AEROSPACE MATERIAL SPECIFICATION

AMS2759™/3	REV. J

Issued 1984-10
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Revised 2020-05

Superseding AMS2759/3H

Heat Treatment Precipitation-Hardening Corrosion-Resistant, Maraging, and Secondary Hardening Steel Parts

RATIONALE

AMS2759/3J changes Tensile (3.4.2), Table 3 notes 5 and 18, and Table 4 note 2.

NOTICE

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

- AMS2759/3J

1. SCOPE

1.1 Purpose

This specification, in conjunction with the general requirements for steel heat treatment covered in AMS2759, establishes the requirements for heat treatment of precipitation-hardening corrosion-resistant, maraging and secondary hardening, steel parts. Parts are defined in AMS2759. Parts made from steels other than those specified in this specification may be heat treated in accordance with the applicable requirements herein using processing temperatures, times, and other parameters recommended by the material producer unless otherwise specified by the purchaser. General ordering instructions are specified in AMS2759.

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

1.3 Application

This specification is applicable to parts made from the steels listed in Table 1.

TO PLACE A DOCUMENT ORDER: **Tel: 877-606-7323 (inside USA and Canada)**
Tel: +1 724-776-4970 (outside USA)
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For more information on this standard, visit
https://www.sae.org/standards/content/AMS2759/3J/

Table 1 - List of steels

Precipitation Hardenable: Martensitic	Precipitation Hardenable: Semi-Austenitic	Precipitation Hardenable: Austenitic	Maraging	Secondary Hardening
15-5 PH	17-7 PH	A-286	Maraging 250	AerMet 100
17-4 PH	PH 15-7 Mo		Maraging 300	AF1410
PH 13-8 Mo	AM 350		Maraging 350	Ferrium M54
Custom 450	AM 355			Ferrium S53
Custom 455				
Custom 465				
MARVAL X12				
MARVAL X12H				
MLX17				

The above designations are trademarks or commercial designations and are for alloy recognition only.

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.

AMS2759 Heat Treatment of Steel Parts, General Requirements

ARP1820 Chord Method of Evaluating Surface Microstructural Characteristics

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 A380 Cleaning, Descaling and Passivation of Stainless Steel Parts, Equipment, and Systems

ASTM E3 Preparation of Metallographic Specimens

3. TECHNICAL REQUIREMENTS

3.1 Pyrometry

Shall be in accordance with AMS2759 and as specified herein.

3.2 Furnace Equipment

Shall be in accordance with AMS2759 and as follows:

a. Furnaces used at temperatures of 1400 °F (760 °C) and higher and for stress relieving: Class 5.

b. Furnaces used at temperatures from 1300 to 1375 °F (704 to 746 °C): Class 3.

c. Furnaces used at temperatures below 1300 °F (704 °C): Class 2.

d. Furnaces shall have a minimum of type D instrumentation in accordance with AMS2750.

3.2.1 Atmospheres

Shall be controlled so as not to contaminate the parts being heat treated. Furnaces used to heat treat other classes of steel using atmospheres that could contaminate precipitation-hardening, maraging, or secondary hardening steel parts, such as endothermic, exothermic, carbon-containing nitrogen-base, etc., shall have purge cycles (see 8.2) run and then shall be tested to ensure that the surfaces of parts are not contaminated beyond the limits specified in 3.4.3. Parts being heat treated shall be suitably isolated from products of combustion. Materials that could attack or contaminate metal shall not contact parts during heat treatment. Composition and maintenance of salt baths shall be such as to prevent contamination of the parts. Salt baths shall be in accordance with AMS2759.

3.2.2 Heating Environment

Type 1 parts shall be heat treated in air or protective atmosphere.

Type 2 parts shall be heat treated in air or protective atmosphere when heating at or below 1450 °F (788 °C) and shall be heat treated in a protective atmosphere when heating above 1475 °F (802 °C).

3.2.2.1 Acceptable protective atmospheres shall be in accordance with AMS2759, and are limited to helium, argon, hydrogen, neutral salt, nitrogen, nitrogen-hydrogen blends, and vacuum in accordance with AMS2769. For scale-free or discoloration-free parts, air atmospheres and air cooling should be avoided.

