SAE Aerospace
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AEROSPACE MATERIAL SPECIFICATION

SAE AMS 2759/3D

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Superseding AMS 2759/3C

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

1. SCOPE:

This specification, in conjunction with the general requirements for steel heat treatment covered in AMS 2759, establishes the requirements for heat treatment of precipitation-hardening corrosion-resistant and maraging steel parts. Parts are defined in AMS 2759.

1.1 Application:

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

TABLE 1 - List of Steels

15-5 PH	PH 13-8 Mo	A-286	Custom 450	Maraging 250
17-4 PH	PH 14-8 Mo	AM-350	Custom 455	Maraging 300
17-7 PH	PH 15-7 Mo	AM-355		

The above designations are trademark 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.

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2.1 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001 or www.sae.org.

AMS 2759 Heat Treatment of Steel Parts, General Requirements

ARP1820 Chord Method of Evaluating Surface Microstructural Characteristics

2.2 ASTM Publications:

Available from ASTM, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959 or www.astm.org.

ASTM A 380 Cleaning and Descaling Stainless Steel Parts, Equipment, and Systems
ASTM E 3 Preparation of Metallographic Specimens
ASTM E 8 Tension Testing of Metallic Materials
ASTM E 8M Tension Testing of Metallic Materials (Metric)

3. TECHNICAL REQUIREMENTS:

3.1 Heat Treatment:

Shall conform to AMS 2759 and requirements specified herein.

3.2 Equipment:

Shall conform to AMS 2759. Furnace temperature uniformity requirements shall be as follows:

3.2.1 Furnaces used at temperatures of 1400 °F (760 °C) and higher and for stress relieving: ± 25 °F (± 14 °C).

3.2.2 Furnaces used at temperatures from 1300 to 1375 °F (704 to 746 °C): ±15 °F (±8 °C).

3.2.3 Furnaces used at temperatures below 1300 °F (704 °C): ±10 °F (±6 °C).

3.3 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, which could contaminate precipitation-hardening or maraging 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 3.5.3. Materials which could attack or contaminate metal shall not contact parts. Composition and maintenance of salt baths shall be such as to prevent contamination of the parts. Salt baths shall be tested in accordance with AMS 2759. Heat treating performed in air shall be in the natural atmosphere of a muffle furnace.

3.3.1 Heating Environment: Parts shall be heat treated in air or protective atmosphere. Acceptable protective atmospheres include argon, helium, hydrogen, neutral salt, and vacuum. Nitrogen and nitrogen-hydrogen blends are permitted below 1425 °F (774 °C). Nitrogen and nitrogen-hydrogen blends are permitted at or above 1425 °F (774 °C) only if 0.020 inch (0.51 mm) is removed from all surfaces after heat treatment. Nitrogen and nitrogen-hydrogen blends are permitted up to 1925 °F (1052 °C) as a backfill quench for vacuum furnaces. Use of nitrogen from dissociated ammonia is prohibited. For scale-free or discoloration-free parts, an air atmosphere and air cooling should be avoided.

3.3.2 Protective Coatings: A supplemental coating is permitted to minimize oxidation of finished machined surfaces when approved by the cognizant engineering organization.

3.4 Procedure:

3.4.1 Acid Cleaning: Parts shall be acid cleaned in accordance with ASTM A 380 before thermal treatment following forming with dies made from lead, kirksite, or other low-melting-temperature materials.

3.4.2 Soaking: During solution heat treating and austenite conditioning, soaking shall be for the required time without interruption. Heating shall be controlled as described in AMS 2759, such that either the heating medium or the part temperature, as applicable, is maintained at the set temperature in Table 3 for the soak time shown in Tables 2, 3, 4, or 6. Soaking shall commence when all control, indicating, and recording thermocouples reach the specified set temperature or if load thermocouples, as defined in AMS 2759, are used, when the part temperature reaches the minimum of the furnace uniformity at the set temperature.

3.4.3 Solution Heat Treating (Solution Annealing, Annealing), Austenite Conditioning, and Aging (Precipitation Heat Treating): Shall be accomplished by heating to the temperature specified in Tables 3 or 6, soaking for the time specified in Tables 3, 4, or 6, and cooling continuously without interruption as specified in Tables 3, 4, and 6.

3.4.3.1 Resolution Heat Treating: Only one resolution heat treatment is permitted.

3.4.4 Stress Relieving: When required by the cognizant engineering organization, heat treated parts shall be stress relieved by heating to 100 F (56 C) degrees below the aging temperature and soaking for at least 1 hour plus 1 hour additional for each inch (25 mm) of thickness or fraction thereof greater than 1 inch (25 mm). When load thermocouples are used, the soaking time shall be at least 1 hour. Stress relieving is prohibited on parts which have been peened or thread-rolled after aging.

