Designation: F2215 – 15

Standard Specification for Balls, Bearings, Ferrous and Nonferrous for Use in Bearings, Valves, and Bearing Applications[1]

This standard is issued under the fixed designation F2215; 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 specification covers requirements for ferrous and nonferrous inch balls. The balls covered in this specification are intended for use in bearings, bearing applications, check valves, and other components using balls.

1.2 This is a general specification. The individual item requirements shall be as specified herein in accordance with the MS sheet standards. In the event of any conflict between requirements of this specification and the MS sheet standards, the latter shall govern.

1.3 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.4 This specification contains many of the requirements of MIL-B-1083, which was originally developed by the Department of Defense and maintained by the Defense Supply Center Richmond.

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 requirements prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A108 Specification for Steel Bar, Carbon and Alloy, Cold-Finished

A276 Specification for Stainless Steel Bars and Shapes

A295 Specification for High-Carbon Anti-Friction Bearing Steel

B21/B21M Specification for Naval Brass Rod, Bar, and Shapes

B124/B124M Specification for Copper and Copper Alloy Forging Rod, Bar, and Shapes

B276 Test Method for Apparent Porosity in Cemented Carbides

B283 Specification for Copper and Copper-Alloy Die Forgings (Hot-Pressed)

D3951 Practice for Commercial Packaging

E18 Test Methods for Rockwell Hardness of Metallic Materials

E112 Test Methods for Determining Average Grain Size

E381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings

E384 Test Method for Knoop and Vickers Hardness of Materials

2.2 *ASTM Adjunct:*[3]

ADJE0381 ASTM Adjuncts: Photographs for Rating Macroetched Steels (3 Plates) Plate I, Plate II, and Plate III

2.3 *ABMA Standard:*[4]

ABMA-STD-10 Metal Balls (Inactive Specification)

2.4 *ANSI Standards:*[5]

ANSI B46.1 Surface Texture (Surface Roughness, Waviness and Lay)

ANSI B89.3.1 Sampling Procedures and Tables for Inspection by Attributes

ANSI/ASQC Z1.4 Sampling Procedures and Tables for Inspection by Attributes

2.5 *Federal Standards:*[6]

FED-STD-151 Metals, Test Methods

QQ-N-286 Specification for Nickel-Copper Aluminum Alloy, Wrought

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[1] This specification is under the jurisdiction of ASTM Committee F34 on Rolling Element Bearings and is the direct responsibility of Subcommittee F34.01 on Rolling Element.

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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 ASTM International Headquarters. Order Adjunct No. ADJE0381

[4] Available from the Anti-Friction Bearing Manufacturers' Association, Inc., 1101 Connecticut Ave., N.W., Suite 700, Washington, DC 20036.

[5] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[6] DLA Document Services Building 4/D 700 Robbins Avenue Philadelphia, PA 19111-5094 http://quicksearch.dla.mil/

2.6 *ISO Standard:*[5]

ISO 3290 Rolling Bearings, Bearing Parts, Balls for Rolling Bearings

2.7 *Military Standards:*[6]

MIL-B-1083 Military Specification: Balls, Bearing, Ferrous and Non-Ferrous (for Use in Bearings, Valves And Bearing Applications) General Specification for

MIL-DTL-197 Packaging of Bearings, Associated Parts and Subassembies

MIL-STD-129 Marking for Shipment and Storage

2.8 *NAS Standard*[7]:

NAS 410 Certification and Qualification of Nondestructive Test Personnel

2.9 *SAE Standards:*[8]

AMS 5618 Steel, Corrosion Resistant Bars, Wire and Forgings

AMS 5630 Steel, Corrosion Resistant Bars, Wire and Forgings

AMS 5749 Steel, Corrosion Resistant Bars, Wire and Forging and Tubing Premium Aircraft Quality for Bearing Applications

AMS 5880 Steel, Corrosion Resistant Bars, Wire and Forging for Bearing Applications

AMS 6440 Specification for Steel Bars, Forgings and Tubing 1.45Cr (0.98-1.10C) (SAE 52100) for Bearing Applications

AMS 6444 Specification for Steel Bars, Forgings and Tubing Premium Aircraft Quality for Bearing Applications

AMS 6490 Specification for Steel Bars, Forgings and Tubing

AMS 6491 Specification for Steel Bars, Forgings and Tubing 4.1Cr-4.2Mo-1.0V (0.80-0.85C) Premium Aircraft-Quality for Bearing Applications, Double Vacuum Melted

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *ball gage deviation (ΔS)*—difference between the lot mean diameter and the sum of the nominal diameter and the ball gage.

3.1.2 *basic diameter*—diameter size of the balls, in inches.

3.1.3 *basic diameter tolerance*—maximum allowable deviation from the specified basic diameter for the indicated grade.

3.1.4 *case depth*—thickness, measured radially from the surface of the hardened case to a point where carbon content or hardness becomes the same as the ball core.

3.1.5 *deviation from spherical form (ΔRw)*—greatest radial distance in any radial plane between a sphere circumscribed around the ball surface and any point on the ball surface.

3.1.6 *grade designation (G)*—indicates the allowable out-of-roundness expressed in millionths of an inch.