3.2.2.1.1 Nitrogen and nitrogen-hydrogen blends are permitted below 1475 °F (802 °C). Nitrogen and nitrogen-hydrogen blends are permitted at or above 1475 °F (802 °C) for Type 1 parts only. Nitrogen and nitrogen-hydrogen blends are permitted up to 1975 °F (1079 °C) as a backfill quench for vacuum furnaces. The use of nitrogen from dissociated ammonia is prohibited.

3.2.3 Protective Coatings

A supplemental coating is permitted to minimize oxidation of parts heated in air.

3.3 Procedure

3.3.1 Cleaning

Shall be in accordance with AMS2759.

3.3.2 Start of Soaking

Start of soak shall be in accordance with AMS2759. When a load thermocouple is used it shall be in contact with the thickest cross-section within each furnace load.

3.3.3 Preheating and Normalizing of Secondary Hardening Grades

Parts should be preheated at 1200 to 1250 °F ± 25 °F (649 to 677 °C ± 14 °C) for a minimum of 30 minutes before normalizing or solution annealing. Normalizing shall be accomplished by heating to the temperature specified in Table 8, soaking for the time specified in Table 4, and cooling in air or a protective atmosphere to ambient temperature.

3.3.4 Annealing of Secondary Hardening Grades

Shall be accomplished by heating to the temperature and soaking for the time specified in Table 8, and cooling in air or a protective atmosphere to ambient temperature.

3.3.5 Re-Solution of Secondary Hardening Grades

Shall be accomplished by heating to the temperature in Table 3 and soaking for the time specified in Table 4.

3.3.5.1 When reworking material (e.g., material with low hardness and/or mechanical properties, equipment malfunctions, interrupted cycles except as allowed by 3.3.6.1), normalizing and annealing are not required before re-solution as long as the solution temperature has not been exceeded.

3.3.6 Solution Heat Treating (Solution Annealing), Austenite Conditioning, and Aging (Precipitation Heat Treating)

Shall be accomplished by heating to the temperature specified in Tables 3 and 6, soaking for the time specified in Tables 3, 4, and 6, and cooling as specified in Tables 3 and 6. Times for low temperature processes (90 °F (32 °C) and below) are cumulative. When a strength or hardness range not listed in Tables 5, 6, or 7 is specified by customer purchasing documents, process the parts at the times and temperatures appropriate to achieve the specified properties. Gas quenching in a vacuum furnace is acceptable when an air cool is specified in Table 3.

3.3.6.1 Aging Cycle Interruption

If the aging cycle is interrupted due to power loss or furnace malfunction that causes the furnace temperature to drop below the required setpoint tolerance, the aging cycle can be continued to complete the required soak time. For example, if power is lost 1 hour and 20 minutes into a 4 hour age cycle, the parts can be re-heated to the aging temperature and aged for 2 hours and 40 minutes in order to complete the 4 hour age. In no cases can the cumulative aging time exceed the maximum time tolerance (for example, 4 hour ages allow +30 minutes, the cumulative aging time cannot exceed 4 hours and 30 minutes). Only one such interruption is allowed per aging cycle. Further interruptions or exceeding the aging time tolerance require reworking via re-solution treatment.

3.3.7 Re-solution heat treating is required in the following cases:

3.3.7.1 Material previously heat treated to the H1150M condition.

3.3.7.2 Material previously heat treated to a lower strength/hardness.

3.3.7.3 Material with low hardness or mechanical properties, equipment malfunctions, interrupted cycles, except as allowed by 3.3.6.1.

3.3.8 Stress relieving, if required, shall be performed in accordance with AMS2759/11.

3.3.9 Carbide Solutioning Treatment (for AM 355).

When required, carbide solutioning (see 8.3.1) shall be accomplished by heating to 1900 °F (1038 °C), soaking for the times shown in Table 2 for the respective section thickness, water quenching to room temperature, cooling to -90 °F (-68 °C) or colder, holding for a minimum of 3 hours, and warming in air to room temperature.

Table 2 - Time for carbide solution treatment

Section Thickness (Inches)	Section Thickness (Millimeters)	Minimum Soaking Time (Hours)
Up to 1, excl	Up to 25, excl	1
1 to 3, incl	25 to 76, incl	2
Over 3	Over 76	3

3.3.10 Straightening

Straightening may be accomplished at ambient temperature, during aging, or after aging by heating to not higher than 50 °F (28 °C) below the final aging temperature. Straightening performed after aging shall be followed by stress relieving.