3.4.5 Carbide Solutioning Treatment (For AM-355): When required, carbide solutioning 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 below, holding for 1 to 3 hours, and warming in air to room temperature.

TABLE 2 - Time for Carbide Solution Treatment

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

3.4.6 Straightening: When approved by the cognizant engineering organization, straightening shall be accomplished at either ambient temperature, during aging, or by heating to not higher than 50 F (28 C) degrees below the aging temperature. Ambient temperature straightening and hot or warm straightening after aging shall be followed by stress relieving. It is permissible to stress relieve after straightening during aging.

3.5 Properties:

Testing shall be as required by AMS 2759 and as specified herein.

3.5.1 Hardness: Precipitation-hardening corrosion-resistant and maraging steel parts shall conform to the hardness shown in Table 5 for the required condition.

3.5.2 Tensile Properties: When tensile tests are required, results shall conform to the specified values. When tensile properties are not specified, they shall conform to those specified by the applicable material specification.

3.5.3 Surface Contamination: 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 1350 °F (732 °C) shall be controlled to not produce carburization or nitriding (See 3.5.3.1) and intergranular oxidation shall not exceed 0.0007 inch (0.018 mm). Parts heat treated in salt baths shall be free of residual salts.

3.5.3.1 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 1350 °F (732 °C) with controlled atmosphere which 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.

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

3.6 Test Methods:

Shall be in accordance with AMS 2759 and as follows:

3.6.1 Surface Contamination: Testing shall be by metallurgical examination at 500X magnification of etched specimens prepared in accordance with ASTM E 3. The chord method in ARP1820 may be used to enhance this examination.

4. QUALITY ASSURANCE PROVISIONS:

The responsibility for inspection, classification of tests, sampling, approval, entries, records, and reports shall be in accordance with AMS 2759 and as specified in 4.1 and 4.2.

4.1 Classification of Tests:

The classification of acceptance, periodic, and preproduction tests shall be as specified in AMS 2759 and as specified in 4.1.1 thru 4.1.3.

4.1.1 Acceptance Tests: Tensile property requirements (3.5.2) for the following are acceptance tests and shall be performed on each lot: AM-350 and AM-355 parts; 17-7PH and PH15-7Mo parts heat treated to the RH Condition; 15-5PH and 17-4PH parts aged from 1100 °F (593 °C) to 1150 °F (621 °C); when specified, for resolution heat treated parts.

4.1.2 Periodic Tests: Surface contamination (3.5.3) is a periodic test and shall be performed for each piece of equipment after the purging of atmospheres whenever the equipment has been used previously to heat treat using atmospheres, such as endothermic, exothermic, carbon-containing nitrogen-base, etc, which could contaminate precipitation-hardening or maraging steel parts.

4.1.3 Preproduction Tests: Surface contamination (3.5.3) 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.

4.2 Sampling and Testing:

Shall be in accordance with AMS 2759 and as follows:

4.2.1 Tensile Testing:

4.2.1.1 For AM-350 and AM-355: One or more tensile specimens conforming to ASTM E 8 or ASTM E 8M 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.

4.2.1.2 For 17-4PH and 15-5PH aged from 1100 °F (593 °C) to 1150 °F (621 °C): One or more tensile specimens conforming to ASTM E 8 or ASTM E 8M shall be processed with each aging load. It shall be of the same alloy designation as the parts.

4.2.1.3 For 17-7PH and PH15-7Mo to the RH Condition: One or more tensile specimen conforming to ASTM E 8 or ASTM E 8M 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.

4.2.1.4 For Resolution Heat Treated Parts: When specified, one or more tensile specimens conforming to ASTM E 8 or ASTM E 8M shall be processed with each load. It shall be of the same alloy designation as the parts and shall continue with the parts through final aging.

4.2.2 Surface Contamination Testing: One or more samples shall be processed.

5. PREPARATION FOR DELIVERY:

See AMS 2759.

6. ACKNOWLEDGMENT:

See AMS 2759.

7. REJECTIONS:

See AMS 2759.

8. NOTES:

Shall be in accordance with 8.1, 8.2, 8.3, and AMS 2759.

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

8.2 Purge Cycles:

Effective purge cycles can be run to remove contamination from refractory furnace linings using inert gases with small amounts of reducing agents.

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 to improve the structural uniformity for further heat treatments.

