Designation: F 2215 – 03

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 F 2215; 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 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 Annex A2 through Annex A9 MS sheet standards. In the event of any conflict between requirements of this specification and the Annex A2 through Annex A9 MS sheet standards, the latter shall govern.

1.3 The values given in inch-pound units are to be regarded as standard. The values given in parentheses are for information only.

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. The following government activity codes may be found in the Department of Defense, Standardization Directory SD-1.[2]

Preparing Activity	Custodians	Review Activities
DLA-GS	Army-AT	Army-AV, EA, AR, MI
	Navy-OS	Navy-SH
	Air Force-99	Air Force- 11, 84

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:*

A 108 Specification for Steel Bars, Carbon, Cold-Finished, Standard Quality[3]

A 276 Specification for Stainless Steel Bars and Shapes[4]

A 295 Specification for High-Carbon Anti-Friction Bearing Steels[3]

A 976 Classification of Insulating Coatings by Composition, Relative Insulating Ability and Application[5]

B 21/B 21M Specification for Naval Brass Rod, Bar and Shapes[6]

B 124 Specification for Copper and Copper Alloy Forging Rod, Bar, and Shapes[6]

B 276 Test Method for Apparent Porosity in Cemented Carbides[7]

B 283 Specification for Copper and Copper Alloy Die Forgings (Hot-Pressed)[6]

D 3951 Practice for Commercial Packaging[8]

E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials[9]

E 112 Test Methods for Determining Average Grain Size[9]

E 140 Standard Hardness Conversion Tables for Metals Relationship Among Brinell Hardness, Vickers Hardness, Rockwell Hardness, Superficial Hardness, Knoop Hardness, and Scleroscope Hardness[9]

E 381 Test Methods for Detector calibration and Analysis of Radionuclides[3]

E 381 ASTM Adjuncts: Photographs for Rating Macroetched Steels (3 Plates)[3]

E 384 Test Method for Microindentation Hardness of Materials[3]

2.2 *SAE Standards:*

AMS 5618 Steel, Corrosion Resistant Bars, Wire and Forgings[10]

AMS 5630 Steel, Corrosion Resistant Bars, Wire and Forgings[10]

AMS 5749 Steel, Corrosion Resistant Bars, Wire and Forging and Tubing Premium Aircraft Quality for Bearing Applications[10]

AMS 5880 Steel, Corrosion Resistant Bars, Wire and Forging for Bearing Applications[10]

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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] The Department of Defense, Standardization Directory, SD-1, may be found at: http://assist.daps.dla.mil/online/start/.

[3] *Annual Book of ASTM Standards*, Vol 01.05.

[4] *Annual Book of ASTM Standards*, Vol 01.03.

[5] *Annual Book of ASTM Standards*, Vol 03.04.

[6] *Annual Book of ASTM Standards*, Vol 02.01.

[7] *Annual Book of ASTM Standards*, Vol 02.05.

[8] *Annual Book of ASTM Standards*, Vol 15.09.

[9] *Annual Book of ASTM Standards*, Vol 03.01.

[10] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990.

AMS 6440 Specification for Steel Bars, Forgings and Tubing 1.45Cr (0.98-1.10C) (SAE 52100) for Bearing Applications[10]
AMS 6444 Specification for Steel Bars, Forgings and Tubing Premium Aircraft Quality for Bearing Applications[10]
AMS 6490 Specification for Steel Bars, Forgings and Tubing[10]
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[10]
2.3 *Federal Standards:*
FED-STD-151 Metals, Test Methods[11]
QQ-N-286 Specification for Nickel-Copper Aluminum Alloy, Wrought[11]
2.4 *Military Standards:*
MIL-DTL-197 Specification for Bearings, Anti-Friction; Associated Parts and Subassemblies; Preparation for and Delivery[11]
MIL-STD-129 Marking for Shipment and Storage[11]
MS 3224 Balls, Bearing, Aircraft Quality Steel[11]
MS 3226 Balls, Bearing, Grade 10, Aircraft Quality Steel[11]
MS 19059 Balls, Bearing, Chrome Alloy Steel[11]
MS 19060 Balls, Bearing, Corrosion Resistant Steel[11]
MS 19061 Balls, Bearing, Carbon Steel[11]
MS 19062 Balls, Bearing, Non-Ferrous Brass[11]
MS 19063 Balls, Bearing, Bonze[11]
MS 19064 Balls, Bearing, Nickel-Copper Alloy (K Monel)[11]
2.5 *ABMA Standard:*
ABMA-STD-10 Metal Balls (Inactive Specification)[12]
2.6 *ANSI Standards:*
B46.1 Surface Texture (Surface Roughness, Waviness and Lay)[13]
B89.3.1 Sampling Procedures and Tables for Inspection by Attributes[13]
2.7 *NAS Standard:*
NAS 410 Certification and Qualification of Nondestructive Test Personnel
2.8 *ISO Standard:*
ISO 3290 Rolling Bearings, Bearing Parts, Balls for Rolling Bearings[13]
2.9 *Automatic Identification Manufacturers (AIM):*
AIM BC1 Uniform Symbology Specification Code 39

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

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

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

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

3.1.4 *case depth*—the 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)*—the 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*—the standard unit steps to express the specific diameter.

3.1.9 *nominal size (Dw)*—the 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*—the difference between the largest diameter and the smallest diameter measured on the same ball.

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

3.1.12 *specific diameter*—the 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*—a 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 *VIMVAR*—vacuum induction melt-vacuum arc remelt.

4. Classification

4.1 This specification covers balls of Compositions 1 through 14 (see Table 1), and Grades 3, 5, 10, 16, 24, 48, 100, 200, 500 and 1000 (see 3.1.6).

TABLE 1 Classification of Balls

Composition Number	Composition
1	chrome alloy steel
2	corrosion-resistant hardened steel
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 resisting unhardened steel

[11] Available from U.S. Government Printing Office Superintendent of Documents, 732 N. Capitol St., NW, Mail Stop: SDE, Washington, DC 20401.
[12] Available from the Anti-Friction Bearing Manufacturers' Association, Inc., 1101 Connecticut Ave., N.W., Suite 700, Washington, DC 20036.
[13] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

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 and ABMA-STD-10),

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 (see Note 1):

5.1.11.1 Traceability records for each ball, when required, including its corresponding heat treat lot, forging lot, consumable electrode remelt number, process lot number, and VIM-VAR heat of steel,

5.1.11.2 Material identification records, when required,

5.1.11.3 Eddy current inspection records, when required, and

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

NOTE 1—The contract or purchase order should specify that the Composition 13 material, eddy current and ultrasonic inspection records are to be maintained for 15 years from the date of purchase order or contract completion, and that the records are to be available for delivery to the purchaser within 3 working days.

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 G51986 or UNS G52986 in accordance with AMS 6440 or AMS 6444 and Specification A 295. Chemical composition shall be tested in accordance with 11.2.

6.1.1 Material used in manufacture of Composition 1 balls shall conform to the inclusion rating specifications given in 7.6.

6.1.2 Material used in the manufacture of Composition 1 balls shall not exhibit defects as shown in Table 2 when tested in accordance with 11.15.1.

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 A 276 and AMS 5618, 5630, 5749 and 5880. Chemical composition shall be tested in accordance with 11.2.

6.2.1 Material used in the manufacture of Composition 2 balls shall conform to the inclusion rating specifications given in 7.6.

6.2.2 Material used in the manufacture of Composition 2 balls shall not exhibit defects as shown in Table 2 when tested in accordance with 11.15.1.

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 A 108. 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 E 381 and E 381 Adjuncts. Tests shall be in accordance with 11.15.2.

6.4 *Composition 4*—Composition 4 balls shall be manufactured from selected silicon molybdenum steel UNS T41902 of the through-hardened type as specified in Table 3. 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 3. 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 B 283, B 124, B 21/B 21M, and B 21/B<usb> 21M. 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 3. 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 3. 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 3. 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

TABLE 2 Classification of Defects

Category	Defect	Testing Method
Major:		
101	presence of more than one nonmetallic inclusions 1/16 to 1/8 in. (SI) long	measure
102	presence of one nonmetallic inclusion over 1/8 in. (SI) long	measure
103	presence of porosity, pipe or internal ruptures	visual
104	balls show evidence of contamination	visual
105	balls not free from decarburization, cracks, pits and indications of soft spots	visual
106	balls (bronze) not free from alloy segregation	visual
107	hardness of balls less than required limits	measure
Minor:		
201	packaging, packing and marking not in accordance with requirements	visual

TABLE 3 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.

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 3. 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 3. 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 1 balls shall be macro-examined in accordance with 11.15.3.

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 A 276. Chemical composition shall be tested in accordance with 11.2.

6.14.1 Material used in manufacture of Composition 14 balls shall conform to the inclusion rating specifications given in 7.6.

6.14.2 Material used in the manufacture of Composition 14 balls shall not exhibit defects as shown in Table 2 when tested in accordance with 11.15.1.

7. Other Requirements

7.1 *Density*—Density shall be as specified in Table 4 when tested in accordance with 11.3.

7.2 *Hardness*:

7.2.1 Hardness shall be as specified in Table 4 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 5 when tested in accordance with 11.9.

7.3 *Fracture Grain Size*—Fracture grain size shall be in accordance with the material specification or as specified in Table 4, 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 B 276 when tested in accordance with 11.6.

TABLE 4 Other Requirements

Composition Number	Hardness[A]	Density, lbm/in.^{3}	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		

[A] Hardness equivalent to those shown are also acceptable. See Standard Hardness Conversion Tables E 140.
[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 5 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 E 384.

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

7.6 *Inclusion Rating*:

7.6.1 *Compositions 1 and 2 Material Samples and Finished Balls*—Compositions 1 and 2 material and finished balls 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 A 295. For balls, fractured surfaces examined visually shall be considered defective if the following are found:

7.6.1.1 Presence of more than one nonmetallic inclusion between 1/16 and 1/8 in. long,

7.6.1.2 Presence of one nonmetallic inclusion over 1/8 in. long, or,

7.6.1.3 Presence of porosity, pipe, or internal ruptures.

7.6.2 *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.

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

7.8 *Passivation*—Composition 2 balls shall be passivated and shall not exhibit visible corrosion when tested in accordance with 11.10.

7.9 *Eddy Current*—Composition 13 balls shall pass the eddy current test given in 11.11, by meeting the requirements given in 11.11.6.

