Designation: B928/B928M – 07

Standard Specification for High Magnesium Aluminum-Alloy Sheet and Plate for Marine Service and Similar Environments[1]

This standard is issued under the fixed designation B928/B928M; 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.

1. Scope*

1.1 This specification covers high magnesium (Note 1) marine application aluminum-alloy (Note 2), in those alloy-tempers shown in Table 2 [Table 3] and Table 4 [Table 5], for flat sheet, coiled sheet, and plate, in the mill finish that are intended for marine and similar environments:

NOTE 1—The term high magnesium in the general sense includes those alloys containing 3 % or more nominal magnesium.

NOTE 2—Throughout this specification use of the term alloy in the general sense includes aluminum as well as aluminum alloy.

1.2 Alloy and temper designations are in accordance with ANSI H35.1/H35.1(M). The equivalent Unified Numbering System alloy designations are those of Table 1 preceded by A9, for example, A95083 for 5083 in accordance with Practice E527.

1.3 The values stated in either SI units (Table 3 and Table 5) or inch-pound units (Table 2 and Table 4) 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 each other. Combining values from the two systems may result in non-conformance with the standard.

1.4 For acceptance criteria for inclusion of new aluminum and aluminum alloys in this specification, see Annex A2.

1.5 *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, unless otherwise noted, form a part of this specification to the extent referenced herein:

2.2 *ASTM Standards:*[2]

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)

B660 Practices for Packaging/Packing of Aluminum and Magnesium Products

B666/B666M Practice for Identification Marking of Aluminum and Magnesium Products

B881 Terminology Relating to Aluminum- and Magnesium-Alloy Products

E3 Guide for Preparation of Metallographic Specimens

E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E34 Test Methods for Chemical Analysis of Aluminum and Aluminum-Base Alloys

E55 Practice for Sampling Wrought Nonferrous Metals and Alloys for Determination of Chemical Composition

E527 Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)

E716 Practices for Sampling Aluminum and Aluminum Alloys for Spectrochemical Analysis

E1251 Test Method for Analysis of Aluminum and Aluminum Alloys by Atomic Emission Spectrometry

G66 Test Method for Visual Assessment of Exfoliation Corrosion Susceptibility of 5XXX Series Aluminum Alloys (ASSET Test)

G67 Test Method for Determining the Susceptibility to Intergranular Corrosion of 5XXX Series Aluminum Alloys by Mass Loss After Exposure to Nitric Acid (NAMLT Test)

2.3 *ANSI Standards:*[3]

H35.1/H35.1(M) Alloy and Temper Designation Systems for Aluminum

[1] This specification is under the jurisdiction of ASTM Committee B07 on Light Metals and Alloys and is the direct responsibility of Subcommittee B07.03 on Aluminum Alloy Wrought Products.

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[2] 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.

[3] 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.**

TABLE 1 Chemical Composition Limits[A,B,C]

Alloy	Silicon	Iron	Copper	Manganese	Magnesium	Chromium	Zinc	Titanium	Other Elements[D]		Aluminum
									Each	Total[E]	
5059	0.45	0.50	0.25	0.6 to 1.2	5.0 to 6.0	0.25	0.4 to0.9	0.20	0.05[F]	0.15	remainder
5083	0.40	0.40	0.10	0.40 to 1.0	4.0 to 4.9	0.05 to 0.25	0.25	0.15	0.05	0.15	remainder
5086	0.40	0.50	0.10	0.20 to 0.7	3.5 to 4.5	0.05 to 0.25	0.25	0.15	0.05	0.15	remainder
5383	0.25	0.25	0.20	0.7 to 1.0	4.0 to 5.2	0.25	0.40	0.15	0.05[G]	0.15	remainder
5456	0.25	0.40	0.10	0.50 to 1.0	4.7 to 5.5	0.05 to 0.20	0.25	0.20	0.05	0.15	remainder