8.3.2 Austenite Conditioning: Heating PH 15-7 Mo, 17-7 PH, PH 14-8 Mo, 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.

8.5 Key Words:

Steels, parts, precipitation-hardening, corrosion-resistant, maraging

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 (4)	Austenite Conditioning and Transformation (See 8.3.2 and 8.3.3) (3) (4)	Aging Set Temp °F (5) (6)	Aging Set Temp °C (5) (6)	Aging Time, Hours (5) (7)
15-5 PH	H 900	1900	1038	Air cool or	None	900	482	1 (8)
and	H 925			faster to		925	496	4 (8)
17-4 PH	H 950			below 90 °F		950	510	4
	H 1000			(32 °C) within		1000	538	4
	H 1025			1 hour		1025	552	4
	H 1050			(9)		1050	566	4
	H 1075					1075	579	4
	H 1100					1100	593	4
	H 1150					1150	621	4
	H 1150 M (10)					(10)	(10)	(10)
17-7 PH	RH 950	1925	1052	Air cool	1750 °F (954 °C), air cool	950	510	1
and	RH 1000			or faster	to ambient and within 1 hour	1000	538	1
PH 15-7 Mo	RH 1050				cool below -90 °F (-68 °C),	1050	566	1
	RH 1075				soak 8 to 9 hours, and	1075	579	1
	RH 1100				air warm to ambient.	1100	593	1
					(Results in Cond. R)			
	TH 950	1925	1052	Air cool	1400 °F (760 °C) for	950	510	1 1/2
	TH 1000			or faster	90 minutes, cool to below	1000	538	1 1/2
	TH 1050				60 °F (16 °C) within 1 hour,	1050	566	1 1/2
	TH 1075				hold below 60 °F (16 °C)	1075	579	1 1/2
	TH 1100				for not less than	1100	593	1 1/2
					30 minutes. (Results			
					in Cond. T)			
	CH 900 (11)	None	None	None	None	900	482	1
PH 13-8 Mo	H 950	1700	927	Air cool	None	950	510	4
	H 1000			or faster		1000	538	4
	H 1025			to below		1025	552	4
	H 1050			60 °F (16 °C)		1050	566	4
	H 1100			within 1 hour		1100	593	4
	H 1150			(9)		1150	621	4
	H 1150M (10)					(10)	(10)	(10)
PH 14-8 Mo	SRH 950	1825	996	Air cool	1700 °F (927 °C), air cool	950	510	1
	SRH 1050			or faster	to ambient and within 1 hour	1050	566	1
					cool below -90 °F (-68 °C),			
					soak 8 to 9 hours, and air			
					warm to ambient.			
	CH 900 (11)	None	None	None	None	900	482	1

TABLE 3 - Heat Treating Procedures (Continued)

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 (4)	Austenite Conditioning and Transformation (See 8.3.2 and 8.3.3) (3) (4)	Aging Set Temp °F (5) (6)	Aging Set Temp °C (5) (6)	Aging Time, Hours (5) (7)
A-286 (12)	Aged	(13)	(13)	Sheet: air cool or faster Other forms: water, oil or polymer (15)	None	(13)	(13)	(13)
AM-350	SCT 850 SCT 950 SCT 1000 SCT 1100	1925	1052	Air cool or faster	1750 °F (954 °C), air cool, cool below -90 °F (-68 °C) within 1 hour, soak for 3 to 5 hours, and air warm to ambient.	850 950 1000 1100	454 510 538 593	3 3 3 3
AM-355	SCT 850 SCT 1000	1900	1038	Air cool or faster	1750 °F (954 °C), water quench, cool below -90 °F (-68 °C) within 1 hour, soak for 3 to 5 hours, and air warm to ambient.	850 1000	454 538	3 3
Custom 450	H 900 H 950 H 1000 H 1025 H 1050 H 1100 H 1150	1900	1038	Air cool or faster	None	900 950 1000 1025 1050 1100 1150	482 510 538 552 566 593 621	4 4 4 4 4 4 4
Custom 455 (14)	H 900 H 950 H 1000	1525	829	Oil, polymer, or water	None	900 950 1000	482 510 538	4 4 4
	CH 850 (14)	None	None	None	None	850	454	1/2
Maraging 250 and Maraging 300	Aged	1500	816	Air cool or faster	None	900	482	4 to 6

TABLE 3 - Heat Treating Procedures (Continued)