3.4 Properties

3.4.1 Hardness

Parts shall conform to the hardness ranges stated in Table 5 for the required condition.

3.4.2 Tensile

3.4.2.1 Tensile properties shall conform to those stated in Table 7 for the following alloys and conditions.

AM 350 and AM 355 parts

17-7 PH and PH 15-7 Mo parts heat treated to an RH Condition

15-5 PH and 17-4 PH parts heat treated to the H1100 and H1150 Conditions, excluding the H1150M Condition

3.4.2.2 If tensile testing is specified for any of the above alloys and either the condition and/or the properties are not specified or are not listed in Table 7, then the properties shall conform to those specified by the applicable material specification.

3.4.2.3 For all the other alloys and conditions listed in Table 7, tensile testing shall only be performed when specified and properties shall conform to those stated in Table 7 for the applicable alloy and condition. If tensile testing is specified and no properties are listed for the material and condition in Table 7, then the tensile properties shall conform to those specified by the applicable material specification.

3.4.3 Surface Contamination for Precipitation Hardenable and Maraging Steels

When any surface of a part is not to be machined after heat treatment, the protective atmosphere or backfill medium in furnaces for heating parts above 1450 °F (788 °C) shall be controlled to not produce carburization or nitriding (see 3.5.1.1) and intergranular oxidation shall not exceed 0.0007 inch (0.018 mm). Parts heat treated in salt baths shall be free of residual salts.

3.4.3.1 Unless specifically informed that the parts will be machined all over, the heat treating processor shall process the parts as though some surfaces will not have subsequent metal removal, and therefore shall heat treat above 1450 °F (788 °C) with controlled atmosphere that will conform to the surface contamination requirements. Unless specified, controlled atmosphere is not required for parts with only raw material surfaces, except those made from sheet or strip.

3.4.3.2 Furnaces used exclusively to heat treat parts which will have all contamination removed shall not require testing.

3.4.4 Surface Contamination for Secondary Hardening Steels

Shall be in accordance with AMS2759/2.

3.5 Test Methods

Shall be in accordance with AMS2759 and as follows:

3.5.1 Surface Contamination

3.5.1.1 Precipitation Hardenable and Maraging Grades

Testing shall be by metallurgical examination between 400 and 600X magnification of etched specimens prepared in accordance with ASTM E3. The chord method in ARP1820 may be used to enhance this examination.

3.5.1.2 Secondary Hardening Grades

Testing shall be performed in accordance with the surface contamination requirements of AMS2759/2.

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 (3.4.1) and tensile (3.4.2) are acceptance tests and shall be performed on each lot of parts. In the event of conflict between hardness and tensile properties, parts shall not be rejected on the basis of hardness if the tensile properties are acceptable when determined on specimens taken from the same heat and load.

4.2 Periodic Tests

Surface contamination (3.4.3) is a periodic test and shall be performed on each piece of equipment after the purging of atmospheres whenever the heat treat equipment has been used previously with atmospheres, such as endothermic exothermic, carbon-containing nitrogen-base, etc., that could contaminate precipitation-hardening or maraging steels.

4.3 Preproduction Tests

Surface contamination (3.4.3) is a preproduction test and shall be performed prior to any production heat treating for each piece of equipment and for each type of atmosphere to be used in each furnace.

4.4 Sampling and Testing

Shall be in accordance with AMS2759 and as follows:

4.4.1 Tensile Testing

4.4.1.1 For AM 350 and AM 355 Parts

One or more tensile samples shall be processed with each austenite-conditioning load. It shall be of the same alloy designation as the parts and shall continue with the parts through final aging.

4.4.1.2 For 17-4 PH and 15-5 PH Parts Heat Treated to the H1100 and H1150 Conditions, Excluding the H1150M Condition (see 3.4.2)

One or more tensile samples shall be processed with each aging load. It shall be of the same alloy designation as the parts.

4.4.1.2.1 H1100 and H1150 parts exhibiting tensile properties lower than required by 3.4.2 may be re-solution treated and precipitation hardened. A precipitation hardening temperature of up to 100 °F (56 °C) less than originally employed may be used, but in no instance shall a time less than 4 hours be employed. Parts not meeting tensile requirements under these conditions are not acceptable and shall be rejected.