[A] Limits are in weight percent maximum unless shown as a range or stated otherwise.
[B] Analysis shall be made for the elements for which limits are shown in this table.
[C] For purposes of determining conformance to these limits, an observed value or a calculated value attained from analysis shall be rounded to the nearest unit in the last right-hand place of figures used in expressing the specified limit, in accordance with the rounding-off method of Practice E29.
[D] Others include listed elements for which no specific limit is shown, as well as unlisted metallic elements, but doesn't include elements shown with composition limits in the footnotes. The producer may analyze samples for trace elements not specified in the specification. However, such analysis is not required and may not cover all metallic Others elements. Should any analysis by the producer or the purchaser establish that an Others element exceeds the limit of Each or that the aggregate of several Others elements exceeds the limit of Total, the material shall be considered nonconforming.
[E] Other Elements—Total shall be the sum of unspecified metallic elements 0.010 % or more, rounded to the second decimal before determining the sum.
[F] 0.05 to 0.25 Zr.
[G] 0.20 Zr max.

H35.2 Dimensional Tolerances for Aluminum Mill Products
H35.2(M) Dimensional Tolerances for Aluminum Mill Products

3. Terminology

3.1 *Definitions*—Refer to Terminology B881 for definitions of product terms used in this specification.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *exfoliation*—corrosion that proceeds laterally from the sites of initiation along planes parallel to the original rolling surface, generally at grain boundaries, forming corrosion products that force metal away from the body of the material, giving rise to a layered appearance.

3.2.2 *intergranular corrosion*—corrosion that preferentially occurs at, or adjacent to, the grain boundaries of a metal or alloy.

3.2.3 *sensitization*—the development of a continuous or nearly continuous grain boundary precipitate in 5xxx alloy-temper material, that causes the material to be susceptible to intergranular forms of corrosion.

3.2.4 *stress-corrosion cracking*—a cracking process that requires the simultaneous action of a corrodent, and sustained tensile stress. (This excludes corrosion-reduced sections, which fail by fast fracture. It also excludes intercrystalline or transcrystalline corrosion which can disintegrate an alloy without either applied or residual stress.)

4. Ordering Information

4.1 Orders for material to this specification shall include the following information:

4.1.1 This specification designation (which includes the number, the year, and the revision letter, if applicable),

4.1.2 Quantity in pieces or pounds [kilograms],

4.1.3 Alloy (see 7.1 and Table 1),

4.1.4 Temper (see 8.1 and Table 2 and Table 4 [Table 3 and Table 5]),

4.1.5 For sheet, whether flat or coiled, and

4.1.6 Dimensions (thickness, width, and length or coil size).

4.2 Additionally, orders for material to this specification shall include the following information when required by the purchaser:

4.2.1 Whether inspection or witness of inspection and tests by the purchaser's representative is required prior to material shipment (see 11.1),

4.2.2 Whether Practices B660 applies and, if so, the levels of preservation, packaging, and packing required (see 15.3),

4.2.3 Whether certification is required (see Section 13), and.

4.2.4 Whether tensile testing should be in the longitudinal or long transverse direction (see 8.5).

5. Responsibility for Quality Assurance

5.1 *Responsibility for Inspection and Tests*—Unless otherwise specified in the contract or purchase order, the producer is responsible for the performance of all inspection and test requirements specified herein. The producer may use his own or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless disapproved by the purchaser in the order or at the time of contract signing. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification where such inspections are deemed necessary to ensure that material conforms to prescribed requirements.

5.2 *Lot Definition*—An inspection lot shall consist of an identifiable quantity of material of the same mill form, alloy, temper, cast or melt lot, and thickness, subjected to inspection at one time.

6. General Quality

6.1 Unless otherwise specified, the material shall be supplied in the mill finish, shall be uniform as defined by the requirements of this specification and shall be commercially sound. Any requirement not so covered is subject to negotiation between producer and purchaser.

