AMERICAN NATIONAL STANDARD

ANSI/AFBMA
Std. 10–
(Revision of ANSI/AFBMA
Std. 10-1983)

AMERICAN NATIONAL STANDARD

AFBMA STANDARD

METAL BALLS

Sponsor
**The Anti-Friction Bearing
Manufacturers Association, Inc.**

Approved June 5, 1989
American National Standards Institute, Inc.

American National Standard

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FOREWORD

(This foreword is not a part of American National Standard 10-1989, Metal Balls.)

This Standard comprises a revision of ANSI/AFBMA Standard 10-1983.

The material in this standard conforms, where possible, to recommendations of the International Standards Organization, Technical Committee 4, Rolling Contact Bearings, in whose work the U.S.A. has actively participated through delegates officially appointed by the American National Standards institute.

Copies of ISO Standards concerning Rolling Contact Bearings (Ball and Roller Bearings) are available from the American National Standards Institute, Inc., 1430 Broadway, New York, N.Y. 10018.

Suggestions for the improvement of this standard gained through experience with its use will be welcomed. These should be sent to the American National Standards Institute, Inc., 1430 Broadway, New York, N.Y. 10018.

The officers of Accredited Standards Committee B3 operating under American National Standards Institute procedures and the organizations represented at the time this standard was submitted are as follows:

S. R. Ahlman, Chairman — G. T. Satterfield, Secretary

American Society of Agricultural Engineers
Anti-Friction Bearing Manufacturers Association
Hydraulic Institute
National Machine Tool Builders Association
U.S. Department of Defense, DISC
U.S. Department of the Navy

AFBMA Standards
for
Ball and Roller Bearings
and Balls

1 — Terminology
4 — Tolerance Definitions and Gaging Practices
7 — Shaft and Housing Fits for Metric Radial Ball and Roller Bearings (Except Tapered Roller Bearings) Conforming to Basic Boundary Plans
8.1 — Ball and Roller Bearing Mounting Accessories, Metric Design
8.2 — Ball and Roller Bearing Mounting Accessories, Inch Design
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24.1 — Thrust Bearings of Ball, Cylindrical Roller and Spherical Roller Types, Metric Design
24.2 — Thrust Bearings of Ball and Cylindrical Roller Types, Inch Design

An AFBMA Standard is intended as a guide to aid the manufacturer, the consumer and the general public. The existence of an AFBMA Standard does not in any respect preclude anyone, whether he has approved the Standard or not from manufacturing, marketing, purchasing, or using products, processes, or procedures not conforming to the standard. AFBMA Standards are subject to revision or withdrawal at any time and users who refer to an AFBMA Standard should satisfy themselves that they have the latest information from the Association.

METAL BALLS

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LIST OF FIGURES

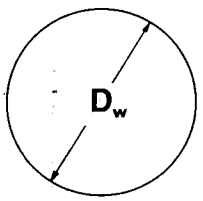
METAL BALLS

BALLS FOR ROLLING CONTACT BEARINGS AND OTHER USES

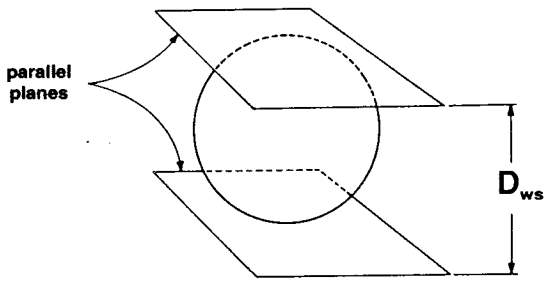
1. SCOPE. This standard establishes the requirements for finished metal balls for rolling contact (ball) bearings and other uses.

2. DEFINITIONS AND SYMBOLS. The following definitions and symbols will apply to terms used in this standard.

2.1 Nominal Ball Diameter, D_w. The diameter value that is used for the purpose of general identification of a ball size; e.g., 1/4", 6mm, etc.

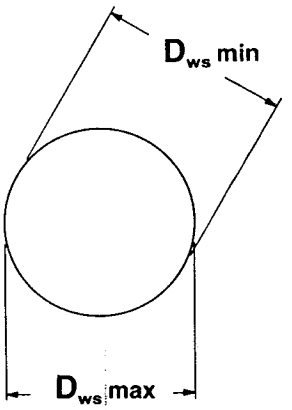


2.2 Single Diameter of a Ball, D_{ws}. The distance between two parallel planes tangent to the surface of the ball.



2.3 Mean Diameter of a Ball, D_{wm}. The arithmetic mean of the largest and the smallest actual single diameters of the ball.

$$D_{wm} = \frac{D_{ws\ max} + D_{ws\ min}}{2}$$

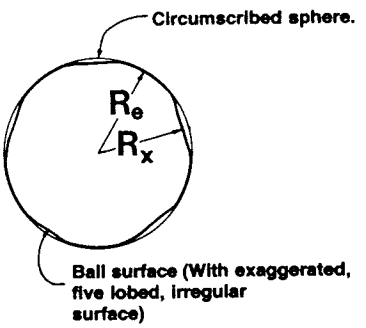


2.4 Ball Diameter Variation, V_{Dws}. The difference between the largest and the smallest actual single diameters of one ball.

$$V_{Dws} = D_{ws\ max} - D_{ws\ min}$$

2.5 Deviation from Spherical Form, $\triangle R_w$. The greatest radial distance in any radial plane between a sphere circumscribed around the ball surface and any point on the ball surface.

$$\triangle R_w = R_e - R_x$$



2.6 Lot. A definite quantity of balls manufactured under conditions which are presumed uniform and which is considered and identified as an entity.

2.7 Lot Mean Diameter, D_{wmL}. (See figure 1) The arithmetic mean of the mean diameter of the largest ball and that of the smallest ball in the lot.

$$D_{wmL} = \frac{D_{wm\ max} + D_{wm\ min}}{2}$$

2.8 Lot Diameter Variation, V_{DwL}. (See figure 1) The difference between the mean diameter of the largest ball and that of the smallest ball in the lot.

$$V_{DwL} = D_{wm\ max} - D_{wm\ min}$$

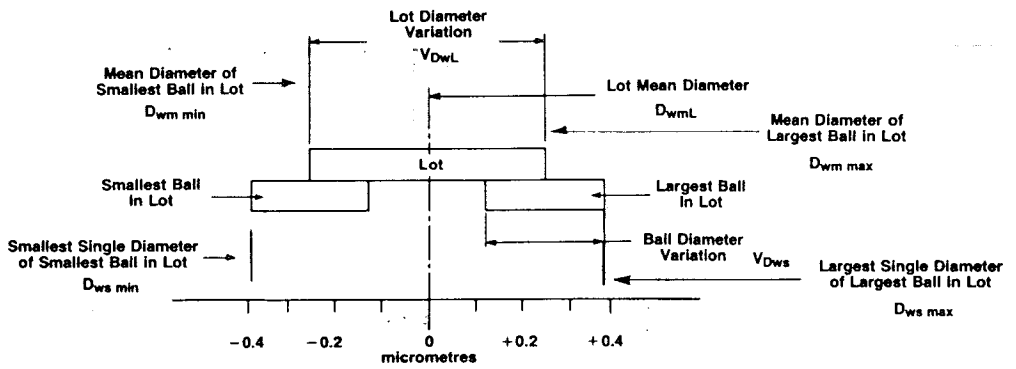


Figure 1, Part 1
VARIATION IN LOT OF GRADE 10 BALLS
(Metric Dimensions)

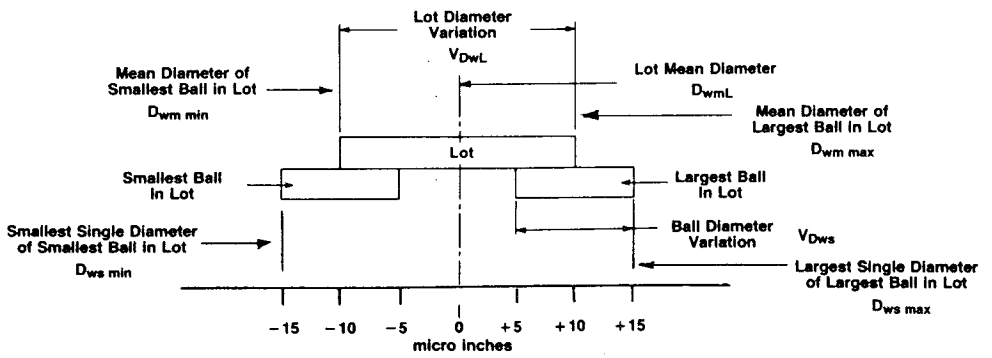


Figure 1, Part 2
VARIATION IN LOT OF GRADE 10 BALLS
(Inch Dimensions)

2.9 Nominal Ball Diameter Tolerance. The maximum allowable deviation of any ball lot mean diameter from the Nominal Ball Diameter.

