Designation: B917/B917M – 12

Standard Practice for Heat Treatment of Aluminum-Alloy Castings from All Processes[1]

This standard is issued under the fixed designation B917/B917M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope*

1.1 This practice covers, when specified by material specification or purchase order, the heat treatment of aluminum alloy castings from all casting processes.

1.1.1 The heat treatment of aluminum alloy castings used in specific aerospace applications is covered in AMS 2771[2] and specific AMS[2] material specifications.

1.1.2 The heat treatment of wrought aluminum alloys is covered in Practice B918/B918M.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.2.1 *SI Units*—The SI units are shown in brackets or in separate tables.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 The following documents of the issue in effect on the date of material purchase form a part of this specification to the extent referenced herein:

2.2 *ASTM Standards:*[3]

B26/B26M Specification for Aluminum-Alloy Sand Castings
B108/B108M Specification for Aluminum-Alloy Permanent Mold Castings
B275 Practice for Codification of Certain Zinc, Tin and Lead Die Castings
B557 Test Methods for Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products
B557M Test Methods for Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products (Metric)
B618/B618M Specification for Aluminum-Alloy Investment Castings
B686/B686M Specification for Aluminum Alloy Castings, High-Strength
B881 Terminology Relating to Aluminum- and Magnesium-Alloy Products
B918/B918M Practice for Heat Treatment of Wrought Aluminum Alloys
B955/B955M Specification for Aluminum-Alloy Centrifugal Castings
B969 Specification for Aluminum-Alloy Castings Produced by the Squeeze Casting, Thixocast and Rheocast Semi-Solid Casting Processes
G110 Practice for Evaluating Intergranular Corrosion Resistance of Heat Treatable Aluminum Alloys by Immersion in Sodium Chloride + Hydrogen Peroxide Solution

2.3 *ANSI Standard:*

H35.1 Alloy and Temper Designation Systems for Aluminum[4]

2.4 *SAE Standard:*

AMS 2771 Heat Treatment of Aluminum Alloy Castings

3. Terminology

3.1 *Definitions:*

3.1.1 Refer to Terminology B881 for terminology relating to the heat treatment of castings.

[1] This practice is under the jurisdiction of ASTM Committee B07 on Light Metals and Alloys and is the direct responsibility of Subcommittee B07.01 on Aluminum Alloy Ingots and Castings.

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[2] Available from Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001, http://www.sae.org.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] Available from Aluminum Association, Inc., 1525 Wilson Blvd., Suite 600, Arlington, VA 22209, http://www.aluminum.org.

***A Summary of Changes section appears at the end of this standard**

4. Equipment

4.1 *Heating Media*—Aluminum castings are typically heat treated in air chamber furnaces; however, lead baths, oil baths, fluidized beds, or even superheated steam may be used in specific applications. The use of uncontrolled heating is not permitted. Whichever heating means are employed, careful evaluation is required to ensure that the casting responds properly to heat treatment and is not overheated or damaged by the heat treatment environment. Salt baths are not recommended for the commercial heat treatment of aluminum castings in volume. (**Warning—**Nitrate baths must not be used in the heat treatment of 5xx.0 series castings because of the inherent explosion hazard.

4.2 *Air Chamber Furnaces*—may be oil or gas-fired or may be electrically heated. The atmosphere in air chamber furnaces must be controlled to prevent porosity resulting from solution heat treatment. Furnace components that are significantly hotter than the metal should be suitably shielded for section thicknesses of less than 0.250 in. [6 mm] to prevent adverse radiation effects. The atmosphere in air chamber furnaces must be controlled to prevent porosity resulting from solution heat treatment (see Note 1). The suitability of the atmosphere in an air-chamber furnace can be demonstrated by testing, in accordance with 8.4.3.1, that products processed in that furnace are substantially free of heat treat induced porosity.

NOTE 1—Heat treat induced porosity may lower mechanical properties and commonly causes blistering of the surface of the material. The condition is most likely to occur in furnaces in which the products of combustion contact the work, particularly if the gases are high in water vapor or contain compounds of sulfur. Surface discoloration is a normal result of solution heat treatment of aluminum alloys and should not be interpreted as evidence of damage from overheating or as heat treat induced porosity.

4.3 *Automatic Recording and Control Equipment*—to control temperature of air furnaces shall be capable of maintaining temperature in the working zone to within ±10°F [±5°C] of the specified temperature.