4.4.1.3 For 17-7 PH and PH 15-7 Mo Parts Heat Treated to the RH Condition

One or more tensile samples shall be processed with each austenite-conditioning load. It shall be of the same alloy designation as the parts and shall continue with the parts through final aging.

4.4.2 Surface Contamination Testing

One or more specimens shall be processed and tested per 3.5.1.

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

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 (l) 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 Effective purge cycles may be run, with reducing gases if necessary, to remove contamination from refractory furnace linings.

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

8.3.1 Carbide Solutioning Treatment

Heating AM 355 to the solution heat treating temperature followed by rapid cooling and then holding at subzero temperatures improves the structural uniformity for further heat treatments.

8.3.2 Austenite Conditioning

Heating PH 15-7 Mo, 17-7 PH, AM 350, and AM 355 to a temperature below that used for solution heat treating. This conditioning treatment produces a metastable austenite for subsequent transformation upon air cooling or subzero cooling.

8.3.3 Transformation

Cooling to a sufficiently low temperature after austenite conditioning to complete the austenite-to-martensite transformation.

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.

Table 3 - Heat treating procedures

Alloy[1]	Final Heat Treat Condition[2]	Solution Heat Treating Set Temp °F[3]	Solution Heat Treating Set Temp °C[3]	Solution Heat Treating Cooling Medium and/or Rate[4]	Austenite Conditioning and Transformation Set Temp (see 8.3.2 and 8.3.3) (3) (4) (17)	Aging Set Temp °F(5) (6)	Aging Set Temp °C(5) (6)	Aging Time, Hours (5) (7)
Precipitation Hardenable: Martensitic								
Wrought 15-5 PH and 17-4 PH	H900	1900	1038	Air cool or faster to below 90 °F (32 °C)[9]	None	900	482	1
	H925					925	496	4
	H950					950	510	4
	H1000					1000	538	4
	H1025					1025	552	4
	H1050					1050	566	4
	H1075					1075	579	4
	H1100					1100	593	4
	H1150					1150	621	4
	H1150M (10)					(10)	(10)	(10)
Cast[16] 15-5 PH and 17-4 PH	H900	1900	1038	Air cool or faster to below 90 °F (32 °C)[9]	None	900	482	1-1/2
	H925					925	496	1-1/2
	H1000					1000	538	4
	H1025					1025	552	4
	H1100					1100	593	4
	H1150					1150	621	4
PH 13-8 Mo	H950	1700	927	Air cool or faster to below 60 °F (16 °C)[9]	None	950	510	4
	H1000					1000	538	4
	H1025					1025	552	4
	H1050					1050	566	4
	H1100					1100	593	4
	H1150					1150	621	4
	H1150M (10)					(10)	(10)	(10)
Custom 450	H900	1900	1038	Air cool or faster	None	900	482	4
	H950					950	510	4
	H1000					1000	538	4
	H1025					1025	552	4
	H1050					1050	566	4
	H1100					1100	593	4
	H1150					1150	621	4
Custom 455	H900	1525	829	Oil, polymer, or water	None	900	482	4
	H950					950	510	4
	H1000					1000	538	4
	CH850[14]	None	None	None	None	850	454	1/2
Custom 465	H950 H1000	1800	982	Oil or water	Within 24 hours of removal from quenchant, cool to -90 °F (-68 °C) or colder for 8 hours minimum, and air warm to ambient.	950 1000	510 538	4 to 8[21] 4 to 8[21]
MARVAL X12	H1000	1545	840	Air, oil, or water	Cool to below 90 °F (32 °C)	1000	538	4[21]
MARVAL X12H	H1000	1545	840	Air, oil, or water	Cool to below 90 °F (32 °C)	1000	538	4[21]
MLX17	H950	1545	840	Oil or water	Within 24 hours of quench, cool to -90 °F (-68 °C) or colder for 8 hours minimum, and air warm to ambient.	950	510	8[21]
	H1000					1000	538	8[21]