2.10 Container Marking Increment. The standard unit steps, in micrometres or in millionths of an inch, used to express the Specific Diameter.

2.11 Specific Diameter. The amount by which the lot mean diameter (D_{wmL}) differs from the nominal diameter (D_w), accurate to the container marking increment for that grade (Table 4). The specific diameter should be marked on the unit container.

2.12 Ball Grade. A specific combination of dimensional form and surface roughness tolerances. A ball grade is designated by a grade number.

2.13 Ball Gage, S. (See Figure 2) The prescribed small amount by which the lot mean diameter should differ from nominal diameter, this amount being one of an established series of amounts. A ball gage, in combination with the ball grade and nominal ball diameter, should be considered as the most exact ball size specification to be used by a customer for ordering purposes.

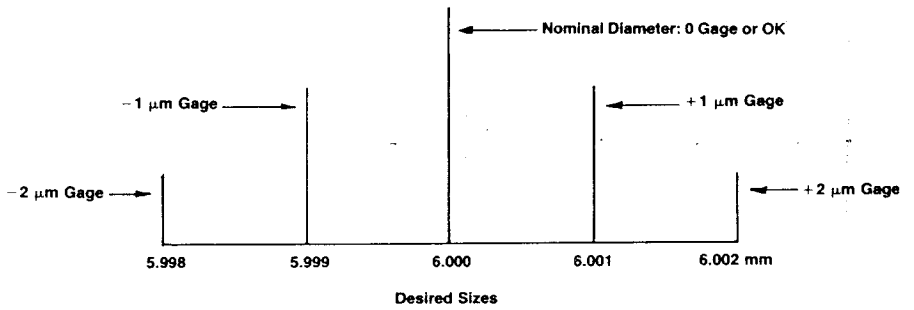


Figure 2, Part 1
BALL GAGE

Illustration based on 6mm Nominal Diameter
(Metric Dimensions)

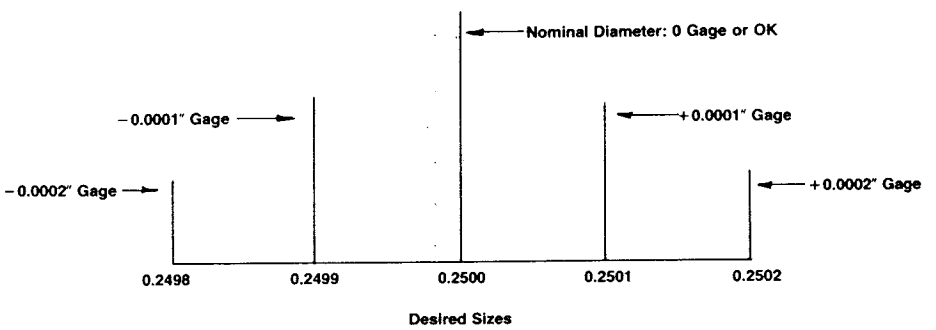


Figure 2, Part 2
BALL GAGE

Illustration Based on 1/4" Nominal Diameter
(Inch Dimensions)

2.14 Ball Gage Deviation, $\triangle S$. (See figure 3) The difference between the lot mean diameter and the sum of the nominal diameter and the ball gage.

$$\triangle S = D_{wmL} - (D_w + S)$$

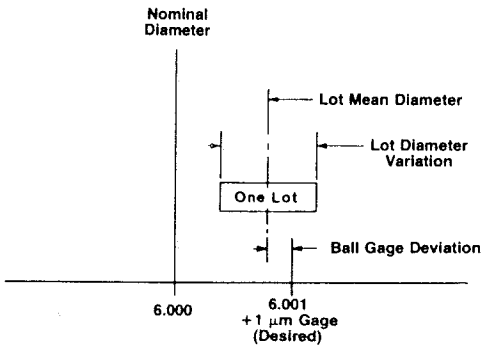


Figure 3, Part 1
BALL GAGE DEVIATION

Illustration based on 6mm Balls ordered as +1 μm Gage
Ball Gage Deviation = −0.75 μm

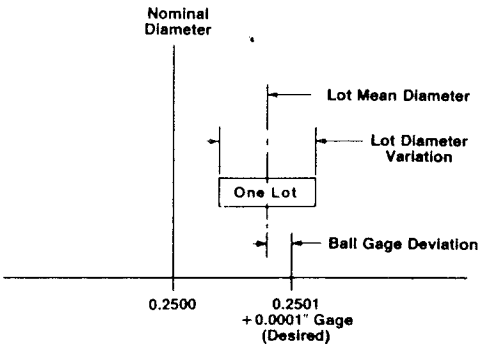


Figure 3, Part 2
BALL GAGE DEVIATION

Illustration based on 1/4" Balls ordered as +0.0001" Gage
Ball Gage Deviation = −30μ inch

2.16 Surface Roughness, R_a. Surface roughness consists of all those irregularities which form surface relief and which are conventionally defined within the area where deviations of form and waviness are eliminated.

2.17 Waviness. The more widely spaced circumferential component of surface texture. (Lacking standardized practices in this field, the specifications and tolerances for waviness are subject to agreement between consumer and manufacturer.)

2.18 Hardness. The measure of resistance to penetration of the ball surface or truncated flat of the ball by a specific indenting shape as determined by specified methods.

2.19 Case Depth. The distance measured radially from the surface of the ball to a point where the hardness becomes the equivalent to R_c 50. This term is applicable to case hardened balls only.

2.20 Passivation. A chemical treatment to remove corrodible surface impurities and to provide a protective film. This term is applicable to corrosion resisting balls only.

3. REQUIREMENTS

3.1 Materials. The materials listed in Table 1 are the most commonly used, however other materials are available from individual suppliers. For typical chemical analysis and a cross reference of other applicable specifications refer to the Unified Numbering System for Metals and Alloys published by the Society of Automotive Engineers, Inc. 400 Commonwealth Drive, Warrendale, Pennsylvania, 15096.

3.2 Hardness. Hardness of balls manufactured of the materials in 3.1 shall be agreed between manufacturer and purchaser. Table 1 shows typical hardness values.

ERRATA SHEET

TABLE 1
COMMONLY USED MATERIAL SPECIFICATION REFERENCE CHART

MATERIAL	COMMON STANDARD	SAE UNIFIED NUMBER	TYPICAL HARDNESS (1)(2)	BALL GRADE	TYPICAL SIZE RANGES FOR VARIOUS GRADES mm	inch
CHROME ALLOY STEEL	AISI/SAE E52100	G – 52986	Rc 60 – 67 (3)(5)	3	0.8 – 25	1/32 – 1
	AISI/SAE E51100	G – 51986		5,10	0.3 – 38	1/64 – 1-1/2
				16,24		
				48,100		
				200	0.8 – 75	1/32 – 2-7/8
				500		
				1000	10 – 115	3/8 – 4-1/2
ALLOY TOOL STEEL	AISI/SAE M50	T – 11350	Rc 60 – 65 (3)(5)	3	0.8 – 12	1/32 – 1/2
				5,10,16		
				24,48	0.8 – 40	1/32 – 1-5/8
	AISI/SAE T1	T – 12001	Rc 60 – 65 (3)(5)			
CORROSION RESISTING HARDENED STEEL	AISI/SAE 440C	S – 44004	Rc 58 – 65 (4)(5)	3,5,10,16	0.3 – 19	1/64 – 3/4
	AISI/SAE 440B	S – 44003	Rc 55 – 62 (4)(5)			
	AISI/SAE 420	S – 42000	Rc 52 min (4)(5)	24	0.8 – 25	1/32 – 1
	AISI/SAE 410	S – 41000	Rb 97 Rc 41 (4)(5)	48	0.8 – 50	1/32 – 2
	AISI/SAE 329	S – 32900	Rc 45 min (4)(5)	100,200	0.8 – 115	1/32 – 4-1/2
CORROSION RESISTING UNHARDENED STEEL	AISI/SAE 302	S – 30200	Rc 25 – 39 (5)(6)	100,200	1.5 – 19	1/16 – 3/4
	AISI/SAE 304	S – 30400	Rc 25 – 39 (5)(6)	500		
	AISI/SAE 305	S – 30500	Rc 25 – 39 (5)(6)			
	AISI/SAE 316	S – 31600	Rc 25 – 39 (5)(6)			
	AISI/SAE 430	S – 43000	Ra 48 – 63 (5)			
CARBON STEEL (7)	AISI/SAE 1008	G – 10080	Rc 60 min (2)	100,200	1.5 – 38	1/16 – 1-1/2
	AISI/SAE 1013	G – 10130	Rc 60 min (2)	500		
	AISI/SAE 1018	G – 10180	Rc 60 min (2)	1000		
	AISI/SAE 1022	G – 10220	Rc 60 min (2)			
SILICON MOLYBDENUM STEEL	AISI/SAE S2	T – 41902	Rc 52 – 60 (3)	200	6.5 – 28	1/4 – 1-1/8
ALUMINUM	AA – 2017	A – 92017	Rb 54 – 72	200	1.5 – 25	1/16 – 1
ALUMINUM BRONZE	CDA – 624	C – 62400	Rb 94 – 98	200	20 – 100	13/16 – 4
	CDA – 630	C – 63000	Rb 94 – 98			
BRASS	CDA – 260	C – 26000	Rb 75 – 87	100,200	1.5 – 19	1/16 – 3/4
				500		
				1000		
BRONZE	CDA – 464	C – 46400	Rb 75 – 98	200,500	1.5 – 19	1/16 – 3/4
				1000		
MONEL 400	AMS – 4730	N – 04400	Rb 85 – 95	100,200	1.5 – 19	1/16 – 3/4
				500		
MONEL K – 500	QA – N – 286	N – 05500	Rc 27 Min	100	1.5 – 19	1/16 – 3/4
				200	1.5 – 45	1/16 – 1-11/16
TUNGSTEN CARBIDE	JIC CARBIDE CLASSIFICATION	NOT APPLICABLE	Ra 84 – 91.5	5	1.2 – 12	3/64 – 1/2
				10	1.2 – 19	3/64 – 3/4
				16	1.2 – 25	3/64 – 1
				24	1.2 – 32	3/64 – 1-1/4