4.4 *Quench Baths*—Quenching is normally performed by immersion of castings in a hot-water bath as described in Tables 1-4. The water baths must be located close enough to solution heat-treating facilities to minimize delay in quenching. Tanks must be of adequate size for the expected work load and must have the means of providing adequate circulation of the quenching media about the work load. Means for heating or cooling the quench water should be available when needed.

NOTE 2—Quenching may be performed by alternative means such as total immersion in a glycol and water solution, a liquefied gas, cold water, hot water, or boiling water, or by air blast or fog to minimize distortion provided samples from the material, so quenched, will conform to the (*1*) mechanical properties, (*2*) other requirements of the applicable casting specification and (*3*) not exhibit more intergranular corrosion susceptibility than if the metal was immersion quenched in cold water. The use of water sprays or high-velocity high-volume jets of water in which the material is thoroughly and effectively flushed is satisfactory for quenching. Alternative quench media are frequently contingent on the particular alloy and the end use of the casting.

5. Furnace Temperature Uniformity and Calibration Requirements

5.1 *Calibration of Equipment:*

5.1.1 Thermocouple wire and sensors shall be calibrated against wire or sensors whose calibration is traceable to NIST). Thermocouples made from calibrated wire rolls may be used in lieu of individually calibrated thermocouples in which case, the roll calibration shall be that of the average of samples taken from both ends of the roll. The roll shall not be used if the difference in the highest and lowest reading exceeds 2°F [1°C].

5.1.2 Working instruments shall be calibrated at least once every three months against a test instrument that is traceable to NIST. Accuracy shall be ± \0.3 % of range.

5.2 *Furnace Temperature Survey:*

5.2.1 A temperature survey, to ensure compliance with the applicable recommendations presented herein, shall be performed for each furnace.

5.2.2 A new temperature survey shall be made after any modification, repair, adjustment (for example, to power controls, or baffles), or rebuild which may have altered the temperature uniformity characteristics of the furnace and reduced the effectiveness of the heat treatment.

5.3 *Batch Furnace Surveys:*

5.3.1 The initial temperature survey shall be made at the maximum and minimum temperature of solution heat treatments and precipitation heat treatments for which each furnace is to be used. There shall be at least one test location for each 25 ft^3 [0.70 m^3] of air furnace volume up to a maximum of 40 test locations, with a minimum of nine test locations, one in each corner and one in the center.

5.3.2 After the initial survey, each furnace shall be surveyed monthly, except as provided in 5.3.7. The monthly survey shall be at one operating temperature for solution heat treatment and one for precipitation heat treatment.

5.3.3 There shall be at least one test location for each 40 ft^3 [1 m^3] of load volume, with a minimum of nine test locations, one in each corner and one in the center.

5.3.4 The surveys shall reflect the normal operating characteristics of the furnace. If the furnace is normally charged after being stabilized at the correct operating temperature, the temperature-sensing elements shall be similarly charged. If the furnace is normally charged cold, the temperature-sensing elements shall be charged cold. After insertion of the temperature-sensing elements, readings should be taken frequently enough to determine when the temperature of the hottest region of the furnace approaches the bottom of the temperature range being surveyed. From that time until thermal equilibrium is reached, the temperature of all test locations should be determined at 2-min intervals in order to detect any over-shooting. After thermal equilibrium is reached, readings should be taken at 5-min intervals for sufficient time to determine the recurrent temperature pattern, but for not less than 30 min. Before thermal equilibrium is reached, none of the temperature readings should exceed the maximum temperature of the range being surveyed. After thermal equilibrium is reached, the maximum temperature variation of all elements (both load and furnace thermocouples) shall not exceed 20°F [10°C] and shall not vary outside the range being surveyed.

TABLE 1 Recommended Heat Treatment for Sand and Investment Type Alloys (Inch-Pound Units)

