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Designation: ~~B595 – 11 (Reapproved 2016)~~ B595 – 21

Standard Specification for ~~Sintered Aluminum~~ Materials for Aluminum Powder Metallurgy (PM) Structural Parts[1]

This standard is issued under the fixed designation B595; 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 ~~sintered~~ aluminum powder metallurgy structural parts made ~~primarily from aluminum powders to which controlled amounts of master alloys or elemental copper, magnesium, and silicon have been added by mixing.~~using admixed materials.

1.2 This specification covers ~~the following variables:~~a material designation code that includes the chemical composition of the material, its guaranteed minimum 0.2 % offset yield strength or ultimate tensile strength, and the temper condition of the material.

~~1.2.1 *Composition*—Depending upon levels of copper, magnesium, and silicon content, two grades, and~~

~~1.2.2 *Density*—Type.~~

~~1.3 Parts ordered to this specification will be in one of the following conditions:~~

~~1.3.1 As-sintered,~~

~~1.3.2 As-repressed for additional density, or~~

~~1.3.3 All other conditions plus heat treated.~~

1.3 *Units*—With the exception of ~~the~~density values for ~~density, for~~ which the ~~use~~g/cm^3 ~~of the gram per cubic centimeter~~ unit is ~~long-standing~~the industry ~~practice, the~~standard, property values stated in ~~SI~~inch-pound units are to be regarded as ~~the standard.~~ standard. Values in SI units result from conversion, are only for information, and are not considered standard.

1.4 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

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[1] This specification is under the jurisdiction of ASTM Committee B09 on Metal Powders and Metal Powder Products and is the direct responsibility of Subcommittee B09.05 on Structural Parts.

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2. Referenced Documents

2.1 *ASTM Standards:*[2]

B243 Terminology of Powder Metallurgy

B962 Test Methods for Density of Compacted or Sintered Powder Metallurgy (PM) Products Using Archimedes' Principle

B963 Test Methods for Oil Content, Oil-Impregnation Efficiency, and Surface-Connected Porosity of Sintered Powder Metallurgy (PM) Products Using Archimedes' Principle

~~E8~~E8/E8M Test Methods for Tension Testing of Metallic Materials ~~[Metric] E0008_E0008M~~

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

E466 Practice for Conducting Force Controlled Constant Amplitude Axial Fatigue Tests of Metallic Materials

E606/E606M Test Method for Strain-Controlled Fatigue Testing

E1269 Test Method for Determining Specific Heat Capacity by Differential Scanning Calorimetry

E1416 Practice for Radioscopic Examination of Weldments

2.2 *MPIF Standards:*[3]

MPIF Standard 10, Method for Determination of the Tensile Properties of Powder Metallurgy (PM) Materials

MPIF Standard 35-SP, Materials Standards for PM Structural Parts

MPIF Standard 72, Guide to Sample Preparation of Aluminum Powder Metallurgy (PM) Materials for Cross-sectional Metallographic Evaluation

3. Terminology

3.1 *Definitions*—Definitions of powder metallurgy terms can be found in Terminology B243. Additional descriptive information is available ~~in the Related Material Section of Volume 02.05 of the~~ under "General Information on PM" on the ~~Annual Book of ASTM Standards.~~ASTM B09 web page.

4. Ordering Information

4.1 Materials for parts covered under this specification shall be ordered by material designation code.

4.2 Orders for ~~material to~~parts under this specification ~~shall~~may include the following information:

4.2.1 Certification, if required (see Section 13),

4.2.2 Dimensions (see Section ~~9.1~~9),

4.2.3 Chemical composition (see 6.1~~),~~, 10.1, and Table 1),

4.2.4 ~~Density (see~~ Test methods and mechanical properties (see Section ~~7.1~~8, Table 2, Table 3, Table X1.1, and Table X1.2),

~~4.1.4 State of heat treatment,~~

4.2.5 ~~Mechanical property requirements (see~~ Density (see Section ~~8.1~~7)~~,~~, Table X1.1, and Table X1.2),

4.2.6 ~~Certification (see~~Special packaging, ~~14.1~~).if required.

5. Materials and Manufacture

5.1 Structural parts shall be made by ~~compacting and sintering metal powders~~ compacting, sintering, and sizing followed by either a T2 or T8 temper to produce finished parts ~~conforming to the requirements of~~ in conformance with this specification.