3.1.7 *lot*—balls from a single production run of balls that are offered for delivery at one time that are of the same dimensions, made from metal material of the same type and composition, formed and fabricated under the same manufacturing processes.

3.1.8 *marking increments*—standard unit steps to express the specific diameter.

3.1.9 *nominal size (Dw)*—basic diameter, in inches, that is used for the purpose of general identification (for example, 1⁄16, 1⁄8, and so forth).

3.1.10 *out-of-roundness*—difference between the largest diameter and the smallest diameter measured on the same ball.

3.1.11 *passivation*—treatment for corrosion-resistant steel to eliminate corrodible surface impurities and provide a protective film.

3.1.12 *specific diameter*—diameter marked on the unit container and expressed in the grade standard marking increment nearest to the average diameter of the balls in that container.

3.1.13 *unit container*—container identified as containing balls from the same manufacturing lot of the same composition, grade, and basic diameter, and within the allowable diameter variation per unit container for the specified grade.

3.2 *Acronyms:*

3.2.1 *CEVM*—consumable electrode vacuum melted.

3.2.2 *VIMVAR*—vacuum induction melt-vacuum arc remelt.

4. Classification

4.1 This specification covers balls of Compositions 1 through 16 (see Table 1), and Grades 3, 5, 10, 16, 24, 48, 100, 200, 500 and 1000 (see 3.1.6).

5. Ordering Information

5.1 When ordering balls in accordance with this specification, specify the following:

5.1.1 ASTM designation number, including year of issue,

5.1.2 Applicable MS sheet standard number,

5.1.3 Diameter of balls, whether standard or nonstandard,

5.1.4 Composition number required (see Table 1),

5.1.5 Grade required (see ISO 3290),

5.1.6 Whether a first article sample is required, and arrangements for testing and approval thereof,

5.1.7 Tests, test conditions, and sampling plans, if other than specified herein,

5.1.8 Quantity required,

5.1.9 Applicable levels of preservation and packing,

5.1.10 Special marking, if required, and

5.1.11 For Composition 13 balls, traceability records for each ball when required, including its corresponding heat treat lot, forging lot, consumable electrode remelt number, process lot number, and VIMVAR heat of steel,

5.1.11.1 Material identification records, when required,

5.1.11.2 Eddy current inspection records, when required, and

5.1.11.3 Ultrasonic inspection record for bar stock material, when required.

[7] Available from Global Engineering Documents, 15 Inverness Way, East Englewood, CO 80112-5704, http://www.global.ihs.com.

[8] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990, http://www.asme.org.

TABLE 1 Classification of Balls

Composition Number	Composition
1	chrome alloy steel (52100)
2	corrosion-resistant hardenable steel (400 series)
3	carbon steel
4	silicon molybdenum steel
5	Brass
6	Bronze
7	aluminum bronze
8	beryllium copper alloy
9	nickel-copper alloy (Monel)
10	nickel-copper-aluminum alloy (K-Monel)
11	aluminum alloy
12	tungsten carbide
13	premium quality bearing steel (double vacuum melted M-50)
14	corrosion resistant austenitic steel (300 series)
15	premium aircraft quality chrome alloy steel (52100 CEVM)
16	premium aircraft quality corrosion resistant alloy steel (440C VIMVAR)

6. Materials and Manufacture

6.1 *Composition 1*—Composition 1 balls shall be manufactured from chrome alloy steel conforming to the chemical composition of UNS G52986 in accordance with AMS 6440. Chemical composition shall be tested in accordance with 11.2.

6.2 *Composition 2*—Composition 2 balls shall be manufactured from corrosion-resistant steel conforming to the chemical composition of UNS S44003, UNS S32900, UNS S42000, UNS S41000, UNS S42700, or UNS S44004 in accordance with Specification A276 and AMS 5618, 5630, 5749 and 5880. Chemical composition shall be tested in accordance with 11.2.

6.3 *Composition 3*—Composition 3 balls shall be manufactured from carbon steel conforming to the chemical composition of UNS G10080 through UNS G10220 in accordance with Specification A108. Chemical composition shall be tested in accordance with 11.2.

6.3.1 The quality of the material used in the manufacture of Composition 3 balls shall have macrograph inspection in accordance with Test Methods E381 and ASTM Adjunct ADJE0381 Adjuncts. Tests shall be in accordance with 11.14.2.