Alloy[A]	Final Temper[A]	Solution Heat Treatment[B, C]		Precipitation Heat Treatment[D]	
		Metal Temperature, ±10°F	Time at Temperature, h	Metal Temperature, ±10°F	Time at Temperature, h
201.0	T6	960	2[E]	room temperature	12 to 24
		then 980	14 to 20	then 310	20
	T7	960	2[E]	room temperature	12 to 24
		then 980	14 to 20	then 370	5
A201.0	T7	955	2[E]	room temperature	12 to 24
		then 985	14 to 20	then 370	5
203.0	T6	955	2[E]	room temperature	12 to 24
		then 1010	5	then 425	16
204.0	T4	970	10	room temperature	5 days[F]
A206.0	T4	950	2[E]	room temperature	5 days
		then 985	14 to 20		
	T43	950	2[E]	room temperature	12 to 24
		then 985	14 to 20	then 320	0.5 to 1
	T6[G]	950	2[E]	room temperature	12 to 24
		then 985	14 to 20	then 310	20
	T7	950	2[E]	room temperature	12 to 24
		then 985	14 to 20	then 370	4 to 5
222.0	O[D, H]	...	...	600[H]	3
	T61	945	6 to 12	310	11
242.0	O[D, H]	...	...	650[H]	3
	T571	...	...	400	8
	T61	960	2 to 6[I]	450	1 to 3
A242.0	T75	965	6 to 10	550	2 to 5
295.0	T4	960	6 to 12	...	...
	T6	960	6 to 12	310	3 to 6
	T62	960	6 to 12	310	12 to 24
	T7	960	6 to 12	500	4 to 6
296.0	T4	950	4 to 8	...	...
	T6	950	4 to 8	310	2 to 8
	T7	950	4 to 8	500	4 to 6
319.0	T4	940	6 to 10	...	...
	T5	...	...	400	8
	T6	940	6 to 12	310	2 to 5
328.0	T6	960	12	310	2 to 5
355.0	T51	...	...	440	7 to 9
	T6	980	6 to 12	310	3 to 5
	T7	980	6 to 12	440	3 to 5
	T71	980	6 to 12	475	4 to 6
C355.0[J]	T6	985	6 to 12	room temperature	8
				then 310	3 to 5
356.0	T51	...	...	440	7 to 9
	T6	1000	6 to 12[K]	310	3 to 5
	T7	1000	6 to 12[K]	400	3 to 5
	T71	1000	6 to 12[K]	475	2 to 4
A356.0	T6	1000	6 to 12[K]	310	2 to 5
	T61	1000	6 to 12[K]	330	6 to 12
	T7	1000	6 to 12[K]	440	8
	T71	1000	6 to 12[K]	475	3 to 6
357.0	T6	1000[H]	8[K]	330	6 to 12
	T61	1000	10 to 12[K]	310	10 to 12
A357.0[J]	T61	1000[H]	8 to 10[K]	room temperature	8
				then 310	8
A390.0	T6	925	8 to 12	350	8
520.0	T4	810	12 to 18[L]	...	...
705.0	T1	...	...	room temperature	21 days
	T5			210	8
707.0	T1	...	...	room temperature	21 days
	T5	...	...	210	8
	T7	990	8 to 16	350	4 to 10
710.0	T5	...	...	room temperature	21 days
				or 315	6 to 8
712.0	T5	...	...	room temperature	21 days
				or 315	6 to 8
713.0	T1	...	...	room temperature	21 days
	T5			250	16
771.0	T5	...	...	355	3 to 5
	T51	...	...	405	6
	T52	...	...	330[J]	6 to 16[M]
	T6	1090	6[D]	265	3
	T53	...	...	360[J,D]	4
	T71	1090	6[D]	285	15
850.0	T5	...	...	430	7 to 9
851.0	T5	...	...	430	7 to 9

TABLE 1 *Continued*

Alloy[A]	Final Temper[A]	Solution Heat Treatment[B, C]		Precipitation Heat Treatment[D]	
		Metal Temperature, ±10°F	Time at Temperature, h	Metal Temperature, ±10°F	Time at Temperature, h
852.0	T5	...	...	430	7 to 9

[A] Designations conform to ANSI H35.1 and to Practice B275.
[B] Quench in water at 150 to 212°F except as noted.
[C] Time at solution temperature may be increased for section thickness over 1 in.
[D] No quenching required. Cool in still air outside the furnace.
[E] Cooling not required prior to second step.
[F] In order to expedite testing, alloy 204.0 test specimens may be precipitation heat treated after quenching by holding at 255°F for 2 h.
[G] This alloy is stress corrosion crack prone when in the T6 temper and should not be used in the T6 temper for applications that see, even mildly corrosive environments.
[H] Solution treatment temperature of 1010°F may be used (to obtain higher solubility) provided no portion of the heat treat oven exceeds 1020°F.
[I] Quenching is accomplished by air blast.
[J] Stress relieve for dimensional stability in the following manner: (*1*) Hold at 775 ± 25°F for 5 h; (*2*) Furnace cool to 650°F for 2 or more h; (*3*) Furnace cool to 450°F for not more than ¾ h; (*4*) Furnace cool to 250°F for approximately 2 h; and (*5*) Cool to room temperature in still air outside the furnace.
[K] The solution times may be reduced when the silicon eutectic has been well modified such as when modified with Sr or Na.
[L] Quench in water at 150 to 212°F for a controlled time of 10 to 20 s, then cool in still air outside the furnace.
[M] Time required depends on variations in cooling rate between 650° and 450°F during stress-relief procedure (Footnote J).