6.2 Each coil, sheet and plate shall be examined to determine conformance to this specification with respect to general quality and identification marking. On approval of the purchaser, however, the producer may use a system of statistical quality control for such examinations.

7. Chemical Composition

7.1 *Limits*—The sheet and plate shall conform to the chemical composition limits specified in Table 1. Conformance shall

TABLE 2 Longitudinal Mechanical Property Limits, Inch-Pound Units[A,B]

Temper	Specified Thickness, in.	Tensile Strength, ksi		Yield Strength (0.2 % offset), ksi		Elongation in 2 in. or 4× Diameter, min, %
		min	max	min	max	
			Alloy 5059			
H116	0.078 to 0.249	54.0	...	39.0	...	10
	0.250 to 0.787	54.0	...	39.0	...	10
	0.788 to 1.575	52.0	...	38.0	...	10
H321	0.078 to 0.249	54.0	...	39.0	...	10
	0.250 to 0.787	54.0	...	39.0	...	10
	0.788 to 1.575	52.0	...	38.0	...	10
			Alloy 5083			
H116	0.063 to 0.499	44.0	. . .	31.0	. . .	10
	0.500 to 1.250	44.0	. . .	31.0	. . .	12
	1.251 to 1.500	44.0	. . .	31.0	. . .	12
	1.501 to 3.000	41.0	. . .	29.0	. . .	12
H321	0.125 to 0.187	44.0	56.0	31.0	. . .	10
	0.188 to 1.500	44.0	56.0	31.0	. . .	12
	1.501 to 3.000	41.0	56.0	29.0	. . .	12
			Alloy 5086			
H116	0.063 to 0.249	40.0	. . .	28.0	. . .	8
	0.250 to 0.499	40.0	. . .	28.0	. . .	10
	0.500 to 1.250	40.0	. . .	28.0	. . .	10
	1.251 to 2.000	40.0	. . .	28.0	. . .	10
H321	0.063 to 0.249	40.0	52.0	28.0	. . .	8
	0.250 to 0.320	40.0	52.0	28.0	. . .	9
			Alloy 5383			
H116	0.118 to 0.500	48.0	...	33.0	...	10
	0.501 to 2.000	48.0	...	33.0	...	10
H321	0.118 to 0.500	48.0	...	33.0	...	10
	0.501 to 2.000	48.0	...	33.0	...	10
			Alloy 5456			
H116	0.063 to 0.499	46.0	. . .	33.0	. . .	10
	0.500 to 1.250	46.0	. . .	33.0	. . .	12
	1.251 to 1.500	44.0	. . .	31.0	. . .	12
	1.501 to 3.000	41.0	. . .	29.0	. . .	12
	3.001 to 4.000	40.0	. . .	25.0	. . .	12
H321	0.100 to 0.187	48.0	59.0	34.0	. . .	10
	0.188 to 0.499	46.0	59.0	33.0	46.0	12
	0.500 to 1.500	44.0	56.0	31.0	44.0	12
	1.501 to 3.000	41.0	54.0	29.0	43.0	12

[A] To determine conformance to this specification, each value for tensile strength and for yield strength shall be rounded to the nearest 0.1 ksi and each value for elongation to the nearest 0.5 %, both in accordance with the rounding method of Practice E29.

[B] The basis for establishment of mechanical property limits is shown in Annex A1.

TABLE 3 Longitudinal Mechanical Property Limits [SI Units][A,B]