Alloy[1]	Final Heat Treat Condition[2]	Solution Heat Treating Set Temp °F[3]	Solution Heat Treating Set Temp °C[3]	Solution Heat Treating Cooling Medium and/or Rate[4]	Austenite Conditioning and Transformation Set Temp (see 8.3.2 and 8.3.3) (3) (4) (17)	Aging Set Temp °F(5) (6)	Aging Set Temp °C(5) (6)	Aging Time, Hours (5) (7)
Precipitation Hardenable: Semi-Austenitic								
17-7 PH and PH 15-7 Mo	RH950	1925	1052	Air cool or faster	1750 °F (954 °C), cool to -90 °F (-68 °C), or colder for 8 hours minimum, and air warm to ambient. (Results in Condition R.)[8]	950	510	1
	RH1000					1000	538	1
	RH1050					1050	566	1
	RH1075					1075	579	1
	RH1100					1100	593	1
	TH950	1925	1052	Air cool or faster	1400 °F (760 °C) for 90 minutes, cool below 60 °F (16 °C) within 1 hour after removal from furnace for 30 minutes minimum. (Results in Condition T.) (19)	950	510	1-1/2
	TH1000					1000	538	1-1/2
	TH1050					1050	566	1-1/2
	TH1075					1075	579	1-1/2
	TH1100					1100	593	1-1/2
	CH900[11]	None	None	None	None	900	482	1
AM 350	SCT 850	1925	1052	Air cool or faster	1750 °F (954 °C), cool to -90 °F (-68 °C), or colder for 3 hours minimum, and air warm to ambient.	850	454	3
	SCT 950					950	510	3
	SCT 1000					1000	538	3
	SCT 1100					1100	593	3
AM 355	SCT 850	1900	1038	Air cool or faster	1750 °F (954 °C), water quench, cool to -90 °F (-68 °C), or colder for 3 hours minimum, and air warm to ambient.	850	454	3
	SCT 1000					1000	538	3

Precipitation Hardenable: Austenitic								
A-286[12]	Aged	(13)	(13)	Sheet: air cool or faster. Other forms: water, oil, or polymer.[15]	None	(13)	(13)	(13)

Maraging								
Maraging 250	Aged	1500	816	Air cool or faster to ambient	None	900	482	4 to 6 hours +0-0.5
Maraging 300	Aged	1500	816	Air cool or faster to ambient	None	900	482	4 to 6 hours +0-0.5
Maraging 350	Aged	1500	816	Air cool or faster to ambient	None	950	510	3 to 6 hours +0-0.5

Alloy[1]	Final Heat Treat Condition[2]	Solution Heat Treating Set Temp °F[3]	Solution Heat Treating Set Temp °C[3]	Solution Heat Treating Cooling Medium and/or Rate[4]	Austenite Conditioning and Transformation Set Temp (see 8.3.2 and 8.3.3) (3) (4) (17)	Aging Set Temp °F(5) (6)	Aging Set Temp °C(5) (6)	Aging Time, Hours (5) (7)
Secondary Hardening								
AerMet 100[20]	260-280	1625	885	Air, oil (160 °F or lower), polymer, or PPGQ below 400 °F (204 °C) within 1 hour and below 150 °F (66 °C) within 2 hours	Within 8 hours of quenching, cool to -90 °F (-68 °C) or colder for 1 hour minimum per inch of thickness or fraction thereof, and warm to ambient.	900[22]	482	6 to 10
	280-300	1625	885	Air, oil (160 °F or lower), polymer, or PPGQ below 400 °F (204 °C) within 1 hour and below 150 °F (66 °C) within 2 hours	Within 8 hours of quenching, cool to -90 °F (-68 °C), or colder for 1 hour minimum per inch of thickness or fraction thereof, and warm to ambient.	900[22]	482	4 to 8
	290-310	1625	885	Air, oil (160 °F or lower), polymer, or PPGQ below 400 °F (204 °C) within 1 hour and below 150 °F (66 °C) within 2 hours	Within 8 hours of quenching, cool to -90 °F (-68 °C), or colder for 1 hour minimum per inch of thickness or fraction thereof, and warm to ambient.	875[22]		4 to 8
AF1410[20]	Aged	1525	829	Oil or polymer[15]	Immediately after quenching cool to -90 °F (-68 °C), or colder for 1 hour minimum, per inch of thickness or fraction thereof and air warm to ambient.	925	496	5
Ferrium M54[20]	Aged	1940	1060	Air, Oil, Polymer, PPGQ	Within 8 hours of quenching, cool to -90 °F (-68 °C), or colder for 1 hour per inch of thickness or fraction thereof, and warm to ambient.	960	516	8 to 12
Ferrium S53[20]	Aged	1985	1085	Air, Oil, Polymer, PPGQ	Within 8 hours of quenching, cool to -90 °F (-68 °C), or colder for 1 hour per inch of thickness or fraction thereof, and warm to ambient.	(18)	(18)	(18)

