant
4330V, 4330Mod[2]	843-857	899	871	oil, polymer, inert gas[13][14]
4335V, 4335Mod[2]	843	899	871	oil, polymer, inert gas[14]
4340[2]	843	899	816-843	oil, polymer, inert gas[13][14]
Hy-Tuf[2]	760	941	871	oil, polymer
300M[2]	843	927	871	oil, polymer, inert gas[13][14]
4340 Mod[2]	843	927	871	oil, polymer, inert gas[13][14]
H-11[3]	857-885	[18]	1010	air, oil, polymer
98BV40 Modified[2]	843	871	843	oil, polymer
D6AC[2]	843	941	885[4]	oil, polymer
52100	[6]	885-913	829-843[7]	oil, polymer[5][13]
9Ni-4Co-0.30C[2][5]	[8]	899-927	843	oil, polymer[5]
M-50	[18]	[9]	1093-1107[10]	salt[11], oil, inert gas[13][14]
NC310YW (AMS6499)[2]	[15]	975[16]	940[12][17]	oil, polymer, inert gas[14]

NOTES:

1 Cool at a rate not to exceed 93 °C per hour to below 538 °C, except cool 4330V, 4335V, and 4340 to below 427 °C, and 300M to below 316 °C.

2 All parts, except those made from H-11, 52100, or M-50 steels, shall be in one of the following conditions prior to austenitizing: normalized, normalized and tempered, or hardened. If such parts have been normalized only, without tempering or overaging, they shall be preheated per 3.4.1 before exposure to the austenitizing temperature.

3 H-11 parts shall be in the annealed condition prior to the initial austenitizing treatment.

4 927 °C permitted for D6AC parts, when approved by the cognizant engineering organization.

5 Immediately after quenching sub-zero cool parts made from 52100 and 9Ni-4Co-0.30C at -68 °C or lower, hold 1 hour minimum, and air warm to room temperature. For parts made from 52100 with a geometry that is susceptible to cracking during sub-zero cooling, a snap temper before sub-zero cooling is allowed (see 8.4.1).

6 Anneal parts made from 52100 at 777 °C for 20 minutes, cool to 743 °C at a rate not faster than 11 °C per hour, cool to 716 °C at a rate not to exceed 6 °C per hour, cool to 677 °C at a rate not faster than 11 °C per hour, and air cool to ambient temperature.

7 816 °C permissible for parts made from 52100 requiring distortion control. Parts shall be hardened from the spherodize annealed condition or the normalized condition.

8 9Ni-4Co-0.30C parts shall be duplex subcritical annealed by heating at 677 °C ± 14 °C for 4 hours ± 1/4 hour, air cooling to ambient temperature, reheating at 621 °C ± 14 °C for 4 hours ± 1/4 hour, and air cooling to ambient temperature or shall be annealed by heating at 621 °C ± 14 °C for not less than 23 hours minimum and air cooling to ambient temperature.

9 Normalizing of M-50 parts should be avoided due to grain growth.

10 M-50 parts shall be preheated to 843 °C prior to austenitizing.

11 For M-50, use 607 °C followed by air cool to ambient temperature or air cool directly to ambient temperature.

12 Sub-zero no more than -70 °C is required for obtaining the maximum hardness.

13 Marquenching in a nitrate/nitrite salt bath, oil bath, or alternate quenchant operated at a set temperature applicable to the alloys processed is permitted. The parts shall be in the marquenching bath only for sufficient time to stabilize the parts at the bath temperature, but not less than 2 minutes, followed by cooling to approximately ambient temperature. Salt residues shall be removed by a hot water rinse before air tempering (see 8.4.2).

14 Parts may be gas quenched as required in 3.4.7.4.

15 For NC310YW, anneal by heating at 920 °C ± 14 °C for 1 hour, cool to 700 °C ± 14 °C and maintain at 700 °C ± 14 °C for 24 hours.

16 For NC310YW, normalizing temperature can be set between 950 °C and 990 °C.

17 For NC310YW, austenitizing temperature can be set between 910 °C and 950 °C.

18 These operations are not recommended.

Table 3A - Tempering set temperatures (inch/pound units)

Material Designation	Tensile Strength Range, ksi[1] 220-240	Tensile Strength Range, ksi[1] 260-280	Tensile Strength Range, ksi[1] 280-305	Hardness Range (HRC)
4330V, 4330Mod[2]	500[3]	-	-	46-49
4335V, 4335Mod[2]	500[3]	-	-	46-49
4340[2]	-	425-490	-	50-54
Hy-Tuf[2]	550[4]	-	-	46-49
300M[2]	-	-	575[5]	53-56
4340 Mod[2]	-	-	575	53-56
H-11[2][6]	1025[3]	-	-	46-49
98BV40 Modified	-	-	500[3]	53-56
D6AC[2]	[7]	[8]	-	46-49/50-56
52100[2]	-	-	-	[9]
9Ni-4Co-0.30C[2]	1000[3]	-	-	46-49
M-50[10]	-	-	-	[11]
NC310YW (AMS6499)	-	-	572[2]	53-56