FOOTNOTES:

1. Rockwell hardness tests shall be conducted on parallel flats in accordance with ASTM Standard E-18 unless otherwise specified.
2. Hardness readings taken on spherical surfaces are subject to the corrections shown in Table 9, Appendix B3. Hardness readings for carbon steel balls smaller than 6 mm (1/8 inch) shall be taken by the microhardness method or as agreed between manufacturer and purchaser.
3. Hardness of balls in any one lot shall be within 3 points on Rockwell C scale.
4. Hardness of balls in any one lot shall be within 4 points on Rockwell C scale.
5. Where microhardness is used see Appendix B1. When microhardness method is used the Rockwell hardness values given above are converted to DPH in accordance with ASTM Standard E-140 "Standard Hardness Conversion Tables for Metals."
6. Annealed hardness of Rb 75 – 90 is available when specified.
7. Choice of carbon steels shown to be at ball manufacturer's option.

TABLE 1
COMMONLY USED MATERIAL SPECIFICATION REFERENCE CHART

MATERIAL	COMMON STANDARD	SAE UNIFIED NUMBER	TYPICAL HARDNESS (1)(2)	BALL GRADE	TYPICAL SIZE RANGES FOR VARIOUS GRADES mm	inch
CHROME ALLOY STEEL	AISI/SAE E52100 AISI/SAE E51100	G – 52986 G – 51986	Rc 60 – 67 (3)(5)	3 5,10 16,24 48,100 200 500 1000	0.8 – 25 0.3 – 38 0.8 – 75 10 – 115	1/32 – 1 1/64 – 1-1/2 1/32 – 2-7/8 3/8 – 4-1/2
ALLOY TOOL STEEL	AISI/SAE M50 AISI/SAE T1	T – 11350 T – 12001	Rc 60 – 65 (3)(5) Rc 60 – 65 (3)(5)	3 5,10,16 24,48	0.8 – 12 0.8 – 40	1/32 – 1/2 1/32 – 1-5/8
CORROSION RESISTING HARDENED STEEL	AISI/SAE 440C AISI/SAE 440B AISI/SAE 420 AISI/SAE 410 AISI/SAE 329	S – 44004 S – 44003 S – 42000 S – 41000 S – 32900	Rc 58 – 65 (4)(5) Rc 55 – 62 (4)(5) Rc 52 min (4)(5) Rb 97 Rc 41 (4)(5) Rc 45 min (4)(5)	 3,5,10,16 24 48 100,200	 0.3 – 19 0.8 – 25 0.8 – 50 0.8 – 115	 1/64 – 3/4 1/32 – 1 1/32 – 2 1/32 – 4-1/2
CORROSION RESISTING UNHARDENED STEEL	AISI/SAE 302 AISI/SAE 304 AISI/SAE 305 AISI/SAE 316 AISI/SAE 430	S – 30200 S – 30400 S – 30500 S – 31600 S – 43000	Rc 25 – 39 (5)(6) Rc 25 – 39 (5)(6) Rc 25 – 39 (5)(6) Rc 25 – 39 (5)(6) Ra 48 – 63 (5)	 100,200 500	 1.5 – 19	 1/16 – 3/4
CARBON STEEL (7)	AISI/SAE 1008 AISI/SAE 1013 AISI/SAE 1018 AISI/SAE 1022	G – 10080 G – 10130 G – 10180 G – 10220	Rc 60 min (2) Rc 60 min (2) Rc 60 min (2) Rc 60 min (2)	 100,200 500 1000	 1.5 – 38	 1/16 – 1-1/2
SILICON MOLYBDENUM STEEL	AISI/SAE S2	T – 41902	Rc 52 – 60 (3)	200	6.5 – 28	1/4 – 1-1/8
ALUMINUM	AA – 2017	A – 92017	Rb 54 – 72	200	1.5 – 25	1/16 – 1
ALUMINUM BRONZE	CDA – 624 CDA – 630	C – 62400 C – 63000	Rb 94 – 98 Rb 94 – 98	200	20 – 100	13/16 – 4
BRASS	CDA – 260	C – 26000	Rb 75 – 87	100,200 500 1000	1.5 – 19	1/16 – 3/4
BRONZE	CDA – 464	C – 46400	Rb 75 – 98	200,500 1000	1.5 – 19	1/16 – 3/4
MONEL 400	AMS – 4730	N – 04400	Rb 85 – 95	100,200 500	1.5 – 19	1/16 – 3/4
MONEL K – 500	QA – N – 286	N – 05500	Rc 27 Min	100 200	1.5 – 19 1.5 – 45	1/16 – 3/4 1/16 – 1-11/16
TUNGSTEN CARBIDE	JIC CARBIDE CLASSIFICATION	NOT APPLICABLE	Ra 84 – 91.5	5 10 16 24	1.2 – 12 1.2 – 19 1.2 – 25 1.2 – 32	3/64 – 1/2 3/64 – 3/4 3/64 – 1 3/64 – 1-1/4

FOOTNOTES:

1. Rockwell hardness tests shall be conducted on parallel flats in accordance with ASTM Standard E-18 unless otherwise specified.
2. Hardness readings taken on spherical surfaces are subject to the corrections shown in Table 9, Appendix B3. Hardness readings for carbon steel balls smaller than 6 mm (1/8 inch) shall be taken by the microhardness method or as agreed between manufacturer and purchaser.
3. Hardness of balls in any one lot shall be within 3 points on Rockwell C scale.
4. Hardness of balls in any one lot shall be within 4 points on Rockwell C scale.
5. Where microhardness is used see Appendix B1. When microhardness method is used the Rockwell hardness values given above are converted to DPH in accordance with ASTM Standard E-140 "Standard Hardness Conversion Tables for Metals."
6. Annealed hardness of Rb 75 – 90 is available when specified.
7. Choice of carbon steels shown to be at ball manufacturer's option.

3.3 Case Depth. Carbon steel balls shall be processed to provide the minimum case depths specified in Table 2.

3.4 Quality of Surface. Surface appearance of balls manufactured from the materials specified in 3.1 shall meet the requirement specified below.

3.4.1 Chrome Alloy, Corrosion Resistant Hardened, and Alloy Tool Steel Balls. These shall be free from cracks, pits, rust and indications of soft spots visible without magnification, except that grades 3, 5 and 10 in sizes 3mm (1/8") diameter and smaller may be inspected by microscopic examination not exceeding 10 power.

3.4.2 Corrosion Resisting Unhardened Steel Balls. These shall be free from cracks, pits, and rust when examined visually without magnification.

3.4.3 Carbon Steel Balls. These shall be free from rust and indications of soft spots when examined visually without magnification.

3.4.4 Silicon Molybdenum Steel Balls. These shall be free from cracks, pits, rust, decarburization and soft spots when examined visually without magnification.