Alloy[1]	Final Heat Treat Condition[2]	Solution Heat Treating Set Temp °F[3]	Solution Heat Treating Set Temp °C[3]	Solution Heat Treating Cooling Medium and/or Rate[4]	Austenite Conditioning and Transformation Set Temp (see 8.3.2 and 8.3.3) (3) (4) (17)	Aging Set Temp °F[5] (6)	Aging Set Temp °C[5] (6)	Aging Time, Hours (5) (7)

NOTES:

(1) These designations are for alloy recognition only.

(2) See Table 7 for specified minimum tensile strength for condition.

(3) Soak for time listed in Table 4 unless otherwise indicated.

(4) Air refers to ambient air. When vacuum furnaces are used for heat treating, cooling in the backfilling gas is acceptable where cooling in still air or air cool is specified.

(5) If hardness exceeds the maximum specified, parts may be re-aged at the same or higher temperatures for a time not to exceed that stated in the table to obtain the required hardness. Note 7 time tolerances apply.

(6) To produce a lower hardness for pretested material, a set temperature up to 10 °F (6 °C) higher than specified may be used.

(7) Except for maraging grades, tolerance for soaking time shall be +10, -0 minutes for 30 minute ages; +15, -0 minutes for 1 hour ages; +30 minutes, -0 minutes for longer ages.

(8) A maximum time delay of 96 hours is permitted between removal of the parts from the 1750 °F (954 °C) furnace and the beginning of refrigeration treatment to Condition RH. Where this requirement is not met, parts require solution treating prior to subsequent processing.

(9) Artificial means may be used to cool below ambient temperature, when necessary, to get below 90 °F (32 °C) or below 60 °F (16 °C).

(10) H1150M is an intermediate soft condition that must be re-solution heat treated to obtain a different final condition. To obtain H1150M, heat at 1400 °F (760 °C) for 2 to 2-1/2 hours, air cool below 90 °F (32 °C) then heat at 1150 °F (621 °C) for 4 hours.

(11) For CH900 do not re-solution heat treat.

(12) Procured in two solution heat treated conditions: (1) 1650 °F (899 °C) for maximum strength and (2) 1750 to 1800 °F (954 to 982 °C) for maximum high temperature characteristics.

(13) See Table 6.

(14) For CH850, do not resolution heat treat.

(15) Gas backfill quenching of forms other than sheet is acceptable provided mechanical properties are tested after precipitation hardening and results conform to requirements.

(16) Homogenize by soaking at 2100 °F (1149 °C) for 90 minutes minimum and cooling to below 90 °F (32 °C).

(17) For sub-zero treatments, interruptions of the soaking period are permitted. The total soak time shall not include any time when the temperature is greater than -90 °F (-68 °C) due to interruptions.

(18) Age Ferrium S53 at 934 °F (501 °C) for 3 hours, ±30 minutes, followed by quenching in oil, polymer, or Positive Pressure Gas Quench (PPGQ) within 30 minutes to below 120 °F (49 °C). Within 8 hours subzero cool at -100 °F (-73 °C) or lower for 1 hour minimum and then let warm in air to a minimum of 75 °F (24 °C). Re-age at 900 °F (482 °C) for 12 hours, +2, -1 hours and air cool.

(19) For parts not meeting the 1 hour time limit for attaining less than 60 °F (16 °C) due to straightening or other interruptions, cool the parts within 72 hours to minus 20 °F (minus 29 °C) or less for 3 hours prior to precipitation hardening.

(20) All parts shall be in the normalized or normalized and annealed condition prior to solution annealing.

(21) When cooling from aging, an oil or water quench is preferred for section sizes greater than about 3 inches (76.2 mm).