Temper	Specified Thickness, mm		Tensile Strength, MPa		Yield Strength (0.2 % offset), MPa		Elongation, min, %[C]	
	over	through	min	max	min	max	in 50 mm	in 5× Diameter (5.65 $\sqrt{A}$)
				Alloy 5059				
H116	1.99	6.30	370	...	270	...	10	...
	6.30	12.50	370	...	270	...	10	...
	12.50	20.00	370	...	270	...	...	10
	20.00	40.00	360	...	260	...	...	10
H321	1.99	6.30	370	...	270	...	10	...
	6.30	12.50	370	...	270	...	10	...
	12.50	20.00	370	...	270	...	...	10
	20.00	40.00	360	...	260	...	...	10
				Alloy 5083				
H116	1.60	12.50	305	. . .	215	. . .	10	. . .
	12.50	30.00	305	. . .	215	. . .	. . .	10
	30.00	40.00	305	. . .	215	. . .	. . .	10
	40.00	80.00	285	. . .	200	. . .	. . .	10
H321	3.20	5.00	305	385	215	. . .	10	. . .
	5.00	12.50	305	385	215	. . .	12	. . .
	12.50	40.00	305	385	215	. . .	. . .	10
	40.00	80.00	285	385	200	. . .	. . .	10
				Alloy 5086				
H116	1.60	6.30	275	. . .	195	. . .	8	. . .
	6.30	12.50	275	. . .	195	. . .	10	. . .
	12.50	30.00	275	. . .	195	. . .	. . .	9
	30.00	50.00	275	. . .	195	. . .	. . .	9
H321	1.60	6.30	275	355	195	. . .	8	. . .
	6.30	8.00	275	355	195	. . .	9	. . .
				Alloy 5383				
H116	3.00	12.50	330	...	230	...	10	...
	12.50	50.00	330	...	230	...	...	10
H321	3.00	12.50	330	...	230	...	10	...
	12.50	50.00	330	...	230	...	...	10
				Alloy 5456				
H116	1.60	12.50	315	. . .	230	. . .	10	. . .
	12.50	30.00	315	. . .	230	. . .	. . .	10
	30.00	40.00	305	. . .	215	. . .	. . .	10
	40.00	80.00	285	. . .	200	. . .	. . .	10
	80.00	110.00	275	. . .	170	. . .	. . .	10
H321	2.50	4.00	330	405	235	. . .	10	. . .
	4.00	12.50	315	405	230	315	12	. . .
	12.50	40.00	305	385	215	305	. . .	10
	40.00	80.00	285	370	200	295	. . .	10

[A] To determine conformance to this specification, each value for tensile strength and for yield strength shall be rounded to the nearest 1 MPa and each value for elongation to the nearest 0.5 %, both in accordance with the rounding method of Practice E29.

[B] The basis for establishment of mechanical property limits is shown in Annex A1.

[C] Elongations in 50 mm apply for thicknesses up through 12.50 mm and in 5× diameter (5.65 $\sqrt{A}$) for thicknesses over 12.50 mm where A is the cross-sectional area of the specimen.

TABLE 4 Long Transverse Mechanical Property Limits, Inch-Pound Units[A,B]

Temper	Specified Thickness, in.	Tensile Strength, ksi		Yield Strength (0.2 % offset), ksi		Elongation in 2 in. or ×4 Diameter, min, %
		min	max	min	max	
			Alloy 5083			
H116	0.118 to 0.249	44.0	. . .	31.0	. . .	10
	0.250 to 0.499	44.0	. . .	31.0	. . .	10
H321	0.118 to 0.236	44.0	55.0	31.0	. . .	10
			Alloy 5086			
H321	0.250 to 0.320	40.0	52.0	28.0	. . .	10

[A] To determine conformance to this specification, each value for tensile strength and for yield strength shall be rounded to the nearest 0.1 ksi and each value for elongation to the nearest 0.5 %, both in accordance with the rounding method of Practice E29.

[B] The basis for establishment of mechanical property limits is shown in Annex A1.

be determined by the producer, by the analysis of samples taken at the time the ingots are cast or samples taken from the finished or semifinished product. If the producer has determined the chemical composition of the material during the

TABLE 5 Long Transverse Mechanical Property Limits [SI Units][A,B]

Temper	Specified Thickness, mm		Tensile Strength, MPa		Yield Strength (0.2 % offset), MPa		Elongation, min, %[C]	
	over	through	min	max	min	max	in 50 mm	in 5x Diameter ($5.65\sqrt{A}$)
				Alloy 5083				
H116	3.00	6.00	305	...	215	...	10	...
	6.00	12.50	305	...	215	...	10	...
H321	3.00	6.00	305	380	215	...	10	...
				Alloy 5086				
H321	6.00	8.00	275	355	195	...	10	...