7.10 *First Article*—When specified in the purchase order or contract, a first article sample shall be provided. The sample item shall meet the requirements of Sections 7, 8, 9, and 14. The purchaser should include specific instructions in the purchase order or contract regarding arrangements for testing and approval of the first article sample.

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 6 and Table 7 and the applicable MS sheet standards (see 2.4) for the respective metallic compositions and grades. Dimensions not within the tolerances specified on the applicable MS sheet standard and Table 6 and Table 7 shall be classified as a defect. Balls shall be tested for dimensional requirements in accordance with 11.13. ISO 3290 provides a listing of additional acceptable sizes.

9. Workmanship, Finish, and Appearance

9.1 Balls shall be free from decarburization, over tempering, and indication of soft spots.

9.2 All surfaces shall be free of scratches, nicks, pits, dents, seams, laps, tears, cracks, and corrosion when examined with an unaided eye. Balls having basic diameters of 1/8 in. or less may be examined by magnification not exceeding 10 times.

9.3 Tolerance limits for scratches, pits, nicks, and dents on Composition 13 balls shall be in accordance with Table 8.

TABLE 6 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 7 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 8 Visual Inspection Limits for Composition 13 Balls

Type of Defect	Acceptable Limits
Pits	0.008 in. maximum dimension for single pit; maximum of 3 permitted in any ¼ -in. diameter circle
Scratches	0.006 in. width; maximum of 1 per ball up to 50 % of circumference, any number up to 25 % of circumference; no cross-scratches permitted.
Nicks, dents, and indentations on balls of less than ½ -in. diameter	0.015 in. maximum dimension
Nicks, dents, and indentations on balls of ½ -in. diameter or larger	0.024 in. maximum dimension

Surface defects not within the tolerance of acceptable limits specified in Table 8 shall be cause for rejection.

9.4 *Visual and Dimensional Testing*—Balls shall meet the requirements of Table 9. Composition 13 balls shall be visually tested in accordance with 11.12.

9.5 *Surface Roughness*—The surface roughness of the balls shall not exceed the value specified in the applicable MS sheet standard (see 2.4) or Table 10 for the specified grade, when tested in accordance with 11.7.

9.6 *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 11.14.

TABLE 10 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 and 14 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*:

TABLE 9 Quality Conformance Inspection

Test	Inspection Level	AQL (Defects Per 100 Units)
Visual (see Table 2 and Table 8)		
Major Defects (see Table 2)	II	1.0
Minor Defects (see Table 2)	II	6.5
Dimensional Examination: (see Tables 6 and 7)		
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

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."

10.2.3 *Eddy Current Inspection*—Composition 13 balls shall be inspected 100 %.

10.3 *First Article Testing*—When a first article sample is required, five sample units shall be tested in accordance with Sections 6 through 12 and the requirements in Table 1 through Table 10.

11. Test Methods

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

11.1.1 *Temperature*—Room ambient.

11.1.2 *Altitude*—Normal ground.

11.2 *Chemical Analysis*:

11.2.1 Chemical analysis of each lot of material shall be tested in accordance with the appropriate material specification.

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*—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 11.13.1. Determine the weight of each sample ball to an accuracy of 2.205×10^{-6} lbm (0.001 g) or 10 % of the weight, whichever is greater. Samples failing to comply with the density test requirements given in Table 4 shall be cause for lot rejection.

11.4 *Ball Hardness*—Select samples of each composition in accordance with Section 10. Test in accordance with Test Methods E 18, except for Composition 6. Test Composition 6 balls in accordance with MS 19063. 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 4, the lot shall be rejected.

11.5 *Fracture Grain Size*—Select samples of Composition 1, 2, and 13 balls in accordance with Section 10. Fracture grain size shall be in accordance with the material specification. Examine in accordance with Test Methods E 112 or the test method appropriate to the material specification. Balls having fracture grain sizes for Compositions 1, 2, and 13 that are not in accordance with the requirements of the material specification shall be cause for rejection.

11.6 *Porosity Test*—Select Composition 12 balls in accordance with Section 10. Prepare and examine the balls in accordance with Test Method B 276 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 9.5 shall be cause for lot rejection.

11.8 *Decarburization*—Select Compositions 1, 2, 3, 4, and 13 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 diameters. 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 5 shall be cause for lot rejection. See Test Method E 384.

11.10 *Passivation*—Select Composition 2 balls in accordance with Section 10. Passivate in accordance with AMS-QQ-P-35 or Classification A 976. Test for acceptance in accordance with the appropriate test method in the passivation specification. Use the following or equivalent test method. Immerse samples in distilled water at 100 ± 5°F for 1 h, and then air dry at 100 ± 5°F for 1 h. Repeat this cycle for a total of 24 h. At the end of the 24-h test period, examine the sample balls for surface corrosion, using a 10× power magnification. Samples exhibiting visible corrosion shall be cause for lot rejection.

11.11 *Eddy Current*:

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

11.11.2 *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.

11.11.3 *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.

11.11.4 *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.

11.11.5 *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.

11.11.6 *Ball Rejection*—Calibration standards trip the reject signal; segregate them from acceptable balls. Reject any production balls that signal equal to or greater than the calibration level of the EDM notch in the calibration standards. Segregate any rejected balls.

11.11.7 *Processing After Eddy Current Testing*—Reinspect any balls that are processed in any way following eddy current testing.

11.12 *Visual Testing for Composition 13 Balls*—Sample balls in accordance with 10.2. 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.

11.13 *Dimensional Testing*:

11.13.1 *Diameter Tolerance Per Ball and Ball and Lot Diameter Variation*—Sample in accordance with Section 10. Take a minimum of 10 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 6 and 7.

11.13.2 *Measurement of Deviation from Spherical Form*—Sample in accordance with Section 10. Test in accordance with Annex A10. If sample balls do not satisfy the requirements of Table 6, the lot shall be rejected.

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

11.13.4 *Specific Diameter Marking*—Sample in accordance with Section 10. Take a minimum of 10 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 7). Any unit package that does not comply with these requirements shall be rejected.

11.14 *Carbides on Finished Composition 13 Balls*—Inspect a five ball sample from each lap load 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 lap load.

11.15 *Macro-Examinations*:

11.15.1 *Compositions 1 and 2 Balls*—Take specimens that are ⅜ in. thick (and representative of the cross section of 4-in. square rolled billets) for forged sections that are 4-in. square (used for forging and re-rolling into coils, tube rounds, and bars) from the top and bottom areas of the first, middle, and last of usable ingots of a heat. Normalize, anneal, harden, and fracture these specimens. Ensure that the specimens do not have external indentations sufficient to guide the fracture during the examination. Examine fractured surfaces for the defects listed in Table 2.

11.15.2 *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 E 381. 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 E 381 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.

11.15.3 *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 10 and as agreed upon between the purchaser and the supplier. The supplier is responsible for performance of all testing and inspection requirements.

13. Certification

13.1 Unless otherwise specified in the contract or purchase order, the supplier is responsible for performance of all testing and inspection requirements as specified herein. Except as otherwise specified in the contract or purchase order, the supplier may use his own or any other facility suitable for the performance of such tests or inspections, or both, unless disapproved by the purchaser.

13.2 When specified in the contract or purchase order, certificates of quality (conformance) supplied by the manufacturer of the metal balls may be furnished instead of actual performance of such testing by the supplier, provided that lot identity has been maintained and can be demonstrated to the purchaser. The certificate shall include the name of the purchaser, contract number, name of the manufacturer or supplier, NSN, item identification, name of the material, lot number, lot size, sample size, date of testing, test method, individual test results, and the specification requirements.

14. Packaging and Package Marking

14.1 *Military Packing*—When MIL-DTL-197 is called out in the contract or purchase order, the balls shall be cleaned, dried, preserved, and packaged in accordance with Level A Method of Preservation and Level C Method of Packaging.

14.2 *Commercial Packing*—When commercial industrial preservation and packaging are called out in the contract or purchase order, the balls shall be cleaned, dried, preserved and packaged in accordance with Practice D 3951.

14.3 *Marking*:

14.3.1 *Military*—In addition to any special or other identification marking required by the contract or purchase order, each unit pack, intermediate and exterior container shall be marked in accordance with MIL-STD-129 and AIM BC1 for bar code requirements.

14.3.2 *Industrial*—Industrial marking shall be in accordance with Practice D 3951.

15. Keywords

15.1 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 10.3.

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 2-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. MS19062 BALLS, BEARING, NONFERROUS BRASS

A2.1 Requirements

A2.1.1 *Material*—Nonferrous brass conforming to chemical composition of SAE CA 260. Balls shall be manufactured from selected brass free from alloy segregation, and shall be free from cracks when examined visually without magnification.

A2.1.2 *Hardness*—Surface hardness of Rockwell Rb 75-87 or equivalent measured on parallel flats.

A2.1.3 *Surface Roughness*—Not to exceed the maximum roughness height value (AA) of 8 µin., interpreted in accordance with ANSI B46.1.

A2.1.4 *Material Density*—306 lb/in.^{3}

A2.1.5 *Part Number*:

A2.1.5.1 The MS part number consists of the MS number, plus the dash number. Example: MS 19062-20001 is the part number for a Grade 200 nonferrous brass-bearing ball with a basic diameter of 0.062500 in.

A2.1.5.2 Dash numbers, formerly designated -1 through -19, have been redesignated -20001 through -20019.

A2.1.6 *Dimensions*—All dimensions are in inches, unless otherwise specified. Column headings in tolerance tables are defined in ABMA-STD-10.

A2.2 Notes

A2.2.1 Referenced documents shall be of the issue in effect on date of invitation for bids.

A2.2.2 For design feature purposes, this specification takes precedence over procurement documents referenced herein.