6.4 *Composition 4*—Composition 4 balls shall be manufactured from selected silicon molybdenum steel UNS T41902 of

TABLE 2 Chemical Compositions for Materials Not Assigned UNS Numbers

Element	Chemical Compositions, weight %						
	Silicon Molybdenum Steel[A]	Brass[B]	Aluminum Bronze[C]	Beryllium Copper Alloy[D]	Nickel-Copper Alloy[E]	Aluminum Alloy[F]	Tungsten Carbide[G]
Carbon	0.45-0.55						
Copper		60-70	remainder	remainder	25-30	3.5-4.5	
Zinc		30-40				0.25 max	
Aluminum			9-14			remainder	
Manganese	0.30-0.60		1.5 max			0.40-1.0	
Nickel			5.5 max	0.20 min,[H] 0.60 max[I]	65-70		
Iron			2.10-4.00		5.0 max[J]	1.0 max	
Beryllium				1.80-2.05			
Silicon	0.90-1.15					0.8 max	
Magnesium						0.20-0.8	
Chromium	0.25 max					0.10 max	
Other elements		0.5 max total			5.0 max total	0.15 max total, 0.05 max each	0.5 max total
Tungsten carbide (WC)							93.5-94.5
Cobalt							5.5-6.5
Phosphorus	0.030 max						
Sulphur	0.030 max						
Molybdenum	0.30-0.50						

[A] Composition 4.
[B] Composition 5.
[C] Composition 7.
[D] Composition 8.
[E] Composition 9.
[F] Composition 11.
[G] Composition 12.
[H] Nickel or cobalt, or both.
[I] Nickel plus cobalt plus iron.
[J] Iron plus zinc.

the through-hardened type as specified in Table 2. Chemical composition shall be tested in accordance with 11.2.

6.5 *Composition 5*—Composition 5 balls shall be manufactured from brass UNS C26000 as specified in Table 2. Chemical composition shall be tested in accordance with 11.2.

6.6 *Composition 6*—Composition 6 balls shall be manufactured from bronze conforming to the chemical composition of UNS C46400 (SAE CDA464) in accordance with Specifications B283, B124/B124M, and B21/B21M. Chemical composition shall be tested in accordance with 11.2.

6.7 *Composition 7*—Composition 7 balls shall be manufactured from aluminum bronze UNS C62400 and UNS C6300 as specified in Table 2. Chemical composition shall be tested in accordance with 11.2.

6.8 *Composition 8*—Composition 8 balls shall be manufactured from beryllium copper as specified in Table 2. Chemical composition shall be tested in accordance with 11.2.

6.9 *Composition 9*—Composition 9 balls shall be manufactured from nickel copper alloy (Monel) UNS N04400 as specified in Table 2. Chemical composition shall be tested in accordance with 11.2.

6.10 *Composition 10*—Composition 10 balls shall be manufactured from nickel-copper-aluminum alloy conforming to the chemical composition of UNS N05500 (K-Monel) in accordance with QQ-N-286. Chemical composition shall be tested in accordance with 11.2.

6.11 *Composition 11*—Composition 11 balls shall be manufactured from aluminum alloy UNS A92017 as specified in Table 2. Chemical composition shall be tested in accordance with 11.2.

6.12 *Composition 12*—Composition 12 balls shall be manufactured from tungsten carbide material as specified in Table 2. Chemical composition shall be tested in accordance with 11.2.

6.13 *Composition 13*—Composition 13 balls shall be manufactured from aircraft-quality steel conforming to the chemical composition of UNS T11350 or UNS T12001 in accordance with AMS 6490 or AMS 6491. Chemical composition shall be tested in accordance with 11.2.

6.13.1 *Ultrasonic Inspection of Bar Stock*—Bar and wire stock selected for the manufacture of Composition 13 balls shall be inspected using the ultrasonic inspection test method in Annex A1. Composition 13 bar and wire stock shall be tested 100 %.

6.13.2 Material used in manufacture of Composition 13 balls shall conform to the inclusion rating specifications given in 7.6.

6.13.3 When a first article sample of Composition 13 ball material is required, chemical testing, fracture grain size, and inclusion rating are required in addition to other tests.

6.13.4 Material used in the manufacture of Composition 13 balls shall be macro-examined in accordance with 11.14.2.

6.14 *Composition 14*—Composition 14 balls shall be manufactured from corrosion-resistant unhardened steel conforming to the chemical composition of UNS S30200, UNS S30400, UNS S30500, UNS S31600, or UNS S43000 in accordance with Specification A276. Chemical composition shall be tested in accordance with 11.2.

6.15 *Composition 15*—Composition 15 balls shall be manufactured from premium quality chrome alloy steel conforming to the chemical composition of UNS G52986 in accordance with AMS 6444. Chemical composition shall be tested in accordance with 11.2.

6.16 *Composition 16*—Composition 2 balls shall be manufactured from corrosion-resistant steel conforming to the chemical composition of UNS S44004 in accordance with Specification A276 and AMS 5618 VIMVAR. Chemical composition shall be tested in accordance with 11.2.

7. Other Requirements

7.1 *Density*—Density shall be as specified in Table 3. Select samples of each composition in accordance with Section 10. Weigh the balls in air and divide the weight of each sample ball by the computed volume of the ball (cm^3). The diameter used in computing the volume of the ball shall be determined in accordance with 11.12.1. Determine the weight of each sample ball to an accuracy of 2.205×10^{-6} lbm (0.001 g) or 0.10 % of the weight, whichever is greater.

7.2 *Hardness:*

7.2.1 Hardness shall be as specified in Table 3 when tested in accordance with 11.4.

7.2.2 *Composition 3 Hardness*—Composition 3 balls shall have a minimum surface hardness of 60 HRC or equivalent when tested in accordance with 11.4. Composition 3 balls shall be case hardened to the depth specified in Table 4 when tested in accordance with 11.9.