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 (4)	Austenite Conditioning and Transformation (See 8.3.2 and 8.3.3) (3) (4)	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 Tables 6 and 7 for specified minimum tensile strength conversion to heat treat condition.
3. Soak for time listed in Table 4, unless otherwise indicated.
4. Air means air or atmosphere.
5. An additional 1 to 1-1/2 hours at the specified temperature or an additional 10 to 20 F (6 to 11 C) degrees for an additional 1 to 1-1/2 hours after aging may be used to lower the hardness or other engineering property.
6. To produce a lower hardness for pretested material, a set temperature up to 10 F (6 C) degrees higher than specified may be used.
7. Time, +10, -0 minutes for 30 minutes ages; +15, -0 minutes for 1 hour ages; +30 minutes, -0 minutes for 1-1/2 hours ages; and +45, -0 minutes for 3, 4, and 16 hours ages.
8. 17-4 PH and 15-5 PH castings, H 900, and H 925 time shall be 1-1/2 hours.
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. H 1150M is an intermediate soft condition that must be re-solution heat treated to obtain a different final condition. To obtain H 1150M, solution heat treat, then heat at 1400 °F (760 °C), air cool below 90 °F (32 °C) for 2 to 2-1/2 hours plus 1150 °F (621 °C) for 4 hours.
11. For CH 900 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 CH 850 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.

TABLE 4 - Soak Times for Solution Heat Treating and Austenite Conditioning

Alloy	Form	Minimum Soak Time Minutes (1) (2) (3) Solution Heat Treating	Minimum Soak Time Minutes (1) (2) (3) Austenite Conditioning
15-5 PH and 17-4 PH	Sheet	3 plus one minute for each 0.010 inch (0.25 mm)	
	All except sheet	30 for inch (25 mm)	
17-7 PH and PH 15-7 Mo	Sheet	3 plus one minute for each 0.010 inch (0.25 mm)	10 plus one minute for each 0.010 inch (0.25 mm)
	All except sheet	30 for inch (25 mm)	30 per inch (25 mm)
PH 13-8 Mo	All	30 for inch (25 mm)	
PH 14-8 Mo	Sheet	3 plus one minute for each 0.010 inch (0.25 mm)	60 per inch (25 mm)
A-286	All	60 for inch (25 mm)	
AM-350	Sheet	3 plus one minute for each 0.010 inch (0.25 mm)	10 plus one minute for each 0.010 inch (0.25 mm)
	All except sheet	30 for inch (25 mm)	30 per inch (25 mm)
AM-355	Sheet	3 plus one minute for each 0.010 inch (0.25 mm)	10 plus one minute for each 0.010 inch (0.25 mm)
	All except sheet	30 for inch (25 mm)	15 per inch (25 mm)
Custom 450 and Custom 455	All	30 for inch (25 mm)	
Maraging 250 and Maraging 300	All	60 for inch (25 mm)	

NOTES:

1. Dimension in inch (mm) means inch (mm) or fraction thereof.
2. Time: +10, -0 minutes.
3. In all cases, the parts shall be held for sufficient time to ensure that the center of the most massive section has reached temperature and the necessary transformation and diffusion have taken place.

TABLE 5 - Required Hardness for Precipitation-Hardening Corrosion-Resistant Steels After Aging

Alloy	Form	Condition	Hardness HRC
15-5 PH and 17-4 PH	All	H 900	40 to 47
		H 925	38 to 45
		H 950	37 to 44
		H 1000	36 to 43
		H 1025	34 to 42
		H 1050	32 to 38
		H 1075	31 to 38
		H 1100	30 to 37
		H 1150	28 to 37
		H 1150M	24 to 30
17-7 PH	All	RH 950	42 to 49
		RH 1000	41 to 46
		RH 1050	40 to 45
		RH 1075	38 to 43
		RH 1100	34 to 40
		TH 950	42 to 48
		TH 1000	40 to 46
		TH 1050	38 to 44
		TH 1075	37 to 42
		TH 1100	34 to 39
		CH 900	46 min
PH 13-8 Mo	All	H 950	45 to 49
		H 1000	43 to 47
		H 1025	41 to 46
		H 1050	40 to 46
		H 1100	34 to 42
		H 1150	30 to 38
		H 1150M	28 to 36
PH 14-8 Mo	Sheet	SRH 950	45 to 51
		SRH 1050	38 to 45
PH 15-7 Mo	Sheet	RH 950	46 to 50
		RH 1000	42 to 46
		RH 1050	39 to 45
		RH 1075	38 to 44
		RH 1100	34 to 42
		TH 1050	40 to 46
		TH 1075	39 to 44
		TH 1100	36 to 41
		CH 900	46 min