6. Chemical Composition

6.1 The material shall conform to the requirements ~~of~~ provided in Table 1.

[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 Metal Powder Industries Federation (MPIF), 105 College Rd. East, Princeton, NJ 08540, http://www.mpif.org.

TABLE 1 Chemical Requirements

Element	Composition, mass %		
	AXX-6061[A]	ACXX-2014[A]	
Copper	0.5 max	3.5–5.0	
Magnesium	0.4–1.2	0.2–0.8	
	Silicon	0.2–0.8	1.2 max
Aluminum, min	96.0	91.5	
Total of other elements, determined by difference, max	1.5	1.5	

TABLE 1 Chemical Composition Requirements (wt.%)[A,B]

Material Designation Code	Al	Cu	Si	Mg	Element
AC-2014	Balance	3.5	0.5	0.2	Minimum
	Balance	5.5	1.2	1.0	Maximum

[A] "XX" denotes thermal condition – see footnote to Other elements: 1.5 wt.% max.Table X1.1

[B] For the purpose of determining conformance with this specification, measured values shall be rounded "to the nearest unit" in the last right-hand digit used in expressing the specification limit, in accordance with the rounding-off method of Practice E29.

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TABLE 3 Minimum Tensile Strength Values (SI)

NOTE 1—Processing parameters used to generate these data, other conditions may be used.

Material Designation Code[C]	Minimum Strength[A,B,D] Yield	Minimum Strength[A,B,D] Ultimate
	MPa	MPa
AC-2014-23-T2	160	
AC-2014-25-T2	170	
AC-2014-32-T8		220
AC-2014-38-T8		265

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[A] Suffix numbers represent minimum strength values in 10^3 psi

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[B] Mechanical property data derived from laboratory prepared test specimens sintered under commercial manufacturing conditions

[C] Thermal Treatment:
-T2: Cold worked (sized) and then naturally aged (room temperature)
-T8: Solution treated at 502 ºC for 70 min at temperature, immediately water quenched, cold worked (sized), overall length (OAL) reduced by approximately 2 %, and artificially aged at 160 ºC for 18 h and air cooled

[D] Tensile properties determined on machined round specimens

6.2 The chemical Chemical analysis shall be madeperformed in accordance with the methods prescribed in the latest edition Vol. 03.05 of the *Annual Book of ASTM Standards,Standards* Vol 03.05, or by any other approved method agreed upon between the manufacturerproducer and the purchaser.

7. Density Physical Properties

7.1 The parts shall conform to the density range prescribed in Table 2.

7.2 The density shall be measured in accordance with Test Method B962.

7.3 If the density does not vary more than 0.1 g/cm^3 from one section of the structural part to any other section, the overall density shall fall within the limits prescribed in Table 2.

TABLE 2 ~~Density~~

~~Type~~	~~Dry Density, g/cm^3~~
~~I~~	~~2.30 to 2.45~~
~~II~~	~~2.45 to 2.60~~
~~III~~	~~2.60 min~~

TABLE 2 Minimum Tensile Strength Values (inch-pound)

NOTE 1—Processing parameters used to generate these data; other conditions may be used.

Material Designation Code[C]	Minimum Strength[A,B,D] Yield	Ultimate
	10^3 psi	
AC-2014-23-T2	23	
AC-2014-25-T2	25	
AC-2014-32-T8		32
AC-2014-38-T8		38

[A] Suffix numbers represent minimum strength values in 10^3 psi
[B] Mechanical property data derived from laboratory prepared test specimens sintered under commercial manufacturing conditions
[C] Thermal Treatment:
-T2: Cold worked (sized) and then naturally aged (room temperature)
-T8: Solution treated at 935 ºF for 70 min at temperature, immediately water quenched, cold worked (sized), overall length (OAL) reduced by approximately 2 %, and artificially aged at 320 ºF for 18 h and air cooled
[D] Tensile properties determined on machined round specimens

7.1 ~~If the density varies more than 0.1 g/cm~~Density ~~from one section of the structural part to any other section, the manufacturer and the purchaser shall agree upon a critical section of the part~~shall be determined in accordance with Test Method B962 ~~where the stresses are the highest. The density of this critical section rather than the average density shall fall within the limits prescribed in Table 2~~.