7.3 *Fracture Grain Size*—Unless otherwise specified, fracture grain size shall be in accordance with the material specification, when tested in accordance with 11.5. Fracture grain size shall not exceed the fracture grain size specified in Table 3, when tested in accordance with 11.5.

7.4 *Porosity*—Composition 12 balls shall not exceed the conditions for A02, B02, and C02 apparent porosity as given in Test Method B276 when tested in accordance with 11.6.

7.5 *Decarburization*—Compositions 1, 2, 3, 4, 13, 15 and 16 balls shall not exhibit decarburization when tested in accordance with 11.8.

7.6 *Inclusion Rating*—Unless otherwise specified, inclusion rating requirements shall be in accordance with the material specification.

7.6.1 *Composition 13 Material Samples and Finished Balls*—Inclusion rating for Composition 13 material samples shall not exceed the inclusion rating specified for billets to be used for wire and rods in the manufacture of balls and rollers as specified in Specification UNS T11350 or UNS T12001. Inclusion rating for finished Composition 13 balls shall be as specified in AMS 6490 or AMS 6491.

TABLE 3 Other Requirements

Composition Number	Hardness[A]	Density, lbm/in.^{3} (reference)	Fracture Grain Size, max, see 7.3
1	58-67 HRC[B]	0.283	8
2	58-65 HRC	0.277	7½
3	min 60 HRC[C]	0.284	. . .
4	52-60 HRC	0.278	. . .
5	75-87 HRB	0.306	. . .
6	75-98 HRB or 15-20 HRC[D]	0.304	. . .
7	15-20 HRC	0.273	. . .
8	min 38 HRC	0.300	. . .
9	85-95 HRB	0.318	. . .
10	min 27 HRC	0.306	. . .
11	54-72 HRB	0.101	. . .
12	87.5-90.4 HRA	0.539	. . .
13	61-64 HRC	0.279	8
14	25-39 HRC		
14 S43000	48-63 HRA		
15	58-67 HRC[B]	0.283	8
16	58-67 HRC[B]	0.277	7½

[A] Hardness equivalent to those shown are also acceptable. See Standard Hardness Conversion Tables E140.
[B] The balls within any unit container shall have a uniform hardness from ball to ball within three points HRC or equivalent.
[C] See 7.2.2.
[D] See 11.4.

TABLE 4 Case Depth Requirements for Composition 3 Balls

Nominal Size, in.		Minimum Case Depth, in.
At Least	But Not	
1⁄64 (SI)	1⁄16	0.005
1⁄16 (SI)	3⁄32	0.015
3⁄32 (SI)	1⁄8	0.020
1⁄8 (SI)	3⁄16	0.025
3⁄16 (SI)	7⁄32	0.030
7⁄32 (SI)	1⁄4	0.035
1⁄4 (SI)	3⁄8	0.045
3⁄8 (SI)	7⁄16	0.055
7⁄16 (SI)	1⁄2	0.065
1⁄2 (SI)	9⁄16	0.070
9⁄16 (SI)	3⁄4	0.075
3⁄4 (SI)	1½	0.080

See Test Method E384.

7.7 *Retained Austenite*—The retained austenite content of Composition 13 balls shall not exceed 3 % by volume, as determined using X-ray diffraction techniques, or other techniques as specified. The retained austenite content of Composition 1, 2, 15 and 16 balls shall not exceed 7 % by volume, as determined using X-ray diffraction techniques, or other techniques as specified.

7.8 *Passivation*—Composition 2 and 16 balls. The surface of the finished balls shall be chemically cleaned or otherwise treated to be passive and free from all non stainless contamination per AMS 2700 or A976M. Test for acceptance in accordance with the appropriate test method in the passivation specification. Samples exhibiting visible corrosion shall be cause for lot rejection.

7.9 *Eddy Current*—Composition 13 balls shall be tested in accordance with 11.10.

7.9.1 *Processing After Eddy Current Testing*—Re-inspect any balls that are processed in any way following eddy current testing.

8. Dimensions, Mass, and Permissible Variations

8.1 The basic diameter of the balls, whether standard or nonstandard, shall be as specified in the purchase order or contract. Tolerance limits for size (diameter) variations and spherical form variations shall be in accordance with Table 5 and Table 6. Dimensions not within the tolerances specified in Table 5 and Table 6 shall be classified as a defect. Balls shall meet the acceptance quality limits (AQL) of Table 8 when tested for dimensional requirements in accordance with 11.12.

9. Workmanship, Finish, and Appearance

9.1 *Visual Inspection*—Balls shall meet the acceptance quality limits (AQL) of Table 8 when visually tested in accordance with 11.11 for compliance with the requirements of 9.1.1 and 9.1.2.