[A]To determine conformance to this specification, each value for tensile strength shall be rounded to the nearest 1 MPa and each value for elongation to the nearest 0.5 %, both in accordance with the rounding method of Practice E29.

[B]The basis for establishment of mechanical property limits is shown in Annex A1.

[C]Elongations in 50 mm apply for thicknesses up through 12.50 mm and in 5× diameter ($5.65\sqrt{A}$) for thicknesses over 12.50 mm where A is the cross-sectional area of the specimen.

course of manufacture, additional sampling and analysis of the finished product shall not be required.

7.2 *Number of Samples*—The number of samples taken for determination of chemical composition shall be as follows:

7.2.1 When samples are taken at the time the ingots are cast, at least one sample shall be taken for each group of ingots cast simultaneously from the same source of molten metal.

7.2.2 When samples are taken from the finished or semifinished product, a sample shall be taken to represent each 4000 lb [2000 kg] or fraction thereof, of material in the lot, except that not more than one sample shall be required per piece.

7.3 *Methods of Sampling*—Samples for determination of chemical composition shall be taken in accordance with one of the following methods:

7.3.1 Samples for chemical analysis shall be taken by drilling, sawing, milling, turning, or clipping a representative piece or pieces to obtain a prepared sample of not less than 75 g. Sampling shall be in accordance with Practice E55.

7.3.2 Sampling for spectrochemical analysis shall be in accordance with Practices E716. Samples for other methods of analysis shall be suitable for the form of material being analyzed and the type of analytical method used.

7.4 *Methods of Analysis*—The determination of chemical composition shall be made in accordance with suitable chemical (Test Methods E34), or spectrochemical (Test Method E1251) methods. Other methods may be used only when no published ASTM method is available. In case of dispute, the methods of analysis shall be as agreed upon between the producer and purchaser.

8. Tensile Properties of Material as Supplied

8.1 *Limits*—The sheet and plate shall conform to the requirements for tensile properties as specified in Table 2 [Table 3] or Table 4 [Table 5]. Table 2 [Table 3] includes specification limits for tensile properties in the longitudinal direction. Table 4 [Table 5] includes specification limits for tensile properties in the long transverse direction.

8.1.1 Tensile property limits for sizes not covered in Table 2 or Table 4 [Table 3 or Table 5] shall be as agreed upon between the producer and purchaser and shall be so specified in the contract or purchase order.

8.2 *Number of Samples*—One sample shall be taken from each end of each parent coil, or parent plate, but no more than one sample per 2000 lb [1000 kg] of sheet or 4000 lb [2000 kg] of plate, or part thereof, in a lot shall be required. Other procedures for selecting samples may be employed if agreed upon between the producer and purchaser.

8.3 *Test Specimens*—Geometry of test specimens and the location in the product from which they are taken shall be as specified in Test Methods B557 or B557M, with the exception that the test direction will be as specified in 8.5.

8.4 *Test Methods*—The tension test shall be made in accordance with Test Methods B557 or B557M.