7.1.1 The producer and purchaser may agree upon a minimum average density for the part and minimum densities for specific regions of the part. Typical density values may be found in Table X1.1 and Table X1.2.

8. Mechanical Properties

8.1 For material in the T2 condition, the minimum guaranteed 0.2 % offset yield strength as shown in Table 2 and Table 3 is a numerical suffix to the material designation code and is read as 10^3 psi. The code is adopted from MPIF Standard 35-SP. All tensile yield strengths are defined as the 0.2 % offset yield strengths.

8.2 For material in the T8 condition, the minimum guaranteed ultimate tensile strength as shown in Table 2 and Table 3 is a numerical suffix to the material designation code and is read as 10^3 psi. The code is adopted from MPIF Standard 35-SP.

8.3 The ~~manufacturer~~producer and ~~the~~ purchaser shall agree ~~on qualification tests for the determination of mechanical properties.~~ upon the method to be used to verify the minimum strength characteristics of the finished parts. Since it is generally impossible to machine tensile test specimens from these parts, alternative strength tests are advisable. An example would be measuring the force needed to break teeth off a gear with the gear properly fixtured.

~~8.2 These tests shall be performed on production parts.~~

~~8.3 These tests shall be determined after consideration of the function of the part.~~

8.4 The ~~limits and sampling plan shall be agreed upon between the manufacturer and purchaser.~~tensile properties shall be measured using machined round specimens prepared in accordance with MPIF Standard 10 and tested in accordance with Test Methods E8/E8M and MPIF Standard 10.

8.5 ~~All shipments of parts subsequent to the establishment of~~Typical mechanical property values may be found in Table X1.1 ~~testing~~and Table X1.2~~conditions shall conform to the limits agreed upon.~~.

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NOTE 1—The mechanical properties in tension and compression that may be expected from standard specimens compacted to size are given in Appendix X1 of this specification.

9. Dimensions and Tolerances Permissible Variations in Dimensions

9.1 Permissible variations in dimensions shall be within the limits specified onin the drawings describing the structural parts accompanying the order or provided by the purchaser, which describe the structural parts that accompany the order, or variations shall be within the limits specified in the order.

10. Workmanship, Finish, and Appearance

10.1 Structural parts shall be uniform in composition.

10.2 When parts are cut or fractured, the exposed surface shall be of uniform appearance.

10. Sampling

10.1 *Chemical Analysis*—If required by purchase agreement,When requested on the purchase order, at least one sample for chemical analysis shall be taken from each lot. A representative sample of chips may be obtained by dry milling, drilling dry-milling, or crushing at least two pieces with clean, dry tools without lubrication. To In order to obtain oil-free chips, the parts selected for test shall have the oil extracted from them in accordance with Test MethodMethods B963, if necessary.

10.2 *Mechanical Tests*—The manufacturerproducer and the purchaser shall agree on the upon a representative number of specimens for mechanical tests.

11. Inspection

11.1 Unless otherwise specified, inspection of parts supplied on contract shall be made by the purchaser.Inspection of the material shall be agreed upon between the producer and purchaser as part of the purchase order or contract.

12. Rejection and Rehearing

12.1 PartsMaterial that failfails to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In the case of dissatisfaction with test results, the producer or supplier may make claim for rehearing. a rehearing.

13. Certification

13.1 When specified in the purchase order or contract, a producer's certification the purchaser shall be furnished to the purchaser that the parts were manufactured, sampled, tested, and inspected in accordance withcertification stating samples representing each lot have been tested and inspected as indicated in this specification and the requirements have been found to meet the requirements. met. When specified in the purchase order or contract, a report of the test results shall be furnished. Test reports may be transmitted to the purchaser by electronic services. The content of the electronically transmitted document shall conform to any existing agreement between the producer and purchaser.

14.2 The purchase order shall specify whether or not the certification includes chemical composition.

14.3 Upon request of the purchaser in the contract or order, the certification of an independent third party indicating conformance to the requirements of this specification may be considered.

14. Keywords

14.1 as-repressed; aluminum alloys; as-sintered; density; interconnected porosity; oil-impregnated; nonferrous powder metallurgy; sintered aluminum; nonferrous structural parts; thermal conditionpowder metallurgy (PM); PM structural parts

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SUPPLEMENTARY REQUIREMENTS

S1. Metallographic Examination

S1.1 *Microstructure*—The Al-Cu alloy system is the most popular production material and displays a matrix of alpha-aluminum, with some precipitates. The GP zones (Cu-rich regions on the {100} planes of the fcc aluminum matrix that are the precursors to the $CuAl_2$ theta phase) cannot be resolved using the light microscope. The presence of coarse $CuAl_2$ precipitates is indicative of an over-aged condition; such precipitates are visible by optical metallography.

S1.1.1 When specified in the purchase order or contract, either or both of the following supplementary requirements may be applied. Details of these supplementary requirements shall be agreed upon in writing between the producer or supplier and purchaser. Supplementary requirements shall in no way negate any requirement of the specification itself. Metallographic samples should be prepared in accordance with MPIF Standard 72.

S1.2 *Sintering*—Requirements for the uniformity and quality of sintering may be agreed upon.

S1.3 *Porosity*—Requirements excluding excessively large pores may be included when specified and agreed upon in writing.

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~~APPENDIX~~APPENDIXES

(Nonmandatory Information)

X1. ~~MECHANICAL PROPERTIES AND HARDNESS DATA~~ USE OF THIS SPECIFICATION

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X1.1 PM Material Code Designation: ~~Data for the mechanical properties of sintered aluminum specimens are given in Table X1.1 The data do not constitute a part of this specification. They merely indicate to the purchaser the mechanical properties that may be expected from special tension specimens conforming to the density and chemical requirements specified. It should be understood that the values represent specimens compacted to size and not specimens cut from commercial parts. See Fig. 20 of Test Methods E8.~~

X1.1.1 The PM material code designation, or identifying code for structural PM parts, defines a specific material as to chemical composition and minimum strength expressed in 10^3 psi (6.895 MPa (6.895 N/mm^2)). For example, AC-2014-23-T2 is an aluminum PM material containing nominally 4 % copper, 0.8 % silicon, and 0.5 % magnesium. It has a minimum yield strength of 23 x 10^3 psi (23 000 psi) in the T2 condition.

X1.1.2 The system offers a convenient means of designating both the chemical composition and minimum strength value of any standard PM material. For each standard material, the density is given as one of the typical values and is no longer a requirement of the specification.

X1.1.3 Code designations in this specification and revisions thereof apply only to PM materials for which specifications have been adopted. In order to avoid confusion, the PM material designation coding system is intended for use only with such materials, and it should not be used to create nonstandard materials. The explanatory notes, property values, and other contents of this specification have no application to any other materials.

X1.1.4 In this coding system, the prefix letters denote the general type of material. For example, the prefix AC represents an aluminum alloy that contains copper (A for aluminum and C for copper). The prefix four-digit code designates the actual alloy, the composition of which is specified in the chemical composition table (see Table X1.1 and Table X1.2).

~~X1.2 Hardness values are given as apparent values, as described in General Description of Production, Properties, and Uses of Metal Powder Sintered Bearings, and Sintered Metal Powder Structural Parts (see gray pages).~~

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TABLE X1.1 Typical Properties of Aluminum PM Materials (Inch-pound)[A,B]

NOTE 1—Processing parameters used to generate these data; other conditions may be used.

Material Designation Code[C]	Tensile Properties[D]			Elastic Constants		Compressive Yield Strength (0.1%)	Apparent Hardness	Density
	Ultimate Strength	Yield Strength (0.2 %)	Elongation (in 1 in.)	Young's Modulus	Poisson's Ratio			
	10^3 psi	10^3 psi	%	10^6 psi		10^3 psi	HRE	g/cm^3
AC-2014-23-T2	29	25	1	8	0.32	24	60	2.50
AC-2014-35-T2	33	27	2	8.5	0.33	25	70	2.60
AC-2014-32-T8	38	38	<1	8	0.32	39	75	2.50
AC-2014-38-T8	45	45	<1	8.5	0.33	43	83	2.60

[A] Suffix numbers represent minimum strength values in 10^3 psi.
[B] Mechanical property data derived from laboratory prepared test specimens sintered under commercial manufacturing conditions
[C] Thermal Treatment:
-T2: Cold worked (sized) and then naturally aged (room temperature)
-T8: Solution treated at 935 ºF for 70 min at temperature, immediately water quenched
[D] Tensile properties determined on machined round specimens