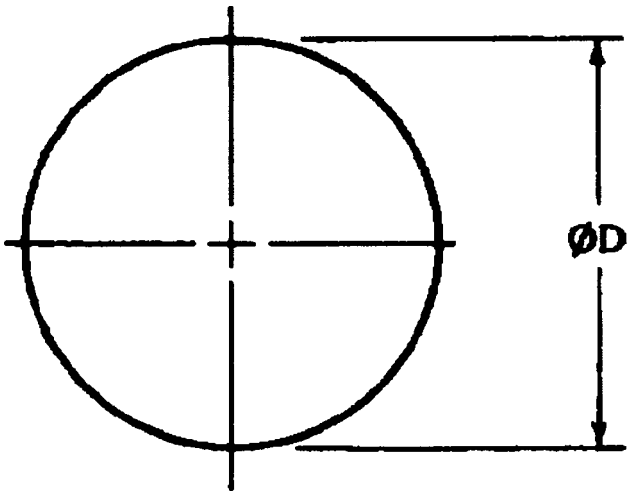


FIG. A2.1

TABLE A2.1 Dash Numbers Basic Diameter

Nominal Ball Diameter	Basic Diameter ØD	Grade 200 Dash No.
1/16	0.062500	20001
3/32	0.093750	20002
1/8	0.125000	20003
5/32	0.156250	20004
3/16	0.187500	20005
7/32	0.218750	20006
1/4	0.250000	20007
9/32	0.281250	20008
5/16	0.312500	20009
11/32	0.343750	20010
3/8	0.375000	20011
13/32	0.406250	20012
7/16	0.437500	20013
15/32	0.468750	20014
1/2	0.500000	20015
9/16	0.562500	20016
5/8	0.625000	20017
11/16	0.687500	20018
3/4	0.750000	20019

TABLE A2.2 Tolerance by Grade for Individual Balls (Tolerance in millionths of an inch)

Grade	Allowable Ball Diameter Variation, V_D	Allowable Deviation from Spherical Form, *W*
200	200	200

TABLE A2.3 Tolerances by Grade for Lots of Balls (Tolerance in millionths of an inch)

Grade	Allowable Lot Diameter Variation	Basic Diameter Tolerance
200	400	±1000

A3. MS3224 BALLS, BEARING, AIRCRAFT QUALITY STEEL

A3.1 Requirements

A3.1.1 *Material*—Aircraft quality steel conforming to the chemical composition of UNS T11350 in accordance with AMS 6490 and AMS 6491 and as specified in procurement document.

A3.1.2 *Hardness*—Shall be 61-64 HRC or equivalent.

A3.1.3 *Surface Roughness*—Tolerance limits for surface roughness as specified in Table A3.2, and in accordance with ANS B46.1.

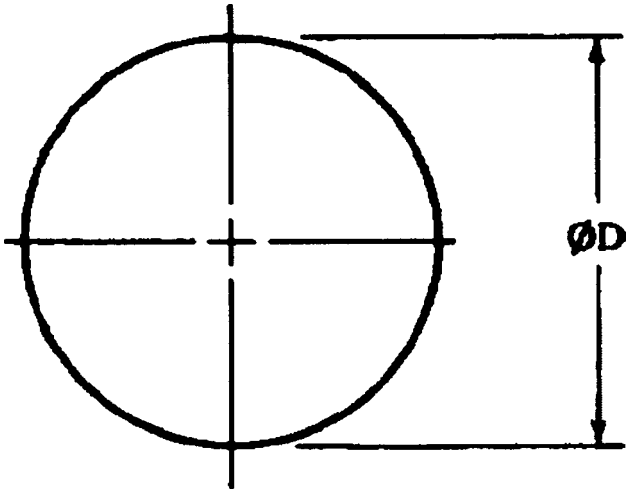


FIG. A3.1

A3.1.4 *Material Density*—Shall be 0.279 lb/in.^{3}

A3.1.5 *Part Number*—Consists of the basic MS number followed by a dash number from Table A3.1 (see Fig. A3.2 for example).

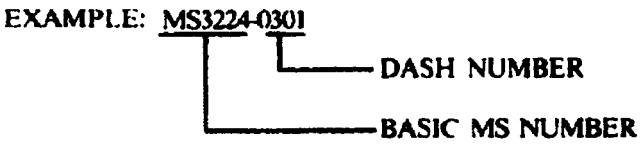
A3.2 Notes

A3.2.1 All dimensions are in inches. Column headings in tolerance tables are in accordance with ABMA-STD-10.

A3.2.2 Grade 10 balls are preferred in most military applications.

A3.2.3 In the event of a conflict between the test of this specification and the references cited herein, the text of this specification shall take precedence.

A3.2.4 Referenced government (or nongovernment) documents of the issue listed in that issue of the Department of Defense Index of Specifications and Standards (DOISS) specified in the solicitation form a part of this specification to the extent specified herein.



NOTE—MS3224-0301 indicates a Grade 3 bearing ball of aircraft-quality steel with a basic diameter of 0.03125 in.

FIG. A3.2 Example

TABLE A3.1 Dash Numbers and Dimensions

ØD Nominal Ball Diameter	Basic Diameter[A]	Grade					
		3	5	10[B]	16	24	48
		Dash Number					
1/32	0.031250	0301	0501	1001	1601	2401	4801
3/64	0.046875	0302	0502	1002	1602	2402	4802
1/16	0.062500	0303	0503	1003	1603	2403	4803
5/64	0.078125	0304	0504	1004	1604	2404	4804
3/32	0.093750	0305	0505	1005	1605	2405	4805
7/64	0.109375	0306	0506	1006	1606	2406	4806
1/8	0.125000	0307	0507	1007	1607	2407	4807
9/64	0.140625	0308	0508	1008	1608	2408	4808
5/32	0.156250	0309	0509	1009	1609	2409	4809
11/64	0.171875	0310	0510	1010	1610	2410	4810
3/16	0.187500	0311	0511	1011	1611	2411	4811
7/32	0.218750	0312	0512	1012	1612	2412	4812
15/64	0.234375	0313	0513	1013	1613	2413	4813
1/4	0.250000	0314	0514	1014	1614	2414	4814
17/64	0.265625	0315	0515	1015	1615	2415	4815
9/32	0.281250	0316	0516	1016	1616	2416	4816
19/64	0.296875	0317	0517	1017	1617	2417	4817
5/16	0.312500	0318	0518	1018	1618	2418	4818
11/32	0.343750	0319	0519	1019	1619	2419	4819
23/64	0.359375	0320	0520	1020	1620	2420	4820
3/8	0.375000	0321	0521	1021	1621	2421	4821
25/64	0.390625	0322	0522	1022	1622	2422	4822
13/32	0.406250	0323	0523	1023	1623	2423	4823
7/16	0.437500	0324	0524	1024	1624	2424	4824
29/64	0.453125	0325	0525	1025	1625	2425	4825
15/32	0.468750	0326	0526	1026	1626	2426	4826
31/64	0.484375	0327	0527	1027	1627	2427	4827
1/2	0.500000	0328	0528	1028	1628	2428	4828
17/32	0.531250	-	0529	1029	1629	2429	4829
9/16	0.562500	-	0530	1030	1630	2430	4830
19/32	0.593750	-	0531	1031	1631	2431	4831
5/8	0.625000	-	0532	1032	1632	2432	4832
21/32	0.656250	-	0533	1033	1633	2433	4833
11/16	0.687500	-	0534	1034	1634	2434	4834
23/32	0.718750	-	0535	1035	1635	2435	4835
3/4	0.750000	-	0536	1036	1636	2436	4836
25/32	0.781250	-	0537	1037	1637	2437	4837
13/16	0.812500	-	0538	1038	1638	2438	4838
27/32	0.843750	-	0539	1039	1639	2439	4839
7/8	0.875000	-	0540	1040	1640	2440	4840
29/32	0.906250	-	0541	1041	1641	2441	4841
15/15	0.937500	-	0542	1042	1642	2442	4842
31/32	0.968750	-	0543	1043	1643	2443	4843
1	1.000000	-	0544	1044	1644	2444	4844
1 1/16	1.062500	-	0545	1045	1645	2445	4845
1 1/8	1.125000	-	0546	1046	1646	2446	4846
1 3/16	1.187500	-	0547	1047	1647	2447	4847
1 1/4	1.250000	-	0548	1048	1648	2448	4848
1 5/16	1.312500	-	0549	1049	1649	2449	4849
1 3/8	1.375000	-	0550	1050	1650	2450	4850
1 7/16	1.437500	-	0551	1051	1651	2451	4851
1 1/2	1.500000	-	0552	1052	1652	2452	4852
1 9/16	1.562500	-	0553	1053	1653	2453	4853
1 5/8	1.625000	-	0554	1054	1654	2454	4854

[A] See Table A3.3 for tolerances.
[B] See A3.2.2.

TABLE A3.2 Tolerance by Grade for Individual Balls (Tolerance in millionths of an inch)

Grade	Allowable Ball Diameter Variation, V_D	Allowable Deviation from Spherical Form, W	Maximum Surface Roughness (Arithmetical Average)
3	3	3	0.5
5	5	5	0.8
10	10	10	1.0
16	16	16	1.0
24	24	24	2.0
48	48	48	3.0

TABLE A3.3 Tolerances by Grade for Lots of Balls (Tolerance in millionths of an inch)

Grade	Allowable Lot Diameter Variation	Basic Diameter Tolerance	Allowable Ball Gage Deviation		Container Marking Increment
			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	[A]	[A]	50

[A] Not applicable.

A4. MS3226 BALLS, BEARING, GRADE 10, AIRCRAFT QUALITY STEEL

A4.1 Requirements

A4.1.1 *Material*—Aircraft-quality steel, chemical composition UNS T11350 in accordance with AMS 6490 and AMS 6491 and as specified as Composition 13 in procurement document.

A4.1.2 *Hardness*—As specified in procurement document.

A4.1.3 *Surface Roughness*—Tolerance limits for surface roughness as specified in Table A4.2 and in accordance with ANSI B46.1.

A4.1.4 *Material Density*—Material density shall be 0.279 lb/in.^{3}

A4.1.5 *Ball Grade*—All balls shall be Grade 10 as defined by ABMA-STD-10.

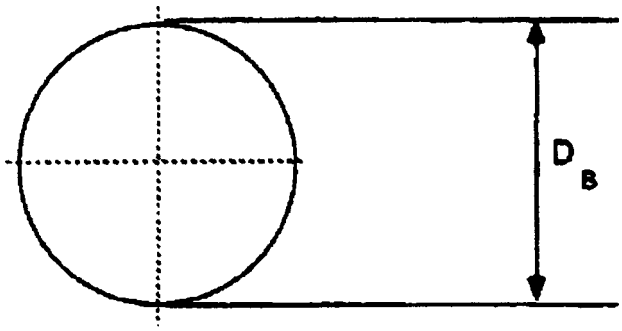


FIG. A4.1

A4.1.6 *Part Number*—The part number shall consist of this MS number followed by a dash and the basic diameter required as selected from Table A4.1 (see Fig. A4.2 for example).