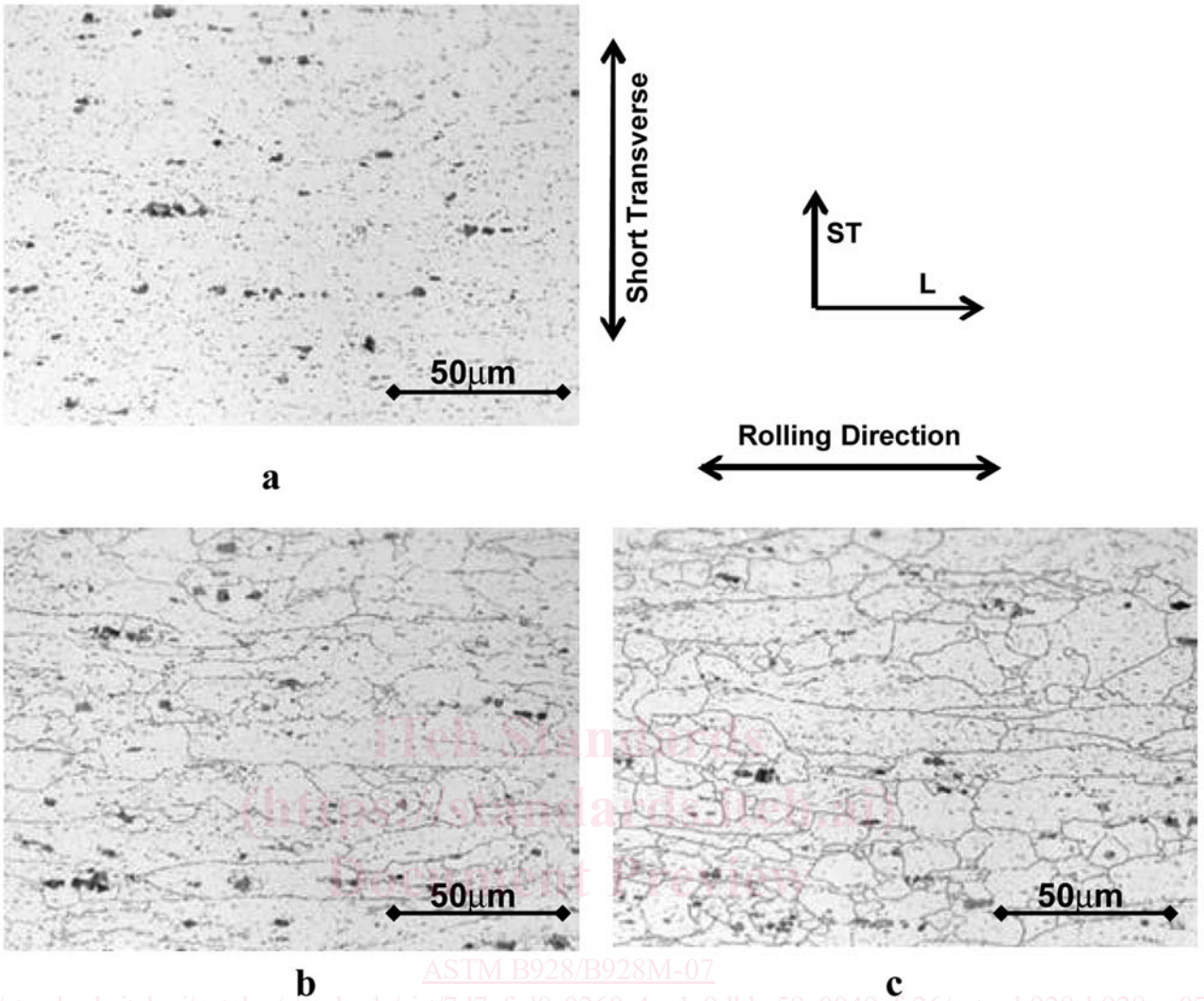
8.5 *Testing Direction*—Tensile testing shall be in the longitudinal direction unless the long transverse direction is specified in the contract or purchase order. Tensile testing direction shall be noted on all documentation.

9. Exfoliation and Intergranular Corrosion Resistance

9.1 Only the Alloy-Tempers shown in Table 2 and Table 4 [Table 3 and Table 5] are manufactured and corrosion tested for intended use in marine hull construction or in marine applications where frequent or constant direct contact with seawater is expected. See Notes 3 and 4. (**Warning**—It is possible to meet the requirements of Test Method G66 (ASSET) and fail the requirements of Test Method G67 (NAMLT). Therefore both tests shall be performed for process qualification (see 9.4), for lot release, that is, in developing producer-established reference photomicrographs (see 9.5), and for surveillance (see 9.8).)