(22) It is recommended to preheat parts at 800 °F (427 °C) for 30 to 60 minutes before age.

Table 4 - Soak time for normalizing, solution heat treating and austenite conditioning

Alloy	Form	Thickness Range (Inches)	Soak Time Normalizing and Solution Heat Treating Time, Minutes[(1)]	Soak Time Austenite Conditioning Time, Minutes[(1)]
Precipitation Hardenable: Martensitic				
15-5 PH 17-4 PH PH 13-8 Mo Custom 450 Custom 455	SHEET AND STRIP ONLY	Up to 0.010 0.011 to 0.020 0.021 to 0.030 0.031 to 0.040 0.041 to 0.050 0.051 to 0.060 0.061 to 0.070 0.071 to 0.080 0.081 to 0.090 0.091 to 0.100 0.101 to 0.110 0.111 to 0.120 0.121 to 0.130 0.131 to 0.140 0.141 to 0.150 0.151 to 0.160 0.161 to 0.170 0.171 to 0.180 0.181 to 0.1875, excl	4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22	Not Applicable
	ALL FORMS EXCEPT SHEET	Up to 1.000 1.001 to 2.000 2.001 to 3.000 3.001 to 3.500 3.501 to 4.000 Over 4.000	30 45 60 75 90 90 plus 15 minutes for each 1/2 inch over 4.00 inches (101.6 mm)	Not Applicable
Custom 465 Marval X12 Marval X12H MLX17	ALL FORMS EXCEPT SHEET	Up to 1.000 1.001 to 2.000 2.001 to 3.000 3.001 to 3.500 3.501 to 4.000 Over 4.000	60 75 90 105 120 120 plus 30 minutes for each 1/2 inch over 4.00 inches (101.6 mm)	Not Applicable

Alloy	Form	Thickness Range (Inches)	Soak Time Normalizing and Solution Heat Treating Time, Minutes[1]	Soak Time Austenite Conditioning Time, Minutes[1]
Precipitation Hardenable: Semi-Austenitic				
17-7 PH PH 15-7 Mo AM 350 AM 355	SHEET ONLY	Up to 0.010 0.011 to 0.020 0.021 to 0.030 0.031 to 0.040 0.041 to 0.050 0.051 to 0.060 0.061 to 0.070 0.071 to 0.080 0.081 to 0.090 0.091 to 0.100 0.101 to 0.110 0.111 to 0.120 0.121 to 0.130 0.131 to 0.140 0.141 to 0.150 0.151 to 0.160 0.161 to 0.170 0.171 to 0.180 0.181 to 0.1875, excl	4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22	10 10 10 10 10 10 10 10 10 10 11 12 13 14 15 16 17 18 19
	ALL FORMS EXCEPT SHEET	Up to 1.000 1.001 to 2.000 2.001 to 3.000 3.001 to 3.500 3.501 to 4.000 Over 4.000	30 45 60 75 90 90 plus 15 minutes for each 1/2 inch over 4.00 inches (101.6 mm)	30 45 60 75 90 90 plus 15 minutes for each 1/2 inch over 4.00 inches (101.6 mm)
Precipitation Hardenable: Austenitic				
A-286	SHEET ONLY	Up to 0.010 0.011 to 0.020 0.021 to 0.030 0.031 to 0.040 0.041 to 0.050 0.051 to 0.060 0.061 to 0.070 0.071 to 0.080 0.081 to 0.090 0.091 to 0.100 0.101 to 0.110 0.111 to 0.120 0.121 to 0.130 0.131 to 0.140 0.141 to 0.150 0.151 to 0.160 0.161 to 0.170 0.171 to 0.180 0.181 to 0.1875, excl	10 10 10 10 10 10 10 10 10 10 11 12 13 14 15 16 17 18 19	Not Applicable
A-286	ALL FORMS EXCEPT SHEET	Up to 1.000 1.001 to 2.000 2.001 to 3.000 3.001 to 3.500 3.501 to 4.000 Over 4.000	60 75 90 105 120 120 plus 30 minutes for each 1/2 inch over 4.00 inches (101.6 mm)	Not Applicable