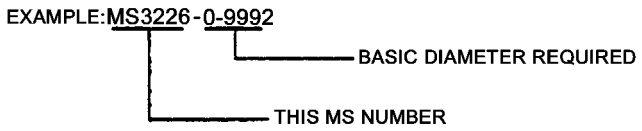
A4.2 Notes

A4.2.1 All dimensions are in inches. Column headings in tolerance tables are in accordance with ABMA-STD-10.

A4.2.2 Some MS3226 part numbers supersede some MS3224 part numbers (see Table A4.4). MS3224 balls cannot be used as replacements for MS3226 balls.

A4.2.3 In the event of a conflict between the text of this specification and the references cited herein, the text of this specification shall take precedence.

A4.2.4 Referenced government (or nongovernment) documents of the issue listed in that issue of the Department of Defense Index of Specifications and Standards (DODISS) specified in the solicitation form a part of this specification to the extent specified herein.



NOTE—MS3226-0.9992 indicates a Grade 10 bearing ball of aircraft-quality steel with a basic diameter of 0.9992 in.

FIG. A4.2 Example

TABLE A4.1 Basic Diameter

Nominal Bell Diameter	Basic Diameter, D_B	Nominal Ball Diameter	Basic Diameter, D_B	Nominal Ball Diameter	Basic Diameter, D_B
1/8	0.1240	7/32	0.2178	5/16	0.3115
	0.1242		0.2180		0.3117
	0.1244		0.2182		0.3119
	0.1246		0.2184		0.3121
	0.1248		0.2186		0.3123
	0.1250		0.2188		0.3125
	0.1252		0.2190		0.3127
	0.1254		0.2192		0.3129
	0.1256		0.2194		0.3131
	0.1258		0.2196		0.3133
	0.1260		0.2198		0.3135
	0.1262		0.2200		0.3137
	0.1264		0.2202		0.3139
	0.1266		0.2204		0.3141
5/32	0.1553	1/4	0.2490	11/32	0.3428
	0.1555		0.2492		0.3430
	0.1557		0.2494		0.3432
	0.1559		0.2490		0.3434
	0.1561		0.2498		0.3436
	0.1563		0.2500		0.3438
	0.1565		0.2502		0.3440
	0.1567		0.2504		0.3442
	0.1569		0.2506		0.3444
	0.1571		0.2508		0.3446
	0.1573		0.2510		0.3448
	0.1575		0.2512		0.3450
	0.1577		0.2514		0.3452
	0.1579		0.2516		0.3454
3/16	0.1865	9/32	0.2803	3/8	0.3740
	0.1867		0.2805		0.3742
	0.1869		0.2807		0.3744
	0.1871		0.2809		0.3746
	0.1873		0.2811		0.3748
	0.1875		0.2813		0.3750
	0.1877		0.2815		0.3752
	0.1879		0.2817		0.3754
	0.1881		0.2819		0.3756
	0.1883		0.2821		0.3758
	0.1885		0.2823		0.3760
	0.1887		0.2825		0.3762
	0.1889		0.2827		0.3764
	0.1891		0.2829		0.3766
13/32	0.4053	1/2	0.4990	19/32	0.5928
	0.4055		0.4992		0.5930
	0.4057		0.4994		0.5932
	0.4059		0.4996		0.5934
	0.4061		0.4998		0.5936
	0.4063		0.5000		0.5938
	0.4065		0.5002		0.5940
	0.4067		0.5004		0.5942
	0.4069		0.5006		0.5944
	0.4071		0.5008		0.5946
	0.4073		0.5010		0.5948
	0.4075		0.5012		0.5950
	0.4077		0.5014		0.5952
	0.4079		0.5016		0.5954
7/16	0.4365	17/32	0.5303	5/8	0.6240
	0.4367		0.5305		0.6242
	0.4369		0.5307		0.6244
	0.4371		0.5309		0.6246
	0.4373		0.5311		0.6248
	0.4375		0.5313		0.6250
	0.4377		0.5315		0.6252
	0.4379		0.5317		0.6254
	0.4381		0.5319		0.6256
	0.4383		0.5321		0.6258
	0.4385		0.5323		0.6260
	0.4387		0.5325		0.6262
	0.4389		0.5327		0.6264
	0.4391		0.5329		0.6266
15/32	0.4678	9/16	0.5615	21/32	0.6553
	0.4680		0.5617		0.6555
	0.4682		0.5619		0.6557

TABLE A4.1 *Continued*

Nominal Bell Diameter	Basic Diameter, D_B	Nominal Ball Diameter	Basic Diameter, D_B	Nominal Ball Diameter	Basic Diameter, D_B
	0.4684		0.5621		0.6559
	0.4686		0.5623		0.6561
	0.4688		0.5625		0.6563
	0.4690		0.5627		0.6565
	0.4692		0.5629		0.6567
	0.4694		0.5631		0.6569
	0.4696		0.5633		0.6571
	0.4698		0.5635		0.6573
	0.4700		0.5637		0.6575
	0.4702		0.5639		0.6577
	0.4704		0.5641		0.6579
11/16	0.6865	25/32	0.7803	29/32	0.9053
	0.6867		0.7805		0.9055
	0.6869		0.7807		0.9057
	0.6871		0.7809		0.9059
	0.6873		0.7811		0.9061
	0.6875		0.7813		0.9063
	0.6877		0.7815		0.9065
	0.6879		0.7817		0.9067
	0.6881		0.7819		0.9069
	0.6883		0.7821		0.9071
	0.6885		0.7823		0.9073
	0.6887		0.7825		0.9075
	0.6889		0.7827		0.9077
	0.6891		0.7829		0.9079
			0.7831		0.9081
			0.7833		0.9083
			0.7835		0.9085
			0.7837		0.9087
23/32	0.7178	13/16	0.8115	15/16	0.9365
	0.7180		0.8117		0.9367
	0.7182		0.8119		0.9369
	0.7184		0.8121		0.9371
	0.7186		0.8123		0.9373
	0.7188		0.8125		0.9375
	0.7190		0.8127		0.9377
	0.7192		0.8129		0.9379
	0.7194		0.8131		0.9381
	0.7196		0.8133		0.9383
	0.7198		0.8135		0.9385
	0.7200		0.8137		0.9387
	0.7202		0.8139		0.9389
	0.7204		0.8141		0.9391
			0.8143		0.9393
			0.8145		0.9395
			0.8147		0.9397
			0.8149		0.9399
3/4	0.7490	7/8	0.8740	1	0.9990
	0.7492		0.8742		0.9992
	0.7494		0.8744		0.9994
	0.7496		0.8746		0.9996
	0.7498		0.8748		0.9998
	0.7500		0.8750		1.0000
	0.7502		0.8752		1.0002
	0.7504		0.8754		1.0004
	0.7506		0.8756		1.0006
	0.7508		0.8758		1.0008
	0.7510		0.8760		1.0010
	0.7512		0.8762		1.0012
	0.7514		0.8764		1.0014
	0.7516		0.8766		1.0016
	0.7518		0.8768		1.0018
	0.7520		0.8770		1.0020
	0.7522		0.8772		1.0022
	0.7524		0.8774		1.0024
1 1/32	1.0303	1 3/16	1.1865	1 3/8	1.3740
	1.0305		1.1867		1.3742
	1.0307		1.1869		1.3744
	1.0309		1.1871		1.3746
	1.0311		1.1873		1.3748
	1.0313		1.1875		1.3750
	1.0315		1.1877		1.3752
	1.0317		1.1879		1.3754

TABLE A4.1 *Continued*

Nominal Bell Diameter	Basic Diameter, D_B	Nominal Ball Diameter	Basic Diameter, D_B	Nominal Ball Diameter	Basic Diameter, D_B
	1.0319		1.1881		1.3756
	1.0321		1.1883		1.3758
	1.0323		1.1885		1.3760
	1.0325		1.1887		1.3762
	1.0327		1.1889		1.3764
	1.0329		1.1891		1.3766
	1.0331		1.1893		1.3768
	1.0333		1.1895		1.3770
	1.0335		1.1897		1.3772
	1.0337		1.1899		1.3774
1 1/16	1.0615	1 1/4	1.2490	1 7/16	1.4365
	1.0617		1.2492		1.4367
	1.0619		1.2494		1.4369
	1.0621		1.2496		1.4371
	1.0623		1.2498		1.4373
	1.0625		1.2500		1.4375
	1.0627		1.2502		1.4377
	1.0629		1.2504		1.4379
	1.0631		1.2506		1.4381
	1.0633		1.2508		1.4383
	1.0635		1.2510		1.4385
	1.0637		1.2512		1.4387
	1.0639		1.2514		1.4389
	1.0641		1.2516		1.4391
	1.0643		1.2518		1.4393
	1.0645		1.2520		1.4395
	1.0647		1.2522		1.4397
	1.0649		1.2524		1.4399
1 1/8	1.1240	1 5/16	1.3115	1 1/2	1.4990
	1.1242		1.3117		1.4992
	1.1244		1.3119		1.4994
	1.1246		1.3121		1.4996
	1.1248		1.3123		1.4998
	1.1250		1.3125		1.5000
	1.1252		1.3127		1.5002
	1.1254		1.3129		1.5004
	1.1256		1.3131		1.5006
	1.1258		1.3133		1.5008
	1.1260		1.3135		1.5010
	1.1262		1.3137		1.5012
	1.1264		1.3139		1.5014
	1.1266		1.3141		1.5016
	1.1268		1.3143		1.5018
	1.1270		1.3145		1.5020
	1.1272		1.3147		1.5022
	1.1274		1.3149		1.5024
1 9/16	1.5615	1 5/8	1.6240		
	1.5617		1.6242		
	1.5619		1.6244		
	1.5621		1.6246		
	1.5623		1.6248		
	1.5625		1.6250		
	1.5627		1.6252		
	1.5629		1.6254		
	1.5631		1.6256		
	1.5633		1.6258		
	1.5635		1.6260		
	1.5637		1.6262		
	1.5639		1.6264		
	1.5641		1.6266		
	1.5643		1.6268		
	1.5645		1.6270		
	1.5647		1.6272		
	1.5649		1.6274		

TABLE A4.2 Tolerance for Individual Balls (Tolerance in millionths of an inch)

Allowable Ball Diameter Variation, V_D	Allowable Deviation from Spherical Form, W	Allowable Surface Roughness (Arithmetical Average)
10	10	1.0