3.4.5 Non-Ferrous Metal Balls. Balls of non-ferrous alloys, aluminum, aluminum bronze, brass, bronze, Monel metal and K-Monel metal shall be free from cracks when examined visually without magnification.

3.4.6 Tungsten Carbide Balls. These shall be free from cracks when examined visually without magnification.

3.5 Geometric Quality. Tolerances for size, form, and surface roughness are listed in Tables 3 and 4 for the various grades.

TABLE 2, Part 1 (METRIC)
CASE DEPTH REQUIREMENTS FOR CARBON STEEL BALLS

Dimensions in millimetres

D_w		MINIMUM CASE (1) DEPTH
at least	but not	
0.3	1.5	0.1
1.5	2.0	0.4
2.0	3.0	0.5
3.0	4.5	0.6
4.5	5.5	0.8
5.5	6.5	0.9
6.5	9.5	1.1
9.5	11.0	1.4
11.0	12.5	1.7
12.5	14.0	1.8
14.0	19.0	1.9
19.0	38.0	2.0

(1) Case Depth shall be determined in accordance with Appendix B2—Recommended Procedure for the Measurement of Case Depth in Carburized and Hardened Carbon Steel Balls.

TABLE 2, Part 2 (INCH)
CASE DEPTH REQUIREMENTS FOR CARBON STEEL BALLS

Dimensions in inches

D_w		MINIMUM CASE (1) DEPTH
at least	but not	
1/64	1/16	.005
1/16	3/32	.015
3/32	1/8	.020
1/8	3/16	.025
3/16	7/32	.030
7/32	1/4	.035
1/4	3/8	.045
3/8	7/16	.055
7/16	1/2	.065
1/2	9/16	.070
9/16	3/4	.075
3/4	1-1/2	.080

(1) Case Depth shall be determined in accordance with Appendix B2—Recommended Procedure for the Measurement of Case Depth in Carburized and Hardened Carbon Steel Balls.

ERRATA SHEET
for Standard 10

The following errors have been found and are corrected as follows:

(1) In Table 3 on page 7, the inch table should show tolerances in micro inches rather than micrometres.

(2) In Table 5 on page 10, the Nominal Ball Diameter 19 was omitted in the mm column and should be placed across from 19.000 00 in the mm column for Diameter.

TABLE 3, Part 1 (METRIC)
TOLERANCES BY GRADE
FOR
INDIVIDUAL BALLS

Tolerances in micrometres

BALL GRADE	ALLOWABLE BALL DIAMETER VARIATION V_{Dws}	ALLOWABLE DEVIATION FROM SPHERICAL FORM $\triangle R_w$	MAXIMUM SURFACE ROUGHNESS ARITHMETIC AVERAGE R_a
3	0.08	0.08	0.012
5	0.13	0.13	0.02
10	0.25	0.25	0.025
16	0.4	0.4	0.025
24	0.6	0.6	0.05
48	1.2	1.2	0.08
100	2.5	2.5	0.125
200	5	5	0.2
500	13	13	*
1000	25	25	*

*Not applicable

TABLE 3, Part 2 (INCH)
TOLERANCES BY GRADE
FOR
INDIVIDUAL BALLS

Tolerances in micro~~metres~~ INCHES

BALL GRADE	ALLOWABLE BALL DIAMETER VARIATION V_{Dws}	ALLOWABLE DEVIATION FROM SPHERICAL FORM $\triangle R_w$	MAXIMUM SURFACE ROUGHNESS ARITHMETIC AVERAGE R_a
3	3	3	0.5
5	5	5	0.8
10	10	10	1
16	16	16	1
24	24	24	2
48	48	48	3
100	100	100	5
200	200	200	8
500	500	500	*
1000	1000	1000	*

*Not applicable

TABLE 4, Part 1 (METRIC)
TOLERANCES BY GRADE
FOR
LOTS OF BALLS

Tolerances in micrometres

BALL GRADE DIAMETER	ALLOWABLE LOT DIAMETER VARIATION V_{DwL}	NOMINAL BALL DEVIATION TOLERANCE	ALLOWABLE BALL GAGE MARKING $\triangle S$ High	$\triangle S$ Low	CONTAINER INCREMENT
3	0.13	*	+0.75	−0.75	0.25
5	0.25	*	+1.25	−1	0.25
10	0.5	*	+1.25	−1	0.25
16	0.8	*	+1.25	−1	0.25
24	1.2	*	+2.5	−2.5	0.25
48	2.4	*	*		1.25
100	5	±12.5	*		*
200	10	±25	*		*
500	25	±50	*		*
1000	50	±125	*		*

*Not applicable.

TABLE 4, Part 2 (INCH)
TOLERANCES BY GRADE
FOR
LOTS OF BALLS

Tolerances in micro inches

BALL GRADE	ALLOWABLE LOT DIAMETER VARIATION V_{DwL}	NOMINAL BALL DIAMETER TOLERANCE	ALLOWABLE BALL GAGE DEVIATION $\triangle S$ High	$\triangle S$ Low	CONTAINER MARKING INCREMENT
3	5	*	+30	−30	10
5	10	*	+50	−40	10
10	20	*	+50	−40	10
16	32	*	+50	−40	10
24	48	*	+100	−100	10
48	96	*	*		50
100	200	±500	*		*
200	400	±1000	*		*
500	1000	±2000	*		*
1000	2000	±5000	*		*

*Not applicable.

3.5.1 Master Balls and Comparative Measurements. All measurements for size and size variation shall be based on comparative measurements made relative to master balls, the sizes of which are traceable to the National Bureau of Standards. The size of master balls shall be corrected to zero gage pressure and to a temperature of 20°C (68°)

3.5.1.1 Master Balls. Master balls shall be made of chrome steel or tungsten carbide, Rc 64 hardness or higher. For ball sizes 1.5 mm (1/16″) diameter and smaller master balls may be of 440C steel, Rc 60 hardness or higher. The permissible diameter variation shall be 1/10th of the allowable diameter variation per ball for the grade of balls to be measured, or 0.05 micrometres (2 micro-inches), whichever is larger. The calibrated diameter of the master ball is defined as the mean of at least twenty (20) randomly oriented diameters and must be known to an accuracy equal to plus or minus the magnitude of the permissible diameter variation of the master ball or plus or minus 0.08 micrometres (3 micro-inches), whichever is larger.

3.5.1.2 Gage Pressures. Gage contact materials shall have at least the same hardness as the ball measured. Gage contacts must be flat, or if convex, have a contact radius not less than 3 mm or 0.125″. Maximum measuring pressures at gage contacts shall not exceed 1.1 Newtons (4 ounces) for balls up to and including 25 mm (1″) nominal diameter and not exceed 2.2 Newtons (8 ounces) for larger nominal diameter, including ball weight if significant.

3.5.1.3 Size Corrections for Balls of Other Materials. For production measurements of balls of materials other than that of the master ball, corrections shall be made to zero gage pressure and to a temperature of 20°C (68°).

3.6 Corrosion Resistance. Corrosion resistant steel balls, hardened and unhardened of materials specified in Table 1 shall be subject to the following requirements.

3.6.1 Passivation. Balls shall be passivation surface treated to remove all traces of corrodible impurities.

3.6.2 Corrosion Test. Finished balls shall be capable of passing the following corrosion test.

A sample of balls shall be immersed in distilled water at 38°C ± 3°C (100°F ± 5°F) for a period of one hour, followed by air drying 38°C ± 3°C (100°F ± 5°F) for a period of one hour. This cycle shall be repeated for a total period of 24 hours.
At the end of the 24 hour period, the sample balls shall be examined for surface corrosion. No ball in the sample may exhibit corrosion visible under 10 power magnification.

4. STANDARD AND PREFERRED SIZES BY MATERIALS AND GRADES

4.1 Standard Nominal Sizes. Table 5 lists standard nominal diameter sizes in the size range 0.3 - 115 mm (1/64 - 4-1/2 inches).

4.2 Preferred Nominal Size Ranges by Materials and Grades. Table 1 lists preferred grades and nominal size ranges by specified materials.

ERRATA SHEET
for Standard 10

The following errors have been found and are corrected as follows:

(1) In Table 3 on page 7, the inch table should show tolerances in micro inches rather than micrometres.

(2) In Table 5 on page 10, the Nominal Ball Diameter 19 was omitted in the mm column and should be placed across from 19.000 00 in the mm column for Diameter.