5.3.5 For furnaces of 10 ft^3 [0.25 m^3] or less the temperature survey may be made with a minimum of three thermocouples located at front, center, and rear or at top, center, and bottom of the furnace.

5.3.6 For furnaces used only for precipitation treatment, after the initial temperature-uniformity survey, as outlined in 5.3.7, surveys need not be made more often than at each 6-month interval provided that (*1*) test specimens from each lot are tested and meet applicable material specifications requirements, (*2*) the furnace is equipped with a multipoint recorder, or (*3*) one or more separate load thermocouples are employed to measure and record actual metal temperatures.

5.3.7 Monthly surveys for batch furnaces are not necessary when the furnace or bath is equipped with a permanent multipoint recording system with at least two sensing thermocouples in each zone or when one or more separate load thermocouples are employed to measure actual metal temperature, providing that uniformity surveys show a history of satisfactory performance for a period of at least 6 months. The sensing thermocouples shall be installed so as to record the temperature of the heated media (air, lead, and so forth) or actual metal temperatures. However, periodic surveys shall also be made at 6-month intervals in accordance with the procedures outlined for the monthly survey.

5.4 *Continuous Furnace Surveys:*

5.4.1 For continuous heat-treating furnaces, the type of survey and the procedures for performing the survey should be established for each particular furnace involved. The types of continuous heat-treating furnaces may vary considerably, depending upon the product and sizes involved. For some types and sizes of furnaces, the only practical way to survey the furnace is to perform an extensive mechanical property survey of the limiting product sizes to verify conformance with the specified mechanical properties for such items. When the type and size of the furnace makes this practical, monthly surveys should be made, using a minimum of two load thermocouples attached to the material. The surveys should reflect the normal operating characteristics of the furnace. The results of these surveys shall indicate that the metal temperature never exceeds the allowable maximum metal temperature specified for solution heat treatment (Tables 1-4 as appropriate) after all load thermocouples have reached the minimum metal temperature specified.

5.4.2 Furnace control temperature-measuring instruments shall not be used to read the temperature of the test temperature sensing elements.

5.5 *Monitoring of Quench*—A monitoring plan shall be developed and utilized for all modes of quenching for all products covered by this practice. The plan should incorporate conductivity or hardness checking, or both, to determine the uniformity of the quench. Areas having substantially higher conductivity or lower hardness than other areas of similar thickness in the lot shall be investigated to ensure that the requirements of the material specification are met.

5.6 *Temperature-Measuring System Check*—The accuracy of the temperature-measuring system shall be checked under operating conditions weekly. Check should be made by inserting a calibrated test temperature-sensing element adjacent to the furnace temperature-sensing element and reading the test temperature-sensing element with a calibrated test potentiometer. When the furnace is equipped with dual potentiometer measuring systems which are checked daily against each other, the above checks may be conducted every 3 months rather than every week. The test temperature-sensing element, potentiometer, and cold junction compensation combination shall have been calibrated against NIST primary or secondary certified temperature-sensing elements, within the previous 3 months, to an accuracy of ±2°F [±1°C].

5.6.1 If the difference between the two readings in 5.6 exceeds ±10°F [±6°C], the cause of the difference shall be determined and corrected before commencing additional thermal processing. The responsible quality organization shall be notified and appropriate corrective action shall be taken and documented including an evaluation of the possible effects of the deviation on castings processed since the last successful test.

6. Preparation for Heat Treatment

6.1 *Furnace Loading:*

TABLE 2 Recommended Heat Treatment for Sand and Investment Type Aluminum Alloys [SI Units]