TABLE A4.3 Tolerance for Lots of Balls (Tolerance in millionths of an inch)

Allowable Lot Diameter Variation	Basic Diameter Tolerance	Allowable Ball Gage Deviation		Container Marking Increment
		High	Low	
20	±100	+50	–40	10

TABLE A4.4 Supersedure Information[A]

Cancelled Part Number	Superseded by	Cancelled Part Number	Superseded by
MS3224-1007	MS3226-0.1250	MS3224-1036	MS3226-0.7500
MS3224-1009	MS3226-0.1563	MS3224-1037	MS3226-0.7813
MS3224-1011	MS3226-0.1875	MS3224-1038	MS3226-0.8125
MS3224-1012	MS3226-0.2188	MS3224-1040	MS3226-0.8750
MS3224-1014	MS3226-0.2500	MS3224-1041	MS3226-0.9063
MS3224-1016	MS3226-0.2813	MS3224-1042	MS3226-0.9375
MS3224-1018	MS3226-0.3125	MS3224-1044	MS3226-1.0000
MS3224-1019	MS3226-0.3438	MS3224-1045	MS3226-1.0625
MS3224-1021	MS3226-0.3750	MS3224-1046	MS3226-1.1250
MS3224-1023	MS3226-0.4063	MS3224-1047	MS3226-1.1875
MS3224-1024	MS3226-0.4375	MS3224-1048	MS3226-1.2500
MS3224-1026	MS3226-0.4688	MS3224-1049	MS3226-1.3125
MS3224-1028	MS3226-0.5000	MS3224-1050	MS3226-1.3750
MS3224-1029	MS3226-0.5313	MS3224-1051	MS3226-1.4375
MS3224-1030	MS3226-0.5625	MS3224-1052	MS3226-1.5000
MS3224-1031	MS3226-0.5938	MS3224-1053	MS3226-1.5625
MS3224-1032	MS3226-0.6250	MS3224-1054	MS3226-1.6250
MS3224-1033	MS3226-0.6563		
MS3224-1034	MS3226-0.6875		
MS3224-1035	MS3226-0.7188		

[A] See A4.2.2.

A5. MS19059 BALLS, BEARING, CHROME ALLOY STEEL

A5.1 Requirements

A5.1.1 *Material*—Chrome alloy steel, conforming to the chemical composition of UNS G51986 in accordance with AMS 6444 or ANS G52986 in accordance with AMS 6440, and as specified in procurement document.

A5.1.2 *Hardness*—Shall be 60-67 HRC or equivalent.

A5.1.3 *Surface Roughness*—Tolerance limits for surface roughness as specified in Table A5.2, and in accordance with ANSI B46.1.

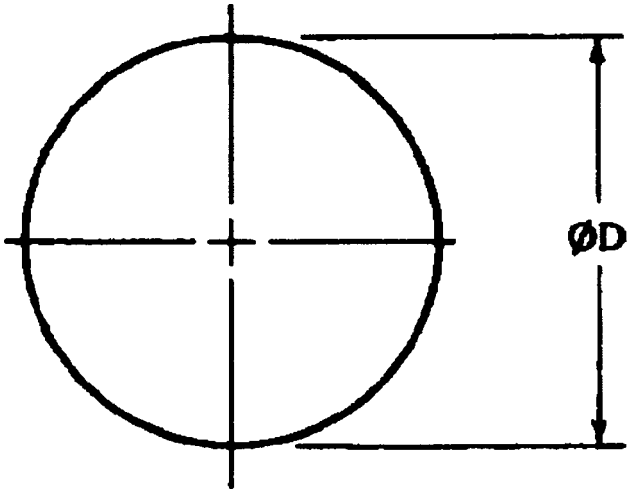


FIG. A5.1

A5.1.4 *Material Density*—Shall be 0.283 lb/in.^{3}

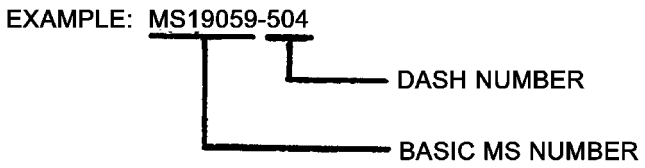
A5.1.5 *Part Number*—Consists of the basic MS number followed by a dash number from Table A5.1 (see Fig. A5.2 for example).

A5.2 Notes

A5.2.1 All dimensions are in inches. Column headings in tolerance tables are in accordance with ABMA-STD-10.

A5.2.2 In the event of a conflict between the text of this specification and the references cited herein, the text of this specification shall take precedence.

A5.2.3 Referenced government (or nongovernment) documents of the issue listed in that issue of the Department of Defense Index of Specifications and Standards (DODISS) specified in the solicitation form a part of this specification to the extent specified herein.



NOTE—MS19059-504 indicates a Grade 5 bearing ball of chrome alloy steel with a basic diameter of 0.062500 in.

FIG. A5.2 Example

TABLE A5.1 Dash Numbers and Dimensions

ØD Nominal Ball Diameter	Basic Diameter[A]	Grade							
		3	5	10	16	24	48	100	200
		Dash Number							
1/64	0.015625	301	501	1001	-	2401	-	-	-
1/32	0.031250	302	502	1002	-	2402	-	-	-
3/64	0.046875	303	503	1003	-	2403	-	-	-
1/16	0.062500	304	504	1004	-	2404	4804	-	-
5/64	0.078125	305	505	1005	-	2405	4805	-	-
3/32	0.093750	306	506	1006	-	2406	4806	-	-
7/64	0.109375	307	507	1007	-	2407	4807	-	-
1/8	0.125000	308	508	1008	-	2408	4808	-	-
9/64	0.140625	309	509	1009	-	2409	4809	-	-
5/32	0.156250	310	510	1010	-	2410	4810	-	-
11/64	0.171875	311	511	1011	-	2411	4811	-	-
3/16	0.187500	312	512	1012	-	2412	4812	-	-
7/32	0.218750	313	513	1013	-	2413	4813	-	-
1/4	0.250000	314	514	1014	-	2414	4814	-	-
9/32	0.281250	315	515	-	-	2415	4815	-	-
5/16	0.312500	316	516	1016	-	2416	4816	-	-
11/32	0.343750	317	517	1017	-	2417	4817	-	-
3/8	0.375000	318	518	1018	-	2418	4818	-	-
13/32	0.406250	319	519	1019	-	2419	4819	-	-
7/16	0.437500	320	520	1020	-	2420	4820	-	-
15/32	0.468750	321	521	1021	-	2421	4821	-	-
1/2	0.500000	322	522	1022	-	2422	4822	-	-
17/32	0.531250	323	523	1023	1623	-	4823	-	-
9/16	0.562500	324	524	1024	1624	2424	4824	-	-
19/32	0.593750	325	525	1025	1625	-	4825	-	-
5/8	0.625000	326	-	1026	1626	2426	4826	-	-
21/32	0.006250	327	527	1027	1627	2427	4827	-	-
11/16	0.687500	328	528	1028	1628	2428	4828	-	-
23/32	0.718750	329	529	1029	1629	2429	4829	-	-
3/4	0.750000	330	530	1030	-	2430	4830	-	-
25/32	0.781250	331	531	1031	1631	2431	4831	-	-
13/16	0.812500	332	532	1032	1632	2432	4832	-	-
27/32	0.843750	333	533	1033	1633	2433	4833	-	-
7/8	0.875000	334	534	1034	1634	2434	4834	-	-
29/32	0.906250	335	535	1035	1635	2435	4835	-	-
15/16	0.937500	336	536	1036	1636	2436	4836	-	-
31/32	0.968750	337	537	1037	1637	2437	4837	-	-
1	1.000000	338	538	1038	1638	2438	4838	-	-
1 1/16	1.062500	-	539	1039	1639	2439	4839	-	-
1 1/8	1.125000	-	540	1040	1640	2440	4840	-	-
1 3/16	1.187500	-	541	1041	1641	2441	4841	-	-
1 1/4	1.250000	-	542	1042	1642	2442	4842	-	-
1 5/16	1.312500	-	543	1043	1643	2443	4843	-	-
1 3/8	1.375000	-	544	1044	-	2444	4844	-	20044
1 7/16	1.437500	-	545	1045	-	2445	4845	-	20045
1 1/2	1.500000	-	546	1046	-	2446	4846	10046	20046
1 9/16	1.562500	-	-	-	-	-	4847	10047	20047
1 5/8	1.625000	-	-	-	-	-	4848	10048	-
1 11/16	1.687500	-	-	-	-	-	4849	10049	20049
1 3/4	1.750000	-	-	-	-	-	4850	10050	20050
1 13/16	1.812500	-	-	-	-	-	4851	10051	20051
1 7/8	1.875000	-	-	-	-	-	4852	10052	20052
1 15/16	1.937500	-	-	-	-	-	4853	10053	20053
2	2.000000	-	-	-	-	-	4854	10054	20054
2 1/8	2.125000	-	-	-	-	-	4855	10055	20055
2 1/4	2.250000	-	-	-	-	-	4856	10056	20056
2 3/8	2.375000	-	-	-	-	-	4857	10057	20057
2 1/2	2.500000	-	-	-	-	-	4858	10058	20058

[A] See Table A5.3 for tolerances.

TABLE A5.2 Tolerance by Grade for Individual Balls (Tolerance in millionths of an inch)

Grade	Allowable Ball Diameter Variation, V_D	Allowable Deviation from Spherical Form, W	Allowable Surface Roughness (Arithmetical Average)
3	3	3	0.5
5	5	5	0.8
10	10	10	1.0
16	16	16	1.0
24	24	24	2.0
48	48	48	3.0
100	100	100	5.0
200	200	200	8.0

TABLE A5.3 Tolerances by Grade for Lots (Tolerance in millionths of an inch)

Grade	Allowable Lot Diameter Variation	Basic Diameter Tolerance	Allowable Ball Gage Deviation		Container Marking Increment
			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	[A]	[A]	50
100	200	±500	[A]	[A]	[A]
200	400	±1000	[A]	[A]	[A]

[A] Not applicable.