9.1.1 Balls shall be free from decarburization, over tempering, and indications of soft spots.

9.1.2 Except as specified for Composition 13 ball surfaces, ball surfaces shall be free from scratches, nicks, pits, dents,

TABLE 5 Tolerances by Grade for Individual Balls

Grade	Allowable Ball Diameter Variation, millionths of an inch, V_{DWS}	Allowable Deviation from Spherical Form, millionths of an inch, ΔRw
3	3	3
5	5	5
10	10	10
16	16	16
24	24	24
48	48	48
100	100	100
200	200	200
500	500	500
1000	1000	1000

TABLE 6 Tolerances by Grade for Lots of Balls

Grade	Allowable Lot Diameter Variation, millionths of an inch, V_{DWL}	Basic Diameter Tolerance, millionths of an inch	Allowable Ball Gage Deviation, millionths of an inch, Δs		Container Marking Increment, millionths of an inch
			High	Low	
3	5	±30	+30	-30	10
5	10	±50	+50	-40	10
10	20	±100	+50	-40	10
16	32	±100	+50	-40	10
24	48	±100	+100	-100	10
48	96	±200			50
100	200	±500			
200	400	±1000			
500	1000	±2000			
1000	2000	±5000			

TABLE 7 Visual Inspection Limits

Type of Defect	Acceptable Limits	Acceptable Limits Composition 15, 16
Pits	0.0008 in maximum dimension for single pit; maximum of 3 permitted in any ¼ in. diameter circle	Allowed if not felt with a 0.005 in. radius probe
Scratches, surface non-metallic inclusions	0.001 in. wide by 0.010 in. long any number allowed as long as they do not cross.	Allowed if not felt with a 0.005 in. radius probe
Nicks, dents and indentations on ball of less than ½ in. diameter	0.015 in. maximum dimension	Allowed if not felt with a 0.005 in. radius probe
Nicks, dents and indentations on balls of ½ in. diameter or larger	0.024 in. maximum dimension	Allowed if not felt with a 0.010 in. radius probe
Seams, laps, tears, cracks, indications of corrosion, raised metal, scants, orange peel	None allowed	None allowed
Stains	0.005 in. major dimension not to exceed.	None allowed

TABLE 8 Quality Conformance Inspection

Test	Inspection Level	AQL (Defects Per 100 Units)
Visual	II	1.0
Dimensional Examination: (see Tables 5 and 6)	II	1.0
Diameter tolerance per ball	S-1	2.5
Ball diameter variation	S-1	2.5
Measurement of deviation from spherical form	S-1	2.5
Tolerances by grade for lots of balls	S-1	2.5
Specific diameter marking	S-1	2.5

seams, laps, tears, cracks, and corrosion when examined in accordance with 11.11. Composition 13 ball surfaces shall not exceed the tolerance limits specified in Table 7 for scratches, nicks, pits, dents, and indentation when examined in accordance with 11.11.1.

9.2 *Surface Roughness*—The surface roughness of the balls shall not exceed the value specified in the applicable MS sheet standard (see 2.7) or Table 9 for the specified grade, when tested in accordance with 11.7.

9.3 *Carbides*—Carbides on the surfaces of finished Composition 13 balls shall not protrude more than 11 µin. above the surface of the ball, when tested in accordance with 11.13.

TABLE 9 Surface Roughness by Grade for Individual Balls

Grade	Maximum Surface Roughness Arithmetical Average, × 10^{-6} in.
3	0.5
5	0.8
10	1.0
16	1.0
24	2.0
48	3.0
100	5.0
200	8.0
500	
1000	

10. Sampling

10.1 *Sampling for Visual and Dimensional Testing of Composition 1 through 12, 14, 15 and 16 Balls*—Sampling shall be done in accordance with ANSI/ASQC Z1.4 or an equivalent sampling Table from "C = 0." The unit of product for sampling purposes shall be one ball as applicable. Acceptance number shall be zero for all sample series unless otherwise specified.

10.2 *Sampling for Examination of Composition 13 Balls:*

10.2.1 *Visual Examination*—Composition 13 balls shall be inspected 100 %.

10.2.2 *Dimensional Examination*—Sampling for dimensional examination of Composition 13 balls shall be in accordance with ANSI/ASQC Z1.4 or an equivalent sampling Table from "C = 0." The sample quantity shall be one ball as applicable. Acceptance number shall be zero for all sample series unless otherwise specified.

11. Test Methods

11.1 *Test Conditions*—Unless otherwise specified, perform all tests under the following conditions:

11.1.1 *Temperature*—Room ambient 20 to 25°C (68 to 77°C).

11.1.2 *Altitude*—Normal ground.

11.1.3 *Humidity*—50 % relative, maximum.

11.2 *Chemical Analysis:*

11.2.1 Chemical analysis of each lot of material shall be tested in accordance with the appropriate material specification. If any of the samples fail to comply with the material requirements, the lot shall be rejected.

11.2.2 When specified in contract or purchase order, certification of chemical analysis (conformance) from the supplier of the specified material may be considered acceptable instead of actual testing by the manufacturer.

11.3 *Density*—Reference value only. See 7.1.

11.4 *Ball Hardness*—Select samples of each composition in accordance with Section 10. Test in accordance with Test Methods E18. Refer to tests made on parallel flats for hardness readings. If any of the samples fail to comply with the ball hardness requirement given in Table 3, the lot shall be rejected.

11.5 *Fracture Grain Size*—Select samples of Composition 1, 2, 13, 15 and 16 balls in accordance with Section 10. Examine in accordance with Test Methods E112 or the test method appropriate to the material specification.