TABLE 5
PREFERRED BALL SIZES

Nominal ball diameter D_w		Diameter	
mm	in	mm	in
0.3		0.300 00	0.011 810
	1/64	0.396 88	0.015 625
0.4		0.400 00	0.015 750
0.5		0.500 00	0.019 680
	0.020	0.508 00	0.020 000
0.6		0.600 00	0.023 620
	0.025	0.635 00	0.025 000
0.7		0.700 00	0.027 560
	1/32	0.793 75	0.031 250
0.8		0.800 00	0.031 496
1		1.000 00	0.039 370
	3/64	1.190 63	0.046 875
1.2		1.200 00	0.047 240
1.5		1.500 00	0.059 060
	1/16	1.587 50	0.062 500
	5/64	1.984 38	0.078 125
2		2.000 00	0.078 740
	3/32	2.381 25	0.093 750
2.5		2.500.00	0.098 420
	7/64	2.778 00	0.109 375
3		3.000 00	0.118 110
	1/8	3.175 00	0.125 000
3.5		3.500 00	0.137 800
	9/64	3.571 87	0.140 625
	5/32	3.968 75	0.156 250
4		4.000 00	0.157 480
	11/64	4.365 63	0.171 875
4.5		4.500 00	0.177 160
	3/16	4.762 50	0.187 500
5		5.000 00	0.196 850
5.5		5.500 00	0.216 540
	7/32	5.556 25	0.218 750
	15/64	5.953 12	0.234 375
6		6.000 00	0.236 220
	1/4	6.350 00	0.250 000
6.5		6.500 00	0.255 900
	17/64	6.746 88	0.265 625
7		7.000 00	0.275 590
	9/32	7.143 75	0.281 250
7.5		7.500 00	0.295 280
	19/64	7.540 63	0.296 875
	5/16	7.937 50	0.312 500
8		8.000 00	0.314 960
8.5		8.500 00	0.334 640
	11/32	8.731 25	0.343 750

Nominal ball diameter D_w		Diameter	
mm	in	mm	in
9		9.000 00	0.354 330
	23/64	9.128 12	0.359 375
	3/8	9.525 00	0.375 000
	25/64	9.921 87	0.390 625
10		10.000 00	0.393 700
	13/32	10.318 75	0.406 250
11		11.000 00	0.433 070
	7/16	11.112 50	0.437 500
11.5		11.500 00	0.452 756
	29/64	11.509 38	0.453 125
	15/32	11.906 25	0.468 750
12		12.000 00	0.472 440
	31/64	12.303 12	0.484 375
	1/2	12.700 00	0.500 000
13		13.000 00	0.511 810
	17/32	13.493 75	0.531 250
14		14.000 00	0.551 180
	9/16	14.287 50	0.562 500
15		15.000 00	0.590 550
	19/32	15.081 25	0.593 750
	5/8	15.875 00	0.625 000
16		16.000 00	0.629 920
	21/32	16.668 75	0.656 250
17		17.000 00	0.669 290
	11/16	17.462 50	0.687 500
18		18.000 00	0.708 660
	23/32	18.256 25	0.718 750
19		19.000 00	0.748 030
	3/4	19.050 00	0.750 000
	25/32	19.843 75	0.781 250
20		20.000 00	0.787 400
	13/16	20.637 50	0.812 500
21		21.000 00	0.826 770
	27/32	21.431 25	0.843 750
22		22.000 00	0.866 140
	7/8	22.225 00	0.875 000
23		23.000 00	0.905 510
	29/32	23.018 75	0.906 250
	15/16	23.812 50	0.937 500
24		24.000 00	0.944 880
	31/32	24.606 25	0.968 750
25		25.000 00	0.984 250
	1	25.400 00	1.000 000
26		26.000 00	1.023 620

TABLE 5
PREFERRED BALL SIZES

Nominal ball diameter D_w		Diameter	
mm	in	mm	in
	1-1/16	26.987 50	1.062 500
28		28.000 00	1.102 360
	1-1/8	28.575 00	1.125 000
30		30.000 00	1.181 100
	1-3/16	30.162 50	1.187 500
	1-1/4	31.750 00	1.250 000
32		32.000 00	1.259 840
	1-5/16	33.337 50	1.312 500
34		34.000 00	1.338 580
	1-3/8	34.925 00	1.375 000
35		35.000 00	1.496 060
36		36.000 00	1.417 320
	1-7/16	36.512 50	1.437 500
38		38.000 00	1.496 060
	1-1/2	38.100 00	1.500 000
	1-9/16	39.687 50	1.562 500
40		40.000 00	1.574 800
	1-5/8	41.275 00	1.625 000
	1-11/16	42.862 50	1.687 500
	1-3/4	44.450 00	1.750 000
45		45.000 00	1.771 650
	1-13/16	46.037 50	1.812 500
	1-7/8	47.625 00	1.875 000
	1-15/16	49.212 50	1.937 500
50		50.000 00	1.968 500
	2	50.800 00	2.000 000
	2-1/8	53.975 00	2.125 000
55		55.000 00	2.165 354
	2-1/4	57.150 00	2.250 000
60		60.000 00	2.559 055
	2-3/8	60.325 00	2.375 000
	2-1/2	63.500 00	2.500 000
65		65.000 00	2.559 055
	2-5/8	66.675 00	2.625 000
	2-3/4	69.850 00	2.750 000
	2-7/8	73.025 00	2.875 000
	3	76.200 00	3.000 000
	3-1/8	79.375 00	3.125 000
	3-1/4	82.550 00	3.250 000
	3-3/8	85.725 00	3.375 000
	3-1/2	88.900 00	3.500 000
	3-5/8	92.075 00	3.625 000
	3-3/4	95.250 00	3.750 000
	3-7/8	98.425 00	3.875 000
	4	101.600 00	4.000 000
	4-1/8	104.775 00	4.125 000
	4-1/4	107.950 00	4.250 000
	4-3/8	111.125 00	4.375 000
	4-1/2	114.300 00	4.500 000

5. QUALITY ASSURANCE PROVISIONS

5.1 Grades 3-24 Inclusive. Unless otherwise required, product shall be capable of passing acceptance inspection in accordance with MIL-STD-105, as required in Specification MIL-B-1083, as stipulated in Table 6.

TABLE 6
APPLICABLE INSPECTION LEVELS AND AQL

ITEM	REQUIREMENTS	INSPECTION LEVEL	AQL
1	Quality of Geometry	S4 (1)	0.4%
2	Quality of Surface	S4	0.4%
3	Surface Roughness, Hardness, Surface Corrosion, Decarburization	Use sample size shown below and accept lot if all test results are within specifications	
		Number of Balls	**Sample Size**
		0–35,000	5
		35,001 and over	8

(1) Minimum sample size of 32 balls shall apply only to lots of 1200 or more pieces. For lots of less than 1200 sample size shall be set by agreement between manufacturer and purchaser.

5.2 Grades 48-1000. Quality assurance provisions for these grades are not standardized and shall be subject to agreement between manufacturer and purchaser.

5.3 Methods of Inspection. All inspection operations shall be carried out in an environment suitable for the grades furnished, by skilled personnel, and with equipment of accuracy and magnification suitable for the various operations required by this standard, as enumerated in 3, and in accordance with Table 6.

5.3.1 Ball Diameter Variation. Measure and record the largest and the smallest diameter of each ball in the sample and compute the diameter variation of each ball. Record the largest variation found on any one ball. Compute in accordance with 2.4.

5.3.2 Lot Diameter Variation. Using the information obtained from 5.3.1, compute the mean diameter of the largest ball in the sample and that of the smallest ball. Compute and record the lot diameter variation in accordance with 2.8.

5.3.3 Deviation from Ball Gage. Using the information obtained from 5.3.2, compute the lot mean diameter in accordance with 2.7. Compute the deviation from ball gage in accordance with 2.14 using the nominal diameter D_w and the ball gage S as ordered.

5.3.4 Deviation from Spherical Form. Pending further standardization of methods, the use of either of the methods specified in Appendix A is permissible.

5.3.5 Surface Roughness. For those grades where surface roughness requirements apply, measurements shall be made on equipment meeting the requirements of, and in accordance with ANSI Standard B46.1.

5.3.6 Surface Appearance. Examination shall be conducted in accordance with the requirements of 3.4 for the material specified.

5.3.7 Hardness. Rockwell Hardness measurements shall be made in accordance with ASTM Standard E-18. Hardness of balls up to 2.5 mm (3/32″) shall be subjected to microhardness testing, recommendations for which are given in Appendix B1. Balls from 2.5 mm (3/32″) to 5 mm (3/16″) shall be subjected to microhardness testing or shall be checked on parallel flats on the HR30N scale and converted to hardness R_c. Hardness of balls from 5 mm (3/16″) and larger shall be tested on the HR_c scale. Hardness of carbon steel balls 3 mm (1/8″) to 6 mm (1/4″) may be taken using a HR30N scale. Hardness of carbon steel balls 6 mm (1/4″) and larger using a HRC Scale are subject to the correction factors in Table 10, Appendix B3. Hardness of corrosion resisting unhardened steel, aluminum, aluminum bronze, brass, bronze, Monel, and K-Monel balls 3 mm (1/8″) and larger may be taken using a superficial hardness test.