TABLE A5.4 Dash Number Changes

Basic Diameter	Grade							
	10		16		24		48	
	Old	New	Old	New	Old	New	Old	New
0.062500	1	1004	-	-	40	2404	79	4804
0.078125	2	1005	-	-	41	2405	80	4805
0.093750	3	1006	-	-	42	2406	81	4806
0.109375	4	1007	-	-	43	2407	82	4807
0.125000	5	1008	-	-	44	2408	83	4808
0.140625	6	1009	-	-	45	2409	84	4809
0.156250	7	1010	-	-	46	2410	85	4810
0.187500	8	1012	-	-	47	2412	86	4812
0.218750	9	1013	-	-	48	2413	87	4813
0.250000	10	1014	-	-	49	2414	88	4814
0.281250	11	1015	-	-	50	2415	89	4815
0.312500	12	1016	-	-	51	2416	90	4816
0.343750	13	1017	-	-	52	2417	91	4817
0.375000	14	1018	-	-	53	2418	92	4818
0.406250	15	1019	-	-	54	2419	93	4819
0.437500	16	1020	-	-	55	2420	94	4820
0.468750	17	1021	-	-	56	2421	95	4821
0.500000	18	1022	-	-	57	2422	96	4822
0.531250	-	-	19	1623	58	2423	97	4823
0.562500	-	-	20	1624	59	2424	98	4824
0.593750	-	-	21	1625	60	2425	99	4825
0.625000	-	-	22	1626	61	2426	100	4826
0.656250	-	-	23	1627	62	2427	101	4827
0.687500	-	-	24	1628	63	2428	102	4828
0.718750	-	-	25	1629	64	2429	103	4829
0.750000	-	-	26	1630	65	2430	104	4830
0.781250	-	-	27	1631	66	2431	105	4831
0.812500	-	-	28	1632	67	2432	106	4832
0.843750	-	-	29	1633	68	2433	107	4833
0.875000	-	-	30	1634	69	2434	108	4834
0.906250	-	-	31	1635	70	2435	109	4835
0.937500	-	-	33	1636	71	2436	110	4836
0.968750	-	-	33	1637	72	2437	111	4837
1.000000	-	-	34	1638	73	2438	112	4838
1.062500	-	-	35	1639	74	2439	113	4839
1.125000	-	-	36	1640	75	2440	114	4840
1.187500	-	-	37	1641	76	2441	115	4841
1.250000	-	-	38	1642	77	2442	116	4842
1.312500	-	-	39	1643	78	2443	117	4843
1.375000	-	-	-	-	-	-	118	4844
1.437500	-	-	-	-	-	-	119	4845
1.500000	-	-	-	-	-	-	120	4846
1.562500	-	-	-	-	-	-	121	4847
1.625000	-	-	-	-	-	-	122	4848
1.687500	-	-	-	-	-	-	123	4849
1.750000	-	-	-	-	-	-	124	4850
1.812500	-	-	-	-	-	-	125	4851
1.875000	-	-	-	-	-	-	126	4852
1.937500	-	-	-	-	-	-	127	4853
2.000000	-	-	-	-	-	-	128	4854
2.125000	-	-	-	-	-	-	129	4855
2.250000	-	-	-	-	-	-	130	4856
2.375000	-	-	-	-	-	-	131	4857
2.500000	-	-	-	-	-	-	132	4858

TABLE A5.5 Part Number Changes

Superseded Number	Replacement Number
MS150451	MS19059-2404
MS150452	MS19059-2406
MS150453	MS19059-2408
MS150454	MS19059-2410
MS150455 through 150481	MS19059-2412 through 19059-2438
MS150482	none
MS150483	MS19059-2439
MS150484	none
MS150485	MS19059-2440
MS150486	none
MS150487	MS19059-2441
MS150488	none
MS150489	MS19059-2442

A6. MS19060 BALLS, BEARING, CORROSION-RESISTANT STEEL

A6.1 Requirements

A6.1.1 *Material*—Corrosion-resistant steel, conforming to the chemical composition of UNS S44003 or UNS S44004 in accordance with Specification A 276 and as specified in procurement document.

A6.1.2 *Hardness*—Shall be 58-65 HRC or equivalent.

A6.1.3 *Surface Roughness*—Tolerance limits for surface roughness as specified in Table A6.2, and in accordance with ANSI B46.1.

A6.1.4 *Material Density*—Shall be 0.277 lb/in.^{3}

A6.1.5 *Part Number*—Consists of the basic MS number followed by a dash number from Table A6.1 (see Fig. A6.2 for example).

A6.2 Notes

A6.2.1 All dimensions are in inches. Column headings in tolerance tables are in accordance with ABMA-STD-10.

A6.2.2 In the event of a conflict between the text of this specification and the references cited herein, the text of this specification shall take precedence.

A6.2.3 Referenced government (or nongovernment) documents of the issue listed in that issue of the Department of Defense Index of Specifications and Standards (DODISS) specified in the solicitation form a part of this specification to the extent specified herein.

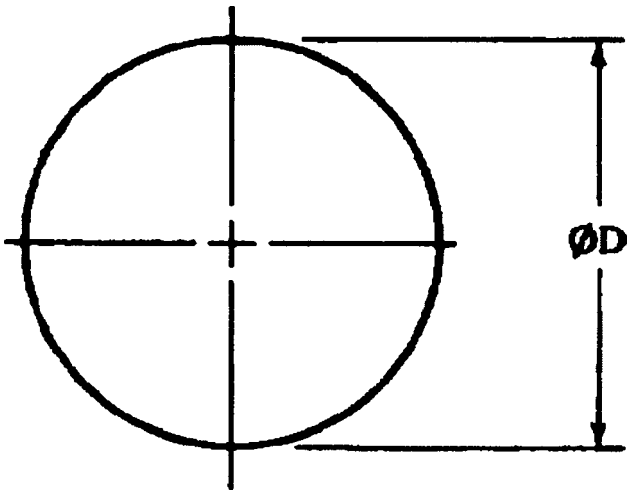
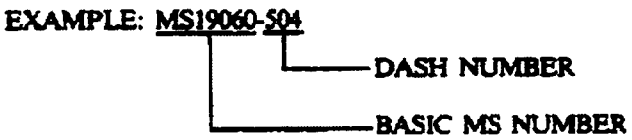


FIG. A6.1



NOTE—MS19060-504 indicates a Grade 5 bearing ball of corrosion-resistant steel with a basic diameter of 0.062500 in.

FIG. A6.2 Example

TABLE A6.1 Dash Numbers and Dimensions

ØD Nominal Ball Diameter	Basic Diameter[A]	Grade						
		3	5	10	16	48	100	200
		Dash Number						
1/64	0.015625	301	501	1001	-	4801	-	-
1/32	0.031250	302	502	1002	-	4802	-	-
3/64	0.046875	303	503	1003	-	4803	-	-
1/16	0.062500	304	504	1004	-	4804	-	-
5/64	0.078125	305	505	1005	-	4805	-	-
3/32	0.093750	306	506	1006	-	4806	-	-
7/64	0.109375	307	507	1007	-	4807	-	-
1/8	0.125000	308	508	1008	-	4808	-	-
9/64	0.140625	309	509	1009	-	4809	-	-
5/32	0.156250	310	510	1010	-	4810	-	-
11/64	0.171875	311	511	1011	-	4811	-	-
3/16	0.187500	312	512	1012	-	4812	-	-
7/32	0.218750	313	513	1013	-	4813	-	-
1/4	0.250000	314	514	1014	-	4814	-	-
9/32	0.281250	315	515	1015	-	4815	-	-
5/16	0.312500	316	516	1016	-	4816	-	-
11/32	0.343750	317	517	1017	-	4817	-	-
3/8	0.375000	318	518	1018	-	4818	-	-
13/32	0.406250	319	519	1019	-	4819	-	-
7/16	0.437500	320	520	1020	-	4820	-	-
15/32	0.468750	321	521	1021	-	4821	-	-
1/2	0.500000	322	522	1022	-	4822	-	-
17/32	0.531250	323	523	1023	-	4823	-	-
9/16	0.562500	324	524	1024	1624	4824	-	-
19/32	0.593750	325	525	1025	1625	4825	-	-
5/8	0.625000	326	526	1026	1626	4826	-	-
21/32	0.656250	327	527	1027	-	4827	-	-
11/16	0.687500	328	528	1028	-	4828	-	-
23/32	0.718750	329	529	1029	-	4829	-	-
3/4	0.750000	330	530	1030	-	4830	-	-
25/32	0.781250	-	-	-	-	4831	-	-
13/16	0.812500	-	-	-	-	4832	-	-
27/32	0.843750	-	-	-	-	4833	-	-
7/8	0.875000	-	-	-	-	4834	-	-
29/32	0.906250	-	-	-	-	4835	-	-
15/16	0.937500	-	-	-	-	4836	-	-
31/32	0.968750	-	-	-	-	4837	-	-
1	1.000000	-	-	-	-	4838	-	-
1 1/16	1.062500	-	-	-	-	4839	-	-
1 1/8	1.125000	-	-	-	-	4840	-	-
1 3/16	1.187500	-	-	-	-	4841	-	-
1 1/4	1.250000	-	-	-	-	4842	-	-
1 5/16	1.312500	-	-	-	-	4843	10043	-
1 3/8	1.375000	-	-	-	-	4844	10044	-
1 7/16	1.437500	-	-	-	-	4845	10045	-
1 1/2	1.500000	-	-	-	-	4846	10046	20046
1 9/16	1.562500	-	-	-	-	4847	10047	20047
1 5/8	1.625000	-	-	-	-	4848	10048	20048
1 11/16	1.687500	-	-	-	-	4849	10049	20049
1 3/4	1.750000	-	-	-	-	4850	10050	20050
1 13/16	1.812500	-	-	-	-	4851	10051	20051
1 7/8	1.875000	-	-	-	-	4852	10052	20052
1 15/16	1.937500	-	-	-	-	4853	10053	20053
2	2.000000	-	-	-	-	4854	10054	20054
2 1/8	2.125000	-	-	-	-	-	10055	20055
2 1/4	2.250000	-	-	-	-	-	10056	20056
2 3/8	2.375000	-	-	-	-	-	10057	20057
2 1/2	2.500000	-	-	-	-	-	10058	20058

[A] See Table A6.3 for tolerances.

TABLE A6.2 Tolerance by Grade for Individual Balls (Tolerance in millionths of an inch)

Grade	Allowable Ball Diameter Variation, V_D	Allowable Deviation from Spherical Form, W	Allowable Surface Roughness (Arithmetical Average)
3	3	3	0.5
5	5	5	0.8
10	10	10	1.0
16	16	16	1.0
48	48	48	3.0
100	100	100	5.0
200	200	200	8.0

TABLE A6.3 Tolerances by Grade for Lots (Tolerance in millionths of an inch)

Grade	Allowable Lot Diameter Variation	Basic Diameter Tolerance	Allowable Ball Gage Deviation		Container Marking Increment
			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
48	96	±200	[A]	[A]	50
100	200	±500	[A]	[A]	[A]
200	400	±1000	[A]	[A]	[A]

[A] Not applicable.