11.6 *Porosity Test*—Select Composition 12 balls in accordance with Section 10. Prepare and examine the balls in accordance with Test Method B276 or other test method as approved by the purchaser. Sample units exceeding the conditions for A02, B02, and C02 apparent porosity shall be cause for lot rejection.

11.7 *Surface Roughness*—Select samples in accordance with Section 10. Test in accordance with ANSI B46.1. Sample units not complying with requirements of 9.2 shall be cause for lot rejection.

11.8 *Decarburization*—Select Compositions 1, 2, 3, 4, 13, 15 and 16 balls in accordance with Section 10. Examine balls for surface decarburization. Polish and microetch transverse sections through the center of sample balls, and examine at a magnification of 100 times. Test specimens exhibiting surface decarburization shall be cause for lot rejection.

11.9 *Case Depth*—Select Composition 3 balls in accordance with Section 10. Polish and microetch transverse sections through the center of sample balls, and examine using appropriate measuring devices or instruments. Test specimens not complying with case depth requirements shown in Table 4 shall be cause for lot rejection. See Test Method E384.

11.10 *Eddy Current*—Eddy current inspection shall be performed on 100 % of Composition 13 balls.

11.10.1 *Personnel*—Personnel performing the eddy current testing shall meet the requirements of NAS 410.

11.10.2 *Calibration Standard*—The calibration standard shall be a ball of the same material, heat treat condition and grade as the ball being tested. The diameter of the calibration standard shall be the same as the nominal diameter of the ball being tested. The calibration standard shall have an electrical discharge machining (EDM) notch on its surface that is between 0.030 and 0.032 in. by 0.004 in. maximum wide and 0.004 in. maximum deep. Measure and record notch dimensions. Calibration standards shall trip the reject signal and shall be segregated from acceptable balls.

11.10.3 *Residual Magnetism*—Check the calibration standard and balls for residual magnetism prior to testing. All parts shall have less than 0.50 gauss before testing.

11.10.4 *Scanning Coverage*—Scanning increments shall be no greater than the diameter of the coil being used for the test. Continuously scan the entire periphery of the ball surface. Use the same scanning speeds for testing and calibration. Verify full scanning of parts being tested at the beginning and at the end of each inspection lot. If fixturing requires adjustment, reinspect all parts inspected since previous check.

11.10.5 *Signal and Noise*—Set up test equipment so that calibration standards produce a signal of 50 % of the screen height. Do not change sensitivity adjustments during testing to compensate for drift within the machine; do not adjust sensitivity greater than ±10 % from the previously established calibration. Verify meter deflection on the calibration standard at the beginning and at the end of each inspection lot.

11.10.6 *Ball Rejection*—Reject any production balls that signal equal to or greater than the calibration level of the EDM notch in the calibration standards.

11.11 *Visual Testing*—Balls shall be inspected in accordance with 10.1 and Table 8 using the unaided eye. Balls having basic diameters of ⅛ in. or less may be examined by magnification not exceeding ten times.

11.11.1 *Visual Testing for Composition 13 Balls*—Sample balls in accordance with 10.2.1. Inspect balls for defects using the unaided eye (unless magnification is specified). Use a radius scribe as the initial determination of acceptability for defects. Use a 0.030-in. radius on balls ½ in. diameter and larger. Use a 0.020-in. radius scribe on balls less than ½ in. diameter. If the defect is detectable with the scribe, or if the acceptance criteria of Table 7 are not met, the ball shall be rejected.

11.12 *Dimensional Testing:*

11.12.1 *Diameter Tolerance Per Ball and Ball and Lot Diameter Variation*—Sample in accordance with Section 10. Take a minimum of ten measurements in random orientations of each sample ball. If samples do not comply with out-of-roundness requirements, the lot shall be rejected. See Tables 5 and 6.

11.12.2 *Measurement of Deviation from Spherical Form*—Sample in accordance with Section 10. Test in accordance with Annex A2. If sample balls do not satisfy the requirements of Table 5, the lot shall be rejected.

11.12.3 *Tolerances by Grade for Lots of Balls*—Sample lots of balls in accordance with Section 10. Take a minimum of ten measurements in random orientations of each sample ball. If sample packages do not comply with the requirements of 8.1, they shall be rejected.

11.12.4 *Specific Diameter Marking*—Sample in accordance with Section 10. Take a minimum of ten measurements in random orientations of each sample ball. Marking shall be within one marking increment of the average diameter of the balls in the unit container (see Table 6). Any unit container that does not comply with these requirements shall be rejected.

11.13 *Carbides on Finished Composition 13 Balls*—Inspect a five ball sample from each lot of finished Composition 13 balls at 250 times or greater magnification. Select 3 random fields per ball, approximately 120° apart. Measure raised carbides using an optical interferometer or other suitable device. If a ball contains a raised carbide with a height above the ball surface in excess of 11 µin., reject the lot.

11.14 *Macro-Examinations*—Conducting Macro-examinations for non-metallic inclusions for each heat of steel in the billet stage is determined to be a best practice but not a requirement of this standard, excluding Composition 3.