Alloy[A]	Final Temper[A]	Solution Heat Treatment[B, C]		Precipitation Heat Treatment[D]	
		Metal Temperature, ±5°C	Time at Temperature, h	Metal Temperature, ±5°C	Time at Temperature, h
201.0	T6	515	2[E]	room temperature	12 to 24
		then 525	14 to 20	then 155	20
	T7	515	2[E]	room temperature	12 to 24
		then 525	14 to 20	then 190	5
A201.0	T7	515	2[E]	room temperature	12 to 24
		then 530	14 to 20	then 190	5
203.0	T6	515	2[E]	room temperature	12 to 24
		then 545	5	then 220	16
204.0	T4	520	10	room temperature	5 days[F]
A206.0	T4	510	2[E]	room temperature	5 days
		then 530	14 to 20		
	T43	510	2[E]	room temperature	12 to 24
		then 530	14 to 20	then 160	0.5 to 1
	T6[G]	510	2[E]	room temperature	12 to 24
		then 530	14 to 20	then 155	20
	T7	510	2[E]	room temperature	12 to 24
		then 530	14 to 20	then 190	4 to 5
222.0	O[D, H]	...	...	315[H]	3
	T61	510	6 to 12	155	11
242.0	O[D, H]	...	...	345[H]	3
	T571	...	...	205	8
	T61	515	2 to 6[I]	230	1 to 3
A242.0	T75	520	6 to 10	290	2 to 5
295.0	T4	515	6 to 12	...	...
	T6	515	6 to 12	155	3 to 6
	T62	515	6 to 12	155	12 to 24
	T7	515	6 to 12	260	4 to 6
296.0	T4	510	4 to 8	...	...
	T6	510	4 to 8	155	2 to 8
	T7	510	4 to 8	260	4 to 6
319.0	T4	505	6 to 10	...	...
	T5	...	...	205	8
	T6	505	6 to 12	155	2 to 5
328.0	T6	515	12	155	2 to 5
355.0	T51	...	...	225	7 to 9
	T6	525	6 to 12	155	3 to 5
	T7	525	6 to 12	225	3 to 5
	T71	525	6 to 12	245	4 to 6
C355.0[J]	T6	530	6 to 12	room temperature	8
				then 155	3 to 5
356.0	T51	...	...	225	7 to 9
	T6	540	6 to 12[K]	155	3 to 5
	T7	540	6 to 12[K]	205	3 to 5
	T71	540	6 to 12[K]	245	2 to 4
A356.0	T6	540	6 to 12[K]	155	2 to 5
	T61	540	6 to 12[K]	165	6 to 12
	T7	540	6 to 12[K]	225	8
	T71	540	6 to 12[K]	245	3 to 6
357.0	T6	540[H]	8[K]	165	6 to 12
	T61	540	10 to 12[K]	155	10 to 12
A357.0[J]	T61	540[H]	8 to 10[K]	room temperature	8
				then 155	8
A390.0	T6	495	8 to 12	175	8
520.0	T4	430	12 to 18[L]	...	...
705.0	T1	...	...	room temperature	21 days
	T5			100	8
707.0	T1	...	...	room temperature	21 days
	T5	...	...	99	8
	T7	530	8 to 16	175	4 to 10
710.0	T5	...	...	room temperature	21 days
				or 155	6 to 8
712.0	T5	...	...	room temperature	21 days
				or 155	6 to 8
713.0	T1	...	...	room temperature	21 days
	T5			120	16
771.0	T5	...	...	180	3 to 5
	T51	...	...	205	6
	T52	...	...	165[J]	6 to 16[M]
	T6	590	6[D]	130	3
	T53	...	...	180[J,D]	4
	T71	590	6[D]	140	15
850.0	T5	...	...	220	7 to 9
851.0	T5	...	...	220	7 to 9

TABLE 2 *Continued*

Alloy[A]	Final Temper[A]	Solution Heat Treatment[B, C]		Precipitation Heat Treatment[D]	
		Metal Temperature, ±5°C	Time at Temperature, h	Metal Temperature, ±5°C	Time at Temperature, h
852.0	T5	...	...	220	7 to 9

[A] Designations conform to ANSI H35.1 and to Practice B275.
[B] Quench in water at 65 to 100°C except as noted.
[C] Time at solution temperature may be increased for section thickness over 25 mm.
[D] No quenching required. Cool in still air outside the furnace.
[E] Cooling not required prior to second step.
[F] In order to expedite testing, alloy 204.0 test specimens may be precipitation heat treated after quenching by holding at 125°C for 2 h.
[G] This alloy is stress corrosion crack prone when in the T6 temper and should not be used in the T6 temper for applications that see, even mildly corrosive environments.
[H] Solution treatment temperature of 545°C may be used (to obtain higher solubility) provided no portion of the heat treat oven exceeds 550°C.
[I] Quenching is accomplished by air blast.
[J] Stress relieve for dimensional stability in the following manner: (*1*) Hold at 415 ± 15°C for 5 h; (*2*) Furnace cool to 345°C for 2 or more h; (*3*) Furnace cool to 230°C for not more than ¾ h; (*4*) Furnace cool to 120°C for approximately 2 h; and (*5*) Cool to room temperature in still air outside the furnace.
[K] The solution times may be reduced when the silicon eutectic has been well modified such as when modified with Sr or Na.
[L] Quench in water at 65 to 100°C for a controlled time of 10 to 20 s, then cool in still air outside the furnace.
[M] Time required depends on variations in cooling rate between 345° and 230°C during stress-relief procedure (Footnote J).