TABLE A6.4 Dash Number Changes

Basic Diameter	Grade									
	10		16		48		100		200	
	Old	New	Old	New	Old	New	Old	New	Old	New
0.015625	-	-	-	-	-	-	-	-	-	-
0.031250	-	-	-	-	-	-	-	-	-	-
0.046875	-	-	-	-	-	-	-	-	-	-
0.062500	1	1004	-	-	16	4804	-	-	-	-
0.078125	-	-	-	-	-	-	-	-	-	-
0.093750	2	1006	-	-	17	4806	-	-	-	-
0.109375	-	-	-	-	-	-	-	-	-	-
0.125000	3	1008	-	-	18	4808	-	-	-	-
0.140625	-	-	-	-	-	-	-	-	-	-
0.156250	4	1010	-	-	19	4810	-	-	-	-
0.171875	-	-	-	-	-	-	-	-	-	-
0.187500	5	1012	-	-	20	4812	-	-	-	-
0.218750	6	1013	-	-	21	4813	-	-	-	-
0.250000	7	1014	-	-	22	4814	-	-	-	-
0.281250	8	1015	-	-	23	4815	-	-	-	-
0.312500	9	1016	-	-	24	4816	-	-	-	-
0.343750	10	1017	-	-	25	4817	-	-	-	-
0.375000	11	1018	-	-	26	4818	-	-	-	-
0.406250	-	-	-	-	26X	4819	-	-	-	-
0.437500	12	1020	-	-	27	4820	-	-	-	-
0.468750	-	-	-	-	27X	4821	-	-	-	-
0.500000	13	1022	-	-	28	4822	-	-	-	-
0.531250	-	-	-	-	-	-	-	-	-	-
0.562500	-	-	14	1624	29	4824	-	-	-	-
0.593750	-	-	-	-	-	-	-	-	-	-
0.625000	-	-	15	1626	30	4826	-	-	-	-
0.656250	-	-	-	-	-	-	-	-	-	-
0.687500	-	-	-	-	31	4828	-	-	-	-
0.718750	-	-	-	-	-	-	-	-	-	-
0.750000	-	-	-	-	32	4830	-	-	-	-
0.781250	-	-	-	-	-	-	-	-	-	-
0.812500	-	-	-	-	33	4832	-	-	-	-
0.843750	-	-	-	-	-	-	-	-	-	-
0.875000	-	-	-	-	34	4834	-	-	-	-
0.906250	-	-	-	-	-	-	-	-	-	-
0.937500	-	-	-	-	35	4836	-	-	-	-
0.968750	-	-	-	-	-	-	-	-	-	-
1.000000	-	-	-	-	36	4838	-	-	-	-
1.062500	-	-	-	-	37	4839	-	-	-	-
1.250000	-	-	-	-	38	4840	-	-	-	-
1.187500	-	-	-	-	39	4841	-	-	-	-
1.250000	-	-	-	-	40	4842	-	-	-	-
1.312500	-	-	-	-	-	-	50	10043	-	-
1.375000	-	-	-	-	-	-	51	10044	-	-
1.437500	-	-	-	-	-	-	52	10045	-	-
1.500000	-	-	-	-	-	-	53	10046	41	20046
1.562500	-	-	-	-	-	-	54	10047	-	-
1.625000	-	-	-	-	-	-	54X	10048	-	-
1.687500	-	-	-	-	-	-	55	10049	-	-
1.750000	-	-	-	-	-	-	56	10050	42	20050
1.812500	-	-	-	-	-	-	57	10051	-	-
1.875000	-	-	-	-	-	-	58	10052	-	-
1.937500	-	-	-	-	-	-	59	10053	-	-
2.000000	-	-	-	-	-	-	-	-	43	20054
2.125000	-	-	-	-	-	-	-	-	44	20055
2.250000	-	-	-	-	-	-	-	-	45	20056
2.375000	-	-	-	-	-	-	-	-	46	20057
2.500000	-	-	-	-	-	-	-	-	47	20058

TABLE A6.5 Part Number Changes

Superseded Number	Replacement Number
MS9461-01 through 9461-04	MS19060-4804 through 19060-4810[A]
MS9461-05 through 9461-11	MS19060-4812 through 19060-4818
MS9461-13 through 9461-31	MS19060-4820 through 19060-4838
MS9461-33	MS19060-4839
MS9461-35	MS19060-4840
MS9461-37	MS19060-4841
MS9461-39	MS19060-4842
MS9461-47	MS19060-4846
MS9461-55	MS19060-4850
MS9461-63	MS19060-4854

[A] Even numbers only.

A7. MS19061 BALLS, BEARING, CARBON STEEL

A7.1 Requirements

A7.1.1 *Material*—Carbon steel conforming to the chemical composition of UNS G10080 through UNS 10220 in accordance with Specification A 108 and as specified in procurement document.

A7.1.2 *Hardness*—Shall be 60 HRC or equivalent. Hardness readings taken on spherical surface are subject to ball hardness corrections for curvatures specified in ABMA-STD-10.

A7.1.3 *Surface Roughness*—Tolerance limits for surface roughness as specified in Table A7.2, and in accordance with ANSI B46.1.

A7.1.4 *Material Density*—Shall be 0.284 lb/in.^{3}

A7.1.5 *Part Number*—Consists of the basic MS number followed by a dash number from Table A7.1 (see Fig. A7.2 for example).

A7.2 Notes

A7.2.1 All dimensions are in inches. Column headings in tolerance tables are in accordance with ABMA-STD-10.

A7.2.2 Dash numbers 20001 through 20021 were formerly dash 1 through 21.

A7.2.3 In the event of a conflict between the text of this specification and the references cited herein, the text of this specification shall take precedence.

A7.2.4 Referenced government (or nongovernment) documents of the issue listed in that issue of the Department of Defense Index of Specifications and Standards (DODISS) specified in the solicitation form a part of this specification to the extent specified herein.

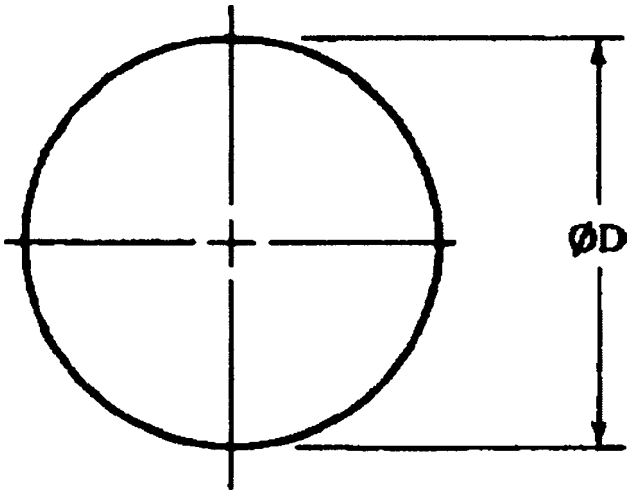
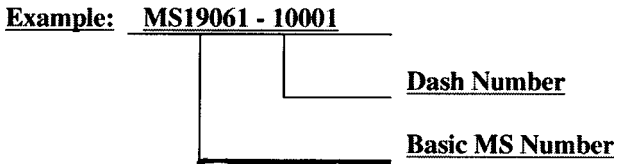


FIG. A7.1



NOTE—MS 19061-10001 indicates a Grade 100 bearing ball of carbon steel with a diameter of 0.062500 in.

FIG. A7.2 Example

TABLE A7.1 Dash Numbers and Dimensions

ØD Nominal Ball Diameter	Basic Diameter[A]	Grade			
		100	200[B]	500	1000
		Dash Number			
1/16	0.062500	10001	20001	50001	100001
3/32	0.093750	10002	20002	50002	100002
1/8	0.125000	10003	20003	50003	100003
5/32	0.156250	10004	20004	50004	100004
3/16	0.187500	10005	20005	50005	100005
7/32	0.218750	10006	20006	50006	100006
1/4	0.250000	10007	20007	50007	100007
9/32	0.281250	10008	20008	50008	100008
5/16	0.312500	10009	20009	50009	100009
11/32	0.343750	10010	20010	50010	100010
3/8	0.375000	10011	20011	50011	100011
13/32	0.406250	10012	20012	50012	100012
7/16	0.437500	10013	20013	50013	100013
15/32	0.468750	10014	20014	50014	100014
1/2	0.500000	10015	20015	50015	100015
9/16	0.562500	10016	20016	50016	100016
5/8	0.625000	10017	20017	50017	100017
11/16	0.687500	10018	20018	50018	100018
3/4	0.750000	10019	20019	50019	100019
7/8	0.875000	10020	20020	50020	100020
1	1.000000	10021	20021	50021	100021

[A] See Table A7.3 for tolerances.
[B] See A7.2.2.

TABLE A7.2 Tolerance by Grade for Individual Balls (Tolerance in millionths of an inch)

Grade	Allowable Ball Diameter Variation, V_D	Allowable Deviation from Spherical Form, W	Maximum Surface Roughness (Arithmetical Average)
100	100	100	5
200	200	200	8
500	500	500	[A]
1000	1000	1000	[A]

[A] Not applicable.

TABLE A7.3 Tolerances by Grade for Lots of Balls (Tolerance in millionths of an inch)

Grade	Allowable Lot Diameter Variation	Basic Diameter Tolerance
100	200	±500
200	400	±1000
500	1000	±2000
1000	2000	±5000

A8. MS19063 BALLS, BEARING, BRONZE

A8.1 Requirements

A8.1.1 *Material*—Bronze conforming to the chemical composition of UNS C46400 (CDA 464) in accordance with Specifications B 21/B 21M, B 124, and B 283 and as specified in procurement document.

A8.1.2 *Hardness*—Shall be as follows:

Basic Diameter	Rockwell Hardness or Equivalent
0.062500 to 0.750000	HRB75-98
0.875000 to 1.250000	HRC15-20

A8.1.3 *Surface Roughness*—Tolerance limits for surface roughness as specified in Table A8.2, and in accordance with ANSI B46.1.