5.3.8 Surface Corrosion. The appropriate visual examination for balls of the various materials as stated in 3.4 shall be conducted using no magnification or microscopic inspection as there stated.

5.3.9 Porosity of Tungsten Carbide Balls. Inspection for porosity of balls of this material shall be conducted in accordance with ASTM Standard B-276.

6. ORDERING SPECIFICATIONS AND PACKAGE MARKING

6.1 Ordering Specifications. Unless otherwise agreed between producer and user, orders for balls shall provide the following information:

Quantity
Material
Nominal Ball Diameter
Grade
Ball Gage (if applicable)

6.1.1 Ball Gage Sign. Since the ball gage is the desired amount by which the lot mean diameter should differ from the nominal diameter, it must be expressed with the proper algebraic sign (+ or −).

Ball gage of 0 is commonly referred to as "OK."

6.1.2 Example of Order. The following example illustrates usual ordering specifications:

Metric

80,000 Pieces
Chrome Alloy Steel
6 mm Nominal Diameter
Grade 16
Ball Gage to be -4 μm

Inch

80,000 Pieces
Chrome Alloy Steel
1/4" Nominal Diameter
Grade 16
Ball Gage to be -0.0002"

Table 7 lists preferred ball gages normally specified.

TABLE 7
PREFERRED BALL GAGES FOR GRADES 3-200
Part 1, METRIC

micrometres units

GRADE	BALL GAGES															
	Minus Gages								OK	Plus Gages						
3,5	−8	−7	−6	−5	−4	−3	−2	−1	0	+1	+2	+3	+4	+5	+6	+7	+8
10,16				−10	−8	−6	−4	−2	0	+2	+4	+6	+8	+10			
24			−12	−10	−8	−6	−4	−2	0	+2	+4	+6	+8	+10	+12		
48					−16	−12	−8	−4	0	+4	+8	+12	+16				
100									0								
200									0								

TABLE 7
PREFERRED BALL GAGES FOR GRADES 3-200
Part 2, INCH

0.0001" (100 micro-inch) units

GRADE	BALL GAGES									
	Minus Gages				OK	Plus Gages				
3,5			−3	−2	−1	0	+1	+2	+3	
10,16		−4	−3	−2	−1	0	+1	+2	+3	+4
24	−5	−4	−3	−2	−1	0	+1	+2	+3	+4	+5
48			−6	−4	−2	0	+2	+4	+6	
100						0				
200						0				

6.2 Package Marking. The ball manufacturer or supplier shall identify packages with the information provided on the order as covered in 6.1, and additionally the specific diameter of the contents shall be stated.

6.2.1 Example of Package Marked in Metric Units. The 6 mm balls supplied to the order illustrated in 6.1.2 would, if perfect size, be D_{wmL} = 5.996 00 mm. In Grade 16 these balls would be acceptable with a D_{wmL} from 5.995 00 to 5.997 25. If they actually measured 5.996 27 mm (which would be rounded off to 5.996 25 mm) each package would be marked:

5,000 balls
Chrome Alloy Steel
6 mm Nominal Diameter
Grade 16
−4 μm Ball Gage
−3.75 μm Specific Diameter

6.2.2 Example of Package Marking in Inch Units. The 1/4″ balls supplied to the order illustrated in 6.1.2 would if perfect size, be D_{wmL} = 0.249 800″. In Grade 16 these balls would be acceptable with D_{wmL} from 0.249 760 to 0.249 850. If they actually measured 0.249 823 (which would be rounded off to 0.249 820) each package would be marked:

5,000 Balls
Chrome Alloy Steel
1/4″ Nominal Diameter
Grade 16
−0.0002 Inch Ball Gage
−0.000 180 Inch Specific Diameter

APPENDIX A

MEASUREMENT OF DEVIATION FROM SPHERICAL FORM

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.

Because of the wide range of nominal diameters, from 0.3 mm to 4 1/2", 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.

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.

A1.1 Method Using Roundness Measuring Equipment

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, 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 micrometres or one (1) microinch. Extreme care must be taken in the interpretation of the polar charts. American National Standard B89.3.1 defines several methods of chart interpretation. For finished metal balls, the minimum circumscribed circle (MCC) method is considered adequate.

A1.2 Method Using Vee Blocks

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. Figure 4 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°.

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.

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.

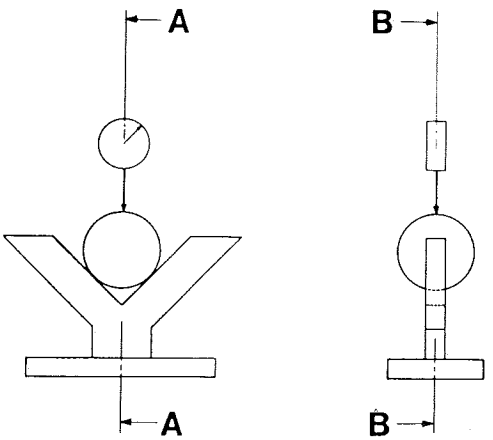


Figure 4
VEE BLOCK

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.

TABLE 8
MAGNIFICATION FACTOR
(Gage Indicator Reading/Deviation From Spherical Form)

Vee	Number of Waves									
Angle	3	5	7	9	11	13	15	17	19	21
90°	2	2	*	*	2	2	*	*	2	2
120°	1	2	2	1	*	*	1	2	2	1

*Not desirable.

APPENDIX B1

Recommended Procedure for Microhardness Testing of Small Balls

B1.1 Scope. This procedure is recommended for use on through hardened balls, smaller than 5 mm (3/16″) in nominal diameter.

B1.2 Sample Size. The sample size for this type of test shall be in accordance with Table 6. Item 3 of this standard.

B1.3 Specimen Preparation. The balls shall be mounted in a suitable plastic material such as Bakelite, Styrene, filled or unfilled Epoxy, etc. Mounted balls shall be ground and polished, using metallographic techniques, (ASM Metals Handbook) so as to present a cross section approximately 1/4 of the ball radius from the ball center, or approximately 0.25 mm (0.010″) from the ball center, whichever is the lesser. See illustration below.