Alloy	Form	Thickness Range (Inches)	Soak Time Normalizing and Solution Heat Treating Time, Minutes[1]	Soak Time Austenite Conditioning Time, Minutes[1]
Maraging				
Maraging 250 Maraging 300 Maraging 350	ALL FORMS EXCEPT SHEET	Up to 1.000 1.001 to 2.000 2.001 to 3.000 3.001 to 3.500 3.501 to 4.000 Over 4.000	60 75 90 105 120 120 plus 30 minutes for each 1/2 inch over 4.00 inches (101.6 mm)	Not Applicable
Secondary Hardening				
AerMet100[2] AF1410[2] Ferrium M54 Ferrium S53	ALL FORMS EXCEPT SHEET	Up to 1.000 1.001 to 2.000 2.001 to 3.000 3.001 to 3.500 3.501 to 4.000 Over 4.000	60 75 90 105 120 120 plus 30 minutes for each 1/2 inch over 4.00 inches (101.6 mm)	Not Applicable

NOTE:
[1] Time is +10 -0 minutes.
[2] Maximum soak time should not exceed three times the stated soak time.

Table 5 - Hardness for precipitation-hardening corrosion-resistant, maraging and secondary hardening grades after aging

Alloy	Form	Condition	Hardness (HRC)
Precipitation Hardenable: Martensitic			
15-5 PH and 17-4 PH	All	H900 H925 H950 H1000 H1025 H1050 H1075 H1100 H1150 H1150M	40 to 47 38 to 45 37 to 44 36 to 43 34 to 42 32 to 38 31 to 38 30 to 37 28 to 37 24 to 30
PH 13-8 Mo	All	H950 H1000 H1025 H1050 H1100 H1150 H1150M	45 to 49 43 to 48 41 to 46 40 to 46 34 to 42 30 to 38 28 to 36
Custom 450	All	H900 H950 H1000 H1025 H1050 H1100 H1150	39 min 37 min 36 min 35 min 34 min 30 min 26 min
Custom 455	All	H900 H950 H1000	47 min 45 min 42 min
	Cold Drawn Wire and Cold Drawn Strip	CH850	(1)
Custom 465	All	H950 H1000	47 min 45 min
Marval X12	All	H1000	39 min
Marval X12H	All	H1000	43 min
MLX17	All	H950 H1000	47 min 45 min
Precipitation Hardenable: Semi-Austenitic			
17-7 PH	All	RH950 RH1000 RH1050 RH1075 RH1100 TH950 TH1000 TH1050 TH1075 TH1100 CH900	42 to 49 41 to 46 40 to 45 38 to 43 34 to 40 42 to 48 40 to 46 38 to 44 37 to 42 34 to 39 46 min

Alloy	Form	Condition	Hardness (HRC)
PH 15-7 Mo	Sheet	RH950	46 to 50
		RH1000	42 to 46
		RH1050	39 to 45
		RH1075	38 to 44
		RH1100	34 to 42
		TH950	(1)
		TH1000	(1)
		TH1050	40 to 46
		TH1075	39 to 44
		TH1100	36 to 41
		CH900	46 min
AM 355	All	SCT 850	41 to 47
	Plate	SCT 1000	37 to 44
	Bar, Forgings	SCT 1000	38 to 44

Precipitation Hardenable: Austenitic			
A-286	Sheet, Plate	125 ksi (862 MPa) min	24 to 35
	All	130 ksi (896 MPa) min	24 to 36
	Sheet, Plate	135 ksi (931 MPa) min	24 to 37
	Sheet, Plate	140 ksi (965 MPa) min	24 to 38
	Bar, Forgings	140 ksi (965 MPa) min	29 to 38
	Bar, Wire	200 ksi (1379 MPa) min	40 min

Maraging			
Maraging 250	All	Age 900	48 min
Maraging 300	All	Age 900	52 min
Maraging 350	All	Age 950	56 min

Secondary Hardening			
AerMet 100	All	260 ksi (1793 MPa) min	50 to 53
		280 ksi (1931 MPa) min	52 to 55
		290 ksi (1999 MPa) min	53 to 56
AF1410	All	220-240 ksi (1517-1655 MPa)	46 to 48
Ferrium M54	All	285 ksi (1965 MPa) min	53 min
Ferrium S53	All	280 ksi (1931 MPa) min	53 min

NOTE:
(1) No values have been established.