6.1.1 Aluminum alloy castings shall be supported and spaced in the furnace racks so as to permit uniform heating to the final heat-treat temperature.

6.1.2 Racking and spacing procedures shall be documented.

6.1.3 Racking and spacing procedures shall allow free circulation of the quench media throughout the workload so that all product surfaces receive an adequate quench to meet the requirements of the material specification.

6.1.4 Batch furnace loading of small parts in baskets to be water quenched shall be controlled by limiting the depth of parts in each layer and the minimum spacing between layers to preclude steam generated in any portion of the load from degrading the quench in another part of the load. Random packing of castings 1 in. [25 mm] or less in thickness should be limited to a maximum layer thickness of 3 in. [75 mm] with a minimum spacing of 3 in. [75 mm] between layers.

NOTE 3—Quenching by dumping small parts into water ensures access of the quenching media to all surfaces of each part.

7. Heat Treatment Procedures

7.1 *Solution Heat Treating*—Recommended solution heat-treatment times and temperatures for various heat-treatable aluminum castings appear in Tables 1 and 2 for sand and investment castings, Tables 3 and 4 for permanent mold-castings, Tables 5 and 6 for centrifugal castings, and Tables 7 and 8 for thixocast and rheocast castings.

7.2 *Soak Time*—The solution heat-treatment temperature specified in the tables is the temperature of the metal being treated. In the absence of a suitable metal temperature measuring device, the soaking times appearing in Tables 1-4 as applicable, may be used. Note that the time ranges quoted are, in most cases quite wide. Typically, structurally modified castings that are solidified rapidly require heat treat soak times close to the low end of each range. Examples include thin permanent mold castings and sand castings in which a fine microstructure is produced due to a rapid rate of cooling. Unmodified castings and those with thick sections will require soak times closer to the high end of the appropriate range. In Al-Si-Mg casting alloys which do not contain copper, it takes only an hour or two to place the silicon and magnesium into solid solution and to remove coring or microsegregation present in the as-cast structure. The solution times called for in Tables 1-4 have been used primarily to change the size and shape of the silicon phase (see 8.4.3.3). In castings where the silicon phase is well modified acceptable elongations (depending on the customer requirements) may be obtained at soak times less than the recommended values specified in Tables 1-4. In any situation, the times chosen must result in castings which meet the required physical and mechanical properties.

7.3 *Quench*—During quenching it is important that cooling proceeds rapidly through the 750 to 500°F [400 to 260°C] range in order to avoid the type of premature precipitation detrimental to tensile properties and corrosion resistance. For casting alloys the quench delay should not exceed 45 s. Reduced quench delay time may be necessary to attain the tensile requirements shown in the product specifications for C355.0 and A356.0 sand-castings or investment-castings and 354.0, A356.0, A357.0, and A444.0 permanent mold castings.

7.4 *Precipitation Heat Treatment (Artificial Aging):*

7.4.1 Recommended times and temperature ranges for precipitation heat-treating various heat-treatable aluminum alloys appear in Tables 1 and 2 for sand castings, Tables 3 and 4 for permanent mold castings, Tables 5 and 6 for centrifugal castings, and Tables 7 and 8 for thixocast and rheocast castings.

7.4.2 Selection of the correct aging time involves knowledge of the aging curve for the alloy in question. As a casting precipitation hardens, there is a natural trade-off of ductility for strength. In choosing an aging time, this must be kept in mind as it relates to the application under consideration. Times towards the minimum in the precipitation hardening ranges in the tables will generate more ductility at a sacrifice in strength. Conversely, the long end of the range may well generate higher strength and hardness but a lower ductility.

7.4.3 At completion of precipitation time at temperature, the work shall be allowed to cool normally to room temperature.

8. Quality Assurance

8.1 *Responsibility for Inspection and Tests*—Unless otherwise specified in the contract, the heat treater is responsible for the performance of all inspection and test requirements specified herein.