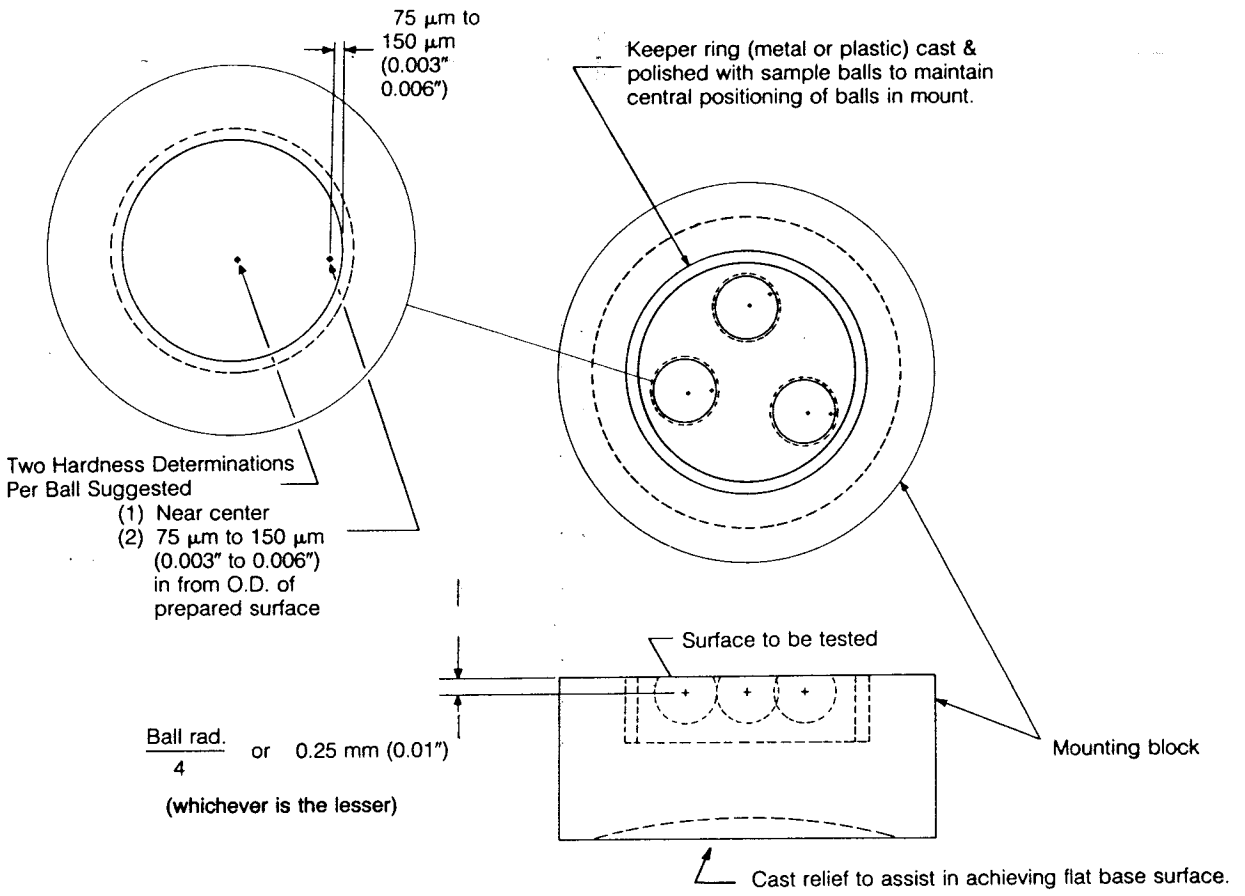


Figure 5
SUGGESTED METHOD OF MOUNTING MINIATURE BALLS FOR MICROHARDNESS TESTING

B1.4 Microhardness Testing. The procedure for hardness testing shall conform to Federal Test Method Std. 151, Method 244-1.

A minimum of two hardness determinations per ball shall be made, one near the center of the prepared surface and one on the same surface at a distance of from 75 to 150 micrometres (0.003" to 0.006") from the edge of the prepared surface.

A test load of 1,000 grams is recommended for all determinations except that in the size range of 1.2 mm (3/64") and smaller where a 300 gram load may be required to remain within the adhesion limits of the specimen to the plastic mounting material. Extremely small diameters may require test loads of less than 300 grams, but it must be pointed out that a clean laboratory environment must be assured.

All hardness determinations shall be reported in DPH values including the test load, e.g.; If a hardness determination of 700 DPH is indicated, employing a 300 gram test load, the hardness to be completely defined, shall be reported as 700 DPH (300 gram load).

B1.5 Reported Hardness. The hardness level of a batch of balls shall be the arithmetic average of all hardness determinations taken on the sample of any given batch. Hardness determinations shall be reported in DPH values.

B1.6 Hardness Conversions. Conversions of DPH hardness values to any other hardness system shall be interpreted only as approximations. The accepted reference for conversions shall be ASTM Standard E-140 "Standard Hardness Conversion Tables of Metals."

APPENDIX B2

Recommended Procedure for Measurement of Case Depth in Carburized and Hardened Carbon Steel Balls

B2.1 Scope. This procedure is used to measure the effective case depth of carburized and hardened carbon steel balls. Effective case depth is defined as the depth radially below the finished ball surface where microhardness tests show the hardness equivalent of Rc 50.

B2.2 General Description. The practical method of measuring effective case depth is by means of microscopic examination of a polished and etched sample of balls prepared in a suitable plastic mount. The depth is read to the transition point between the case and core where the effective case depth corresponds to the hardness equivalent of Rc 50. The microhardness test is used only in referee cases and consists in plotting hardness values taken radially at 0.125 mm (0.005") increments on a suitable graph, from which the depth at equivalent Rc 50 may be read. The case depth is read by the microscopic method using an X20 binocular microscope fitted with a calibrated scale in the eye-piece. Higher magnifications may be used if it is necessary to more clearly define the transition zone.

B2.3 Test Procedure

B2.3.1 Microstructure Examination.

(a) Mount balls in a suitable plastic material and grind them to one-half their diameter.

(b) Polish for microstructure examination and etch the specimen using a 2% nital etch solution and rinse thoroughly after etch with alcohol.

(c) Read the case depth on each ball. Case depth is measured using a calibrated eye-piece, employing binocular microscope of 20X power. The case depth is measured radially and includes all the transition zone from the case up to the core. Greater magnification is acceptable if it is necessary to more clearly define the transition zone.

(d) The readings are then recorded. (See attached form, page 21)

(e) The range in effective case depth in any lot of balls is the difference in the maximum and minimum readings observed on the entire sample inspected.

B2.3.2 Microhardness Examination—for referee determination of case depth and range of case depth within a lot.

(a) Use the same mounted balls that were used for the microstructure examination.

(b) Select two(2) balls that have the minimum and maximum visual case depth.

(c) Make microhardness readings on a radial traverse of the ball at 0.125 mm (0.005") intervals starting at the transition zone nearest to the outside of
the ball and continuing toward the center until at least two readings are taken that are approximately the same.

(d) These readings are plotted on a suitable plot sheet (see attached forms, pages 22 and 23, and a line drawn to fit these plotted readings.

(e) The effective case depth is the reading at which the line reaches Rc 50.

(f) The range in effective case depth in any lot of balls is the difference in case depth by microhardness readings observed in the two (2) balls that had the minimum and maximum visual case depth.

(g) Minimum case depth values are as shown in Table 2, page 6.

CASE DEPTH
MICROSTRUCTURE EXAMINATION*
RECORD OF READINGS

BALL SIZE _____ SPEC. _____ HEAT NO. _____ LOT NO. _____

FURNACE NO. _____ OPERATOR _____ TIME _____ DATE _____

	4 SAMPLES 5 BALLS EACH			
	DEPTH	DEPTH	DEPTH	DEPTH
1				
2				
3				
4				
5				
TOTAL				
X				
R				

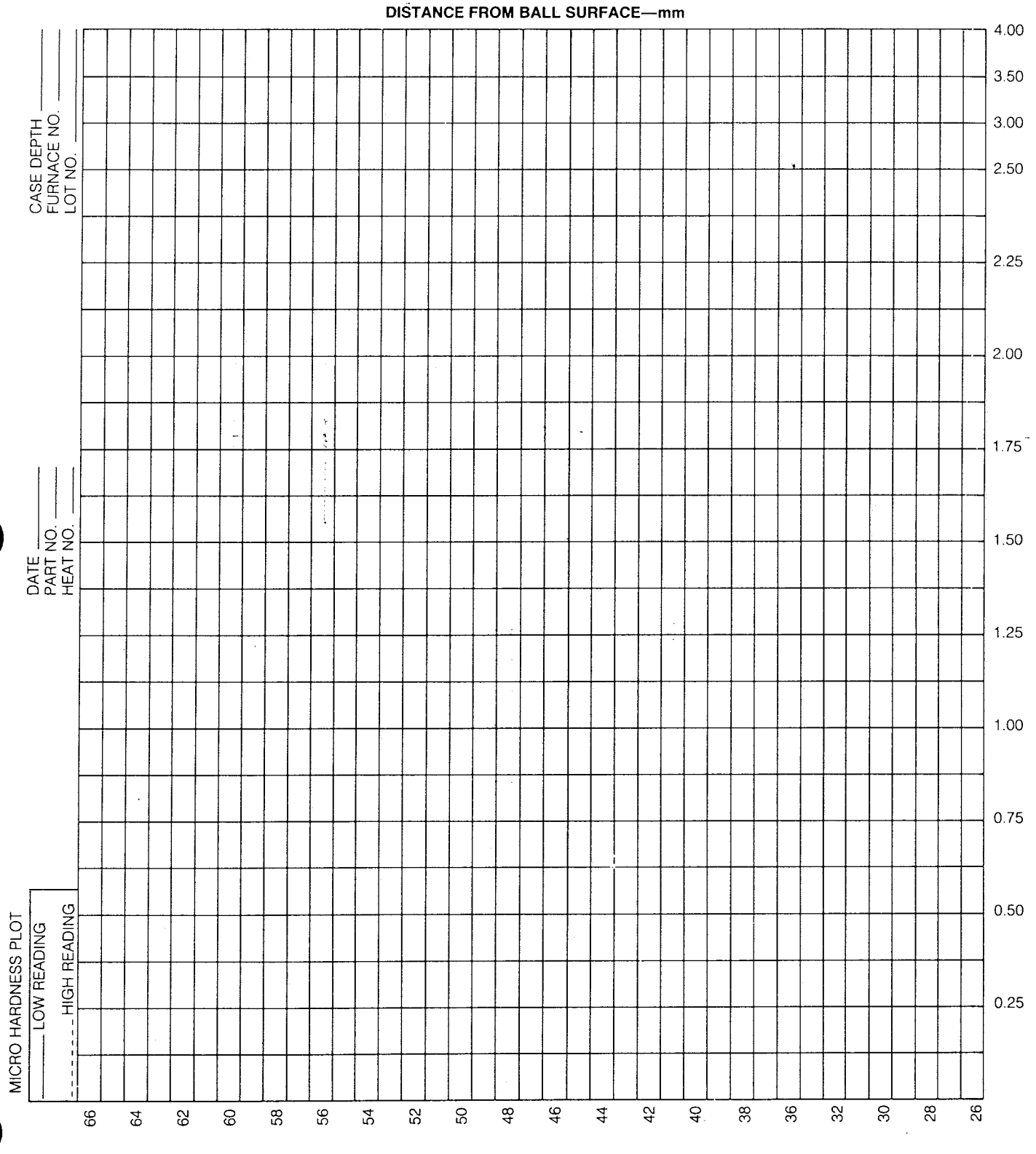
$\overline{X}$ = _____

$\overline{R}$ = _____

*Referred to in B2.3.1(d).