NOTE 3—*Background Information*—Aluminum-magnesium-alloy products that have a continuous or nearly continuous grain boundary precipitate are susceptible to intergranular forms of corrosion, (that is, IGC, SCC, or exfoliation corrosion). Examples of varying degrees of grain boundary precipitate continuity are shown in Figs. 1 and 2. The term "sensitization" is used to describe the development of this susceptible microstructure. The type of corrosion that occurs in a sensitized 5xxx alloy will depend primarily on the morphology of the grain structure and on the residual and applied stresses that are present. The extent of corrosion that will occur depends on the degree of continuity of the grain boundary precipitation and the corrosiveness of the environment. Both recrystallized and unrecrystallized 5xxx alloys that have been sensitized, are susceptible to intergranular corrosion, and when subjected to sustained tensile stress, may exhibit intergranular stress corrosion cracking. Unrecrystallized 5xxx alloys that have been sensitized are also susceptible to exfoliation corrosion.

NOTE 4—Alloys 5059, 5083, 5086, 5383, and 5456 should not be used for service, which provides prolonged exposure to temperatures exceeding



Specimens prepared as per 9.6.1 (Phosphoric Acid etched). (This is as-produced material, not subjected to Test Method G67 testing.) Metallographic examination is to be conducted ×500 magnification.

Figure 1a has discontinuous grain boundary precipitation, typical of a mass-loss of less than 15 mg/cm^2 in Test Method G67.

Figure 1b has semi-continuous grain boundary precipitation and would likely fall in the mid-range, 15–25 mg/cm^2 in Test Method G67.

Figure 1c has a continous network of grain boundary precipitation, typical of a mass loss greater than 25 mg/cm^2 in Test Method G67.

(**Warning**—These photomicrographs are examples of typical microstructures and due to variations in alloy, temper and process, they may or may not be similar to the microstructure of production sheet or plate. These photographs shall not be used in lieu of producer-established reference photographs for comparison with production material in surveillance or in determining process qualification or lot release.)

FIG. 1 Examples of Microstructures with Varied Degrees of Grain Boundary Beta-phase Continuity, for a *Partially Recrystallized* Grain Structure.

150°F [65°C] (whether continuous exposure or discontinuous exposure) because of the risk of sensitization and the resulting susceptibility to intergranular corrosion and stress corrosion cracking. Cold forming can also increases susceptibility to intergranular corrosion and stress corrosion cracking.

9.2 *Exfoliation-Corrosion Resistance*—The alloy-tempers listed in Table 2 and Table 4 [Table 3 and Table 5] shall be capable of exhibiting no evidence of exfoliation corrosion and a pitting rating of PB or better when subjected to the test described in Test Method G66 (ASSET).

9.3 *Intergranular-Corrosion Resistance*—The alloy-tempers listed in Table 2 and Table 4 [Table 3 and Table 5] shall be capable of exhibiting resistance to intergranular corrosion as indicated by an acceptable mass-loss when tested in accordance with Test Method G67 (NAMLT). Test Method G67 mass loss results shall be interpreted as defined in 9.3.1 through 9.3.4.

9.3.1 *Pass*—Samples with mass loss no greater than 100 mg/in.^{2} [15 mg/cm^2], shall be accepted.

9.3.2 *Fail*—Samples with mass loss greater than 160 mg/in.^{2} [25 mg/cm^2] and the lots they represent, shall be rejected.

9.3.3 *Questionable*—Samples with mass loss greater than 100 mg/in.^{2} [15 mg/cm^2] but less than 160 mg/in.^{2} [25 mg/cm^2] shall be deemed questionable and shall be subjected to metallographic examination (See 9.3.4).

9.3.4 *Examination of Samples Deemed Questionable*—A longitudinal face perpendicular to the rolled surface of Test