NOTES:
1 Absence of values indicates the respective steel is not recommended for the specified tensile strength range.
2 At least two tempering operations are required.
3 Minimum tempering temperature.
4 220 to 250 ksi for Hy-Tuf.
5 Use this tempering temperature for 275 to 305 ksi range for 300M, when specified.
6 At least three tempering operations are required for H-11.
7 For D6AC, first temper: 1000 °F minimum; second temper: 1015 to 1060 °F.
8 For D6AC, first temper: 550 °F minimum; second temper: 550 to 700 °F.
9 For 52100, 58 to 65 HRC, temper at 340 to 450 °F.
10 Triple tempering required for M-50; double tempering permitted when approved by the cognizant engineering organization.
11 For M-50, 60 to 64 HRC, temper at 1000 to 1025 °F.

Table 3B - Tempering set temperatures (SI units)

Material Designation	Tensile Strength Range, MPa[1] 1517-1655	Tensile Strength Range, MPa[1] 1793-1931	Tensile Strength Range, MPa[1] 1931-2103	Hardness Range (HRC)
4330V 4330Mod[2]	260[3]	-	-	46-49
4335V 4335Mod[2]	260[3]	-	-	46-49
4340[2]	-	218-254	-	50-54
Hy-Tuf[2]	288[4]	-	-	46-49
300M[2]	-	-	302[5]	53-56
4340 Mod[2]	-	-	302	53-56
H-11[6]	552[3]	-	-	46-49
98BV40 Modified	-	-	260[3]	53-56
D6AC[2]	[7]	[8]	-	46-49/50-56
52100[2]	-	-	-	[9]
9Ni-4Co-0.30C[2]	538[3]	-	-	46-49
M-50[10]	-	-	-	[11]
NC310YW (AMS6499)	-	-	300[2]	53-56

NOTES:
1 Absence of values indicates the respective steel is not recommended for the specified tensile strength range.
2 At least two tempering operations are required.
3 Minimum tempering temperature.
4 1517 to 1724 MPa for Hy-Tuf.
5 Use this tempering temperature for 1896 to 2103 MPa range for 300M, when specified.
6 At least three tempering operations are required for H-11.
7 For D6AC, first temper: 538 °C minimum; second temper: 546 to 571 °C.
8 For D6AC, first temper: 288 °C minimum; second temper: 288 to 371 °C.
9 For 52100, 58 to 65 HRC, temper at 171 to 232 °C.
10 Triple tempering required for M-50; double tempering permitted when approved by the cognizant engineering organization.
11 For M-50, 60 to 64 HRC, temper at 538 to 552 °C.

Table 4 - Soak time for annealing, normalizing, and austenitizing

Thickness[1] Inches	Thickness[1] Millimeters	Minimum Soak Time [2][3][4][5][6] Air or Atmosphere	Minimum Soak Time [2][3][4][5][6] Salt
Up to 0.250	Up to 6.35	25 minutes	18 minutes
Over 0.250 to 0.500	Over 6.35 to 12.70	45 minutes	35 minutes
Over 0.500 to 1.000	Over 12.70 to 25.40	1 hour 0 minutes	40 minutes
Over 1.000 to 1.500	Over 25.40 to 38.10	1 hour 15 minutes	45 minutes
Over 1.500 to 2.000	Over 38.10 to 50.80	1 hour 30 minutes	50 minutes
Over 2.000 to 2.500	Over 50.80 to 63.50	1 hour 45 minutes	55 minutes
Over 2.500 to 3.000	Over 63.50 to 76.20	2 hours 0 minutes	1 hour 0 minutes
Over 3.000 to 3.500	Over 76.20 to 88.90	2 hours 15 minutes	1 hour 5 minutes
Over 3.500 to 4.000	Over 88.90 to 101.60	2 hours 30 minutes	1 hour 10 minutes
Over 4.000 to 4.500	Over 101.60 to 114.30	2 hours 45 minutes	1 hour 15 minutes
Over 4.500 to 5.000	Over 114.30 to 127.00	3 hours 0 minutes	1 hour 20 minutes
Over 5.000 to 8.000	Over 127.00 to 203.20	3 hours 30 minutes	1 hour 40 minutes
Over 8.000	Over 203.20	[7]	[8]

NOTES:
1 Thickness is the minimum dimension of the heaviest section of the part.
2 Soak time commences as specified in AMS2759.
3 In all cases, the parts shall be held for sufficient time to ensure that the center of the most massive area has reached temperature and the necessary transformation and diffusion have taken place.
4 Maximum soak time should not exceed three times the minimum soak time, except for subcritical annealing.
5 Austenitizing of M-50 for more than 10 minutes should be avoided due to grain growth.
6 Longer times may be necessary for parts with complex shapes or parts that do not heat uniformly.
7 4 hours plus 30 minutes for every 3 inches (76 mm) or increment of 3 inches (76 mm) greater than 8 inches (203 mm).
8 2 hours plus 20 minutes for every 3 inches (76 mm) or increment of 3 inches (76 mm) greater than 8 inches (203 mm).