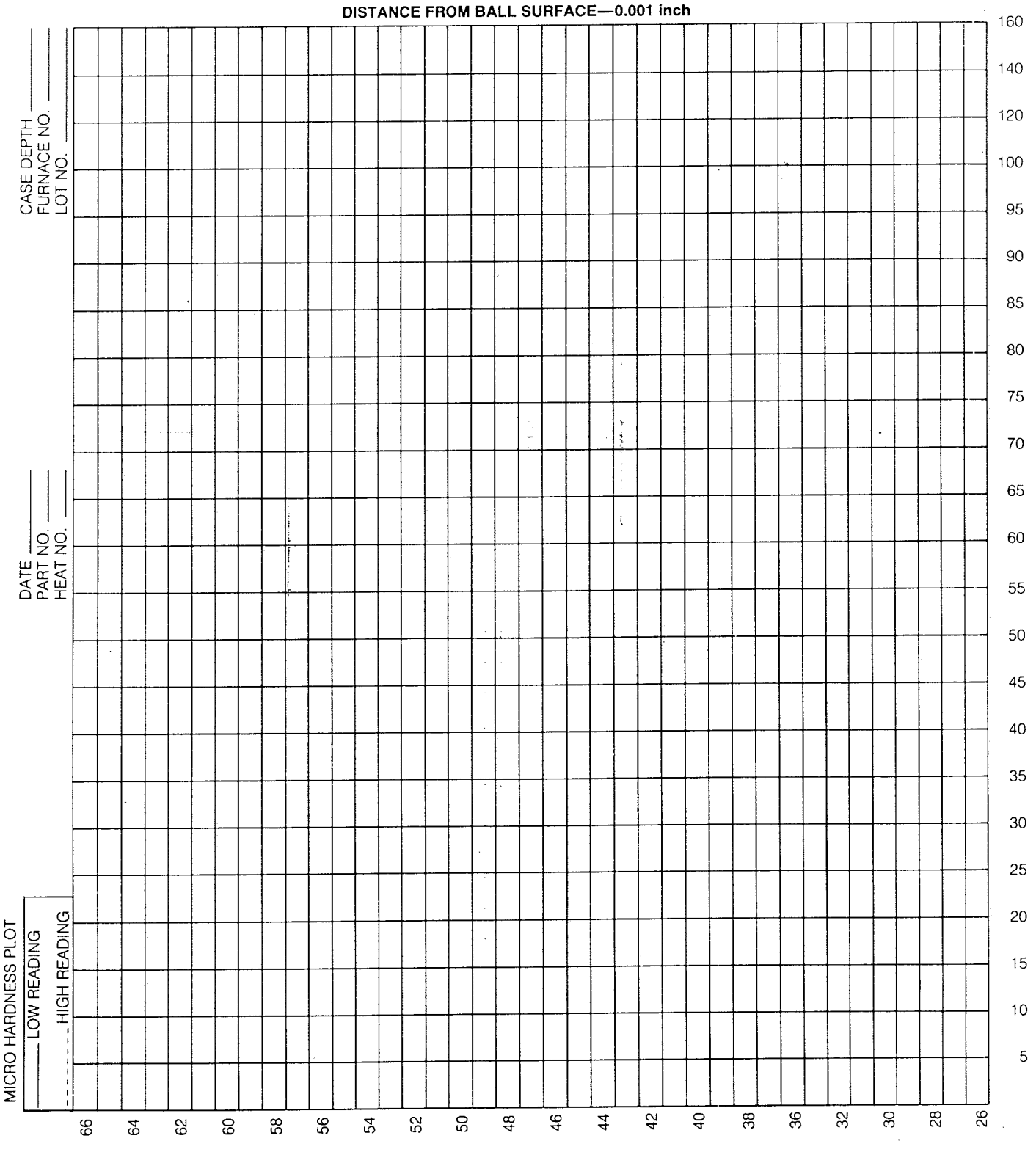
APPENDIX B2 (Cont'd)

CASE DEPTH
MICROHARDNESS EXAMINATION*
SAMPLE PLOT SHEET



*Referred to in B2.3.2(d)

CASE DEPTH MICROHARDNESS EXAMINATION* SAMPLE PLOT SHEET



*Referred to in B2.3.2(d)

APPENDIX B3

Corrections for Hardness Readings taken on Spherical Surfaces

Table 9 below will be found useful for converting Rockwell C Scale readings taken on ball surfaces to equivalent values applicable to flat surfaces in the nominal size range of 6 mm to 25 mm (1/4" - 1") diameter.

TABLE 9
BALL HARDNESS CORRECTIONS FOR CURVATURES (1)
Part 1, METRIC SIZES

CORRECTIONS TO BE ADDED TO ROCKWELL "C" READING OBTAINED ON SPHERICAL SURFACES (2)

RC Readings	BALL DIAMETERS						
	6 mm	8 mm	10 mm	12 mm	15 mm	20 mm	25 mm
20	12.8	9.3	7.6	6.6	5.2	4.0	3.2
25	11.7	8.4	6.9	5.9	4.6	3.5	2.8
30	10.5	7.5	6.1	5.2	4.1	3.1	2.4
35	9.4	6.6	5.4	4.6	3.6	2.7	2.1
40	8.0	5.7	4.5	3.8	3.0	2.2	1.8
45	6.7	4.9	3.8	3.2	2.5	1.8	1.4
50	5.5	4.0	3.0	2.6	2.0	1.4	1.1
55	4.3	3.1	2.3	1.9	1.5	1.0	0.8
60	3.0	2.2	1.7	1.2	1.0	0.6	0.4
65	1.9	1.3	0.9	0.6	0.4	0.2	0.1

(1) This table is for chrome alloy steel and corrosion resisting hardened and unhardened steel belts, and carbon steel balls.

(2) Hardness readings of balls taken on spherical surfaces are affected by the curvature and hardness level of the ball. Because of these factors, corrections are necessarily added to the as-read hardness. For ball sizes and hardness values other than shown, interpolate between values above.

TABLE 9
BALL HARDNESS CORRECTIONS FOR CURVATURES (1)
Part 2, INCH SIZES

CORRECTIONS TO BE ADDED TO ROCKWELL "C" READING OBTAINED ON SPHERICAL SURFACES (2)

RC Readings	BALL DIAMETERS						
	1/4"	5/16"	3/8"	1/2"	5/8"	3/4"	1"
20	12.1	9.3	7.7	6.1	4.9	4.1	3.1
25	11.0	8.4	7.0	5.5	4.4	3.7	2.7
30	9.8	7.5	6.2	4.9	3.9	3.2	2.4
35	8.6	6.6	5.5	4.3	3.4	2.8	2.1
40	7.5	5.7	4.7	3.6	2.9	2.4	1.7
45	6.3	4.9	4.0	3.0	2.4	1.9	1.4
50	5.2	4.0	3.2	2.4	1.9	1.5 1.1	
55	4.1	3.1	2.5	1.8	1.4	1.1	0.8
60	2.9	2.2	1.8	1.2	0.9	0.7	0.4
65	1.8	1.3	1.0	0.5	0.3	0.2	0.1

(1) This table is for chrome alloy steel and corrosion resisting hardened and unhardened steel balls, and carbon steel balls.

(2) Hardness readings of balls taken on spherical surfaces are affected by the curvature and hardness level of the ball. Because of these factors, corrections are necessarily added to the as-read hardness. For ball sizes and hardness values other than shown, interpolate between values above.

APPENDIX C

TABLE 10
DENSITY OF COMMON BALL MATERIALS

Material	DENSITY	
	Grams per Cubic Centimeter	Pounds per Cubic Inch
Steel		
Chrome Alloy	7.833	.283
Corrosion Resisting Hardened	7.677	.277
AISI M-50	7.