11.14.1 *Composition 3 Balls*—Select samples for examination from the billets for the wire or rods used in the manufacture of the balls, in accordance with Method 321 of FED-STD-151. Conduct macro-examination of each heat of steel in accordance with Test Methods E381. The quality of steel as indicated by the results of the macro-examination shall be as agreed upon between the producer and the vendor. Defects exhibiting profiles of an unacceptable condition in Plates I, II, and III in Test Methods E381 Adjuncts shall not be considered acceptable. When specified in the purchase order or contract, a certified material analysis report (certificate of conformance) submitted by the mill supplier is an acceptable alternate to the macro-examination of the material.

11.14.2 *Composition 13 Balls*—Perform macro-examination in accordance with AMS 6490 and AMS 6491.

12. Inspection

12.1 Inspection of the balls shall be in accordance with the requirements of Sections 6 through 11 and Table 1 through Table 9 and as agreed upon between the purchaser and the supplier. The supplier is responsible for performance of all testing and inspection requirements.

13. Keywords

13.1 ball bearing; ball valve; bearing; bearing accessories; bearing rolling elements

ANNEXES

(Mandatory Information)

A1. TEST METHOD FOR ULTRASONIC TESTING OF COMPOSITION 13 BAR STOCK

A1.1 Scope

A1.1.1 This annex covers the procedure for ultrasonic testing of Composition 13 bar stock selected for the manufacture of bearing balls.

A1.2 Significance and Use

A1.2.1 Balls may be used in engine and gearbox bearings on rotary and fixed winged aircraft.

A1.3 Personnel

A1.3.1 Personnel performing the inspection shall meet the requirements of NAS 410.

A1.4 Sampling

A1.4.1 Sampling shall be done in accordance with 10.2.

A1.5 Calibration and Standardization

A1.5.1 *Calibration Standard*—Reference pieces for calibration shall be of the same material, metal travel distance, surface finish, and ultrasonic response as the bar stock being tested.

A1.5.2 *Reference Test Pieces:*

A1.5.2.1 *For Bar Stock 5/8 to 1½ in.-Diameter*—The reference test piece shall be a bar of at least 3 ft. in length. For near zone testing, metal travel shall be four-tenth the diameter and nine-tenth the diameter of the test piece to flat bottom holes (FBHs) 0.020 in. in diameter. For far zone testing, metal travel shall be six-tenth the diameter and one-tenth the diameter of the test piece to FBHs 0.020 in. diameter. For angle scanning, a shear notch 0.0070 ± 0.0005 in. deep, axially oriented, and located at least 8 in. from the end of the bar shall be used. The notch shall be produced from a 1-in. end mill with a 0.0002-in.

maximum radius. Ultrasonic reflectors shall be spaced a minimum of 2 in. apart.

A1.5.2.2 *For Bar Stock 1/2 to 5/8 in.-Diameter*—The reference test piece shall have all the requirements of A1.5.1 and A1.5.2.1, except for the following: for near zone testing, metal travel of nine-tenth the test piece diameter shall be replaced with metal travel to a 0.020-in. diameter FBH of 0.062-in. depth. For far zone testing, metal travel of one-tenth the test piece diameter shall be replaced with metal travel of 0.06 in. to a 0.020-in. FBH.

A1.5.2.3 *For Bar Stock Less Than 1/2-in. Diameter*—For bar stock less than 0.500 in. diameter, only one FBH providing one half diameter travel is required in addition to the shear notch of A1.5.2.1.

A1.6 Procedure

A1.6.1 *Longitudinal Scan*—While maintaining the correct water path, obtain a 2-in. signal from the highest attenuated 0.020-in. FBH. Adjust the sensitivity and distance amplitude control to bring near and far FBHs within ±10 % of a 2-in. amplitude indication. Establish compatibility between the reference block and the material to be tested by comparing the first unsaturated back reflection from the block with the corresponding back reflection from the material to be tested. Gain shall be set to give an 80 % of screen signal from the FBH with a depth of six-tenth the diameter of the test piece. Check the compatibility in at least three well-separated areas on the material to be tested. Set the gate width for near zone testing to include response from FBH with a depth of one-tenth (or 0.062-in. holes) and a six-tenth test piece diameter. Set the gate width for far zone testing to include the response from FBH with a depth of a four-tenth and a nine-tenth test piece diameter. Set the alarm sensitivity to ensure 100 % of a 0.020-in. diameter FBH inspection level. Use a maximum surface scanning speed of 15 in./s. Hash or ultrasonic noise exceeding 50 % of the response from a FBH is not acceptable.

A1.6.2 *Loss of Backface*—Set the instrument so the first backface reflection from the full round reference block is 80 % of the screen saturation. Gate the first backface reflection and set the alarm at 50 % or less of loss in the backface signal. Observe the scanning speed, noise level, and indexing requirement listed under the longitudinal scan. Inspect and evaluate the loss of backface areas.