A8.1.4 *Material Density*—Shall be 0.304 lb/in.^{3}

A8.1.5 *Preferred Balls*—Balls with basic diameter of 0.750000 and smaller are preferred. Balls with basic diameter greater than 0.750000 are inactive for new design.

A8.1.6 *Part Number*—The part number shall consist of the basic MS number followed by a dash number from Table A8.1 (see Fig. A8.2 for example).

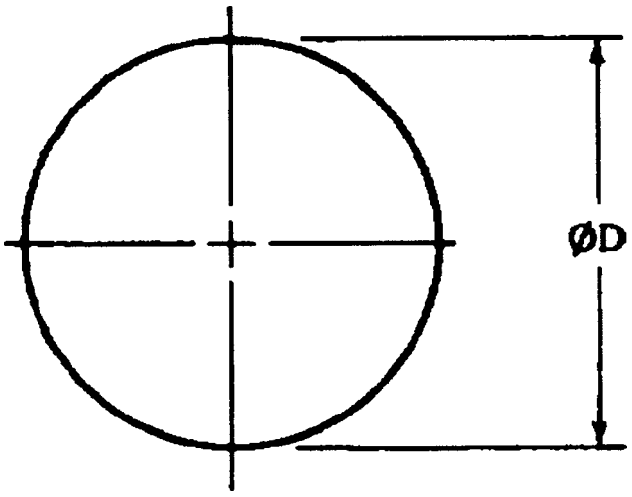
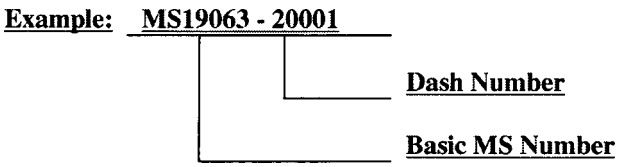


FIG. A8.1



NOTE—MS19063-20001 indicates a Grade 200 bearing ball of bronze with a basic diameter of 0.062500 in.

FIG. A8.2 Example

A8.2 Notes

A8.2.1 All dimensions are in inches. Column headings in tolerance tables are in accordance with ABMA-STD-10.

A8.2.2 Dash numbers 20001 through 20023 were formerly dash 1 through 23.

A8.2.3 In the event of a conflict between the text of this specification and the references cited herein, the text of this specification shall take precedence.

A8.2.4 Referenced government (or nongovernment) documents of the issue listed in that issue of the Department of Defense Index of Specifications and Standards (DODISS) specified in the solicitation form a part of this specification to the extent specified herein.

TABLE A8.1 Dash Numbers and Dimensions

ØD Nominal Ball Diameter	Basic Diameter[A]	Grade		
		200[B]	500	1000
		Dash Number		
1/16	0.062500	20001	50001	100001
3/32	0.093750	20002	50002	100002
1/8	0.125000	20003	50003	100003
5/32	0.156250	20004	50004	100004
3/16	0.187500	20005	50005	100005
7/32	0.218750	20006	50006	100006
1/4	0.250000	20007	50007	100007
9/32	0.281250	20008	50008	100008
5/16	0.312500	20009	50009	100009
11/32	0.343750	20010	50010	100010
3/8	0.375000	20011	50011	100011
13/32	0.406250	20012	50012	100012
7/16	0.437500	20013	50013	100013
15/32	0.468750	20014	50014	100014
1/2	0.500000	20015	50015	100015
9/16	0.562500	20016	50016	100016
5/8	0.625000	20017	50017	100017
11/16	0.687500	20018	50018	100018
3/4	0.750000	20019	50019	100019
7/8	0.875000	20020	[C]	[C]
1	1.000000	20021	[C]	[C]
1 1/8	1.125000	20022	[C]	[C]
1 1/4	1.250000	20023	[C]	[C]

[A] See Table A8.3 for tolerances.
[B] See A8.2.2.
[C] See A8.1.5.

TABLE A8.2 Tolerance by Grade for Individual Balls (Tolerance in millionths of an inch)

Grade	Allowable Ball Diameter Variation, V_D	Allowable Deviation from Spherical Form, W	Maximum Surface Roughness (Arithmetical Average)
200	200	200	8
500	500	500	[A]
1000	1000	1000	[A]

[A] Not applicable.

TABLE A8.3 Tolerances by Grade for Lots of Balls (Tolerances in millionths of an inch)

Grade	Allowable Lot Diameter Variation	Basic Diameter Tolerance
200	400	±1000
500	1000	±2000
1000	2000	±5000

A9. MS19064 BALLS, BEARING, NICKEL-COPPER ALLOY (K-MONEL)

A9.1 Requirements

A9.1.1 *Material*—Nickel-copper alloy (K-Monel) conforming to the chemical composition of UNS N05500 in accordance with QQ-N-286 and as specified in procurement document

A9.1.2 *Hardness*—Shall have a minimum hardness of 27 HRC or equivalent.

A9.1.3 *Surface Roughness*—Tolerance limits for surface roughness as specified in Table A9.2, and in accordance with ANSI B46.1.

A9.1.4 *Material Density*—Shall be 0.306 lb/in.^{3}

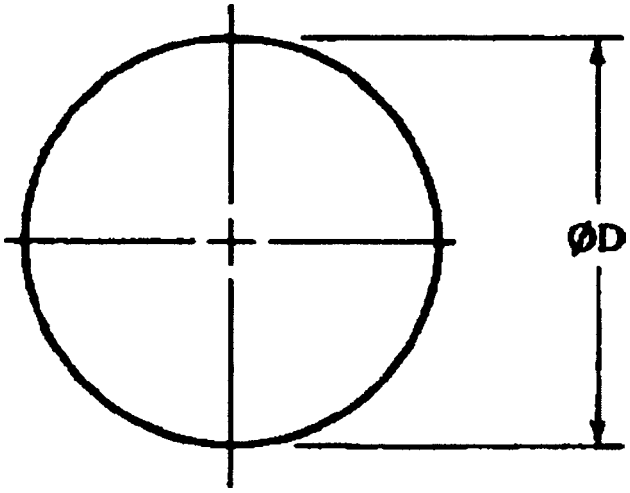


FIG. A9.1

A9.1.5 *Part Number*—The part number shall consist of the basic MS number followed by a dash number from Table A9.1 (see Fig. A9.2for example).

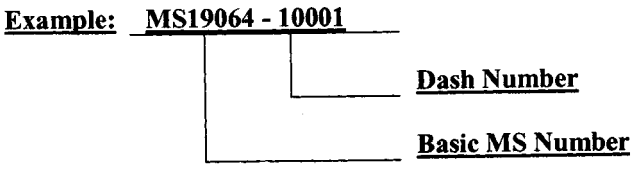
A9.2 Notes

A9.2.1 All dimensions are in inches. Column headings in tolerance tables are in accordance with ABMA-STD-10.

A9.2.2 Dash numbers 20001 through 20024 were formerly dash 1 through 24.

A9.2.3 In the event of a conflict between the text of this specification and the references cited herein, the text of this specification shall take precedence.

A9.2.4 Referenced government (or nongovernment) documents of the issue listed in that issue of the Department of Defense Index of Specifications and Standards (DODISS) specified in the solicitation form a part of this specification to the extent specified herein.



NOTE—MS19064-10001 indicates a Grade 100 nickel-copper alloy (K-Monel) with a basic diameter of 0.062500 in.

FIG. A9.2 Example

TABLE A9.1 Dash Numbers and Dimensions

ØD Nominal Ball Diameter	Basic Diameter[A]	Grade	
		100	200[B]
		Dash Number	
1/16	0.062500	10001	20001
3/32	0.093750	10002	20002
1/8	0.125000	10003	20003
5/32	0.156250	10004	20004
3/16	0.187500	10005	20005
7/32	0.218750	10006	20006
1/4	0.250000	10007	20007
9/32	0.281250	10008	20008
5/16	0.312500	10009	20009
11/32	0.343750	10010	20010
3/8	0.375000	10011	20011
7/16	0.437500	10012	20012
1/2	0.500000	10013	20013
9/16	0.562500	10014	20014
5/8	0.625000	10015	20015
11/16	0.687500	10016	20016
3/4	0.750000	10017	20017
13/16	0.812500	10018	20018
7/8	0.875000	10019	20019
15/16	0.937500	10020	20020
1	1.000000	10021	20021
1 1/8	1.125000	10022	20022
1 1/4	1.250000	10023	20023
1 1/2	1.500000	10024	20024

[A] See Table A9.3 for tolerances.
[B] See A9.2.2.

TABLE A9.2 Tolerance by Grade for Individual Balls (Tolerance in millionths of an inch)

Grade	Allowable Ball Diameter Variation, V_D	Allowable Deviation from Spherical Form, W	Maximum Surface Roughness (Arithmetical Average)
100	100	100	5
200	200	200	8

TABLE A9.3 Tolerances by Grade for Lots of Balls (Tolerances in millionths of an inch)

Grade	Allowable Lot Diameter Variation	Basic Diameter Tolerance
100	200	±500
200	400	±1000

A10. MEASUREMENT OF DEVIATION FROM SPHERICAL FORM

A10.1 General Information

A10.1.1 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.

A10.1.2 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.

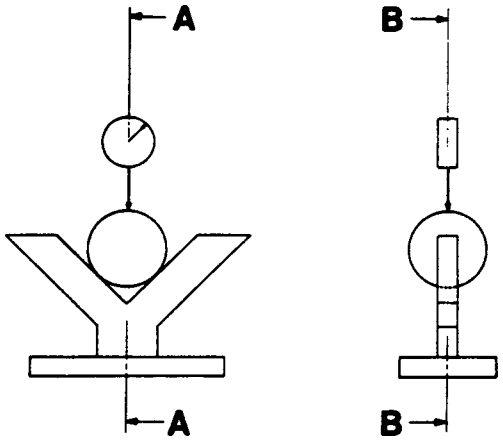
A10.1.3 Since metal balls are essentially quite uniform as to errors of form in any one lot, it is considered sufficient to explore not more than three profiles in three equatorial planes each oriented approximately 90° from the other on individual balls of the sample.

A10.2 Method Using Roundness Measuring Equipment

A10.2.1 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.

A10.3 Method Using Vee Blocks

A10.3.1 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. A10.1 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°.



NOTE—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. A10.1 Vee Block

A10.3.2 The magnification factors for the ratio of the indicator reading to the wave height or deviation from spherical form are shown in Table 8. 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.

A10.3.3 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.