A1.6.3 *Angle Scan Test*—Position the transducer over the angle reference notch area for maximum response. Rotate the reference standard so the center of the standard block and the notch are on a horizontal plane. Adjust the gain to obtain a 2-in. signal and adjust the flaw alarm for a 1-in. signal. Set the gate width to include the area at which the signal from the reference notch is detected. Ensure that the scan speed, acceptable noise level, and indexing are as established under the longitudinal scan.

A1.7 Interpretation of Results

A1.7.1 *Longitudinal Scan*—Discontinuities in excess of the response from a 0.020-in. diameter FBH at the estimated discontinuity depth shall not be acceptable.

A1.7.2 *Loss of Back Reflection*—Any loss of back reflection in excess of 50 % of full saturation of the screen shall be considered unacceptable with the instrument set so the first back reflection from the correct test block is at 80 % of the screen adjusted for nonlinearity.

A1.7.3 *Angle Scan*—Discontinuities in excess of 50 % of the response from the axially oriented notch shall not be acceptable.

A1.8 Precision and Bias

A1.8.1 All bar stock for Composition 13 balls must meet all of the requirements for UT testing as set forth in this specification. Material shall be 100 % inspected.

A2. MEASUREMENT OF DEVIATION FROM SPHERICAL FORM

A2.1 General Information

A2.1.1 Deviation from spherical form on finished metal balls may occur in the form of two or more almost equally spaced waves around equatorial profiles. For balls having two waves or higher orders of even numbers of waves, the measurement of single diameters of the balls may be an adequate measure provided several equatorial profiles are subjected to measurement. However, as is most usual, odd numbers of waves of considerable magnitude may also be present which cannot be fully detected by simple two-point measurements.

A2.1.2 Because of the wide range of nominal diameters, from 0.3 mm to 4½ in., measurement of these errors of form can be a slow and difficult process, particularly on the smaller sizes of balls. Two basic methods for detecting errors of spherical form are in use. Most recently developed involves the use of specially designed, highly precise equipment generally identified by the term "Roundness Measuring Equipment." Older equipment, still in common use today for the larger sizes of balls, involves the use of "Vee Blocks" and associated linear comparators of appropriate magnification.

A2.1.3 Since metal balls are essentially quite uniform as to errors of form in any one lot, it is considered sufficient to explore not more than three profiles in three equatorial planes each oriented approximately 90° from the other on individual balls of the sample.

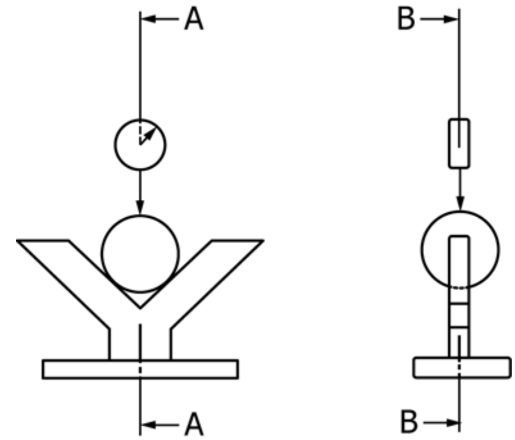
A2.2 Method Using Roundness Measuring Equipment

A2.2.1 Two basic designs of Roundness Measuring Equipment are in use today. One design operates on the basis of stylus and associated linear transducer rotating around the ball in contact with its surface, and the other involves the rotation of the ball against a similar linear transducer. The extremely small motions of the stylus are, in both designs, suitably amplified and recorded on a polar chart which discloses the shape in the form of the number and extent of the waves but with radial deviations greatly magnified. The overall accuracy of the rotating spindle and associated amplifying and recording equipment must be very high, in the order of 0.025 µm or 1 µin. Extreme care must be taken in the interpretation of the polar charts. ANSI B89.3.1 defines several methods of chart interpretation. For finished metal balls, the minimum circumscribed circle (MCC) method is considered adequate.

A2.3 Method Using Vee Blocks

A2.3.1 For the larger sizes of balls, it is practical to use Vee Blocks having specific included angles and associated linear comparators or dial indicators of magnification appropriate for the grade of ball being measured. Fig. A2.1 illustrates the proper use of this type of equipment. This equipment is useful for detecting odd numbers of waves but no one Vee angle is adequate for the determination of all such odd orders of waves. The most desirable angles for wave numbers up to 21 appear to be 90° and 120°.

A2.3.2 The magnification factors for the ratio of the indicator reading to the wave height or deviation from spherical form are shown in Table 7. In certain cases, combinations of Vee angles and numbers of waves present will show little or no indication—these are indicated by asterisks (*) and such readings should be disregarded. If the number of waves is known, the deviation from spherical form is obtained by dividing the indicator reading by the appropriate factor taken from this table.



NOTE 1—The point of stylus/ball contact must be on Axis A-A which is the bisector of the Vee and Axis B-B which is the axis of the ball; also the spindle of the indicator must be in alignment with Axes A-A and B-B.

FIG. A2.1 Vee Block

A2.3.3 If, as is usual, the number of waves is unknown, readings should be taken on the three equatorial planes at 90° to each other, first on a simple two-point gage and then successively using the 90° and the 120° Vee Blocks. The deviation from spherical form is the highest of these three types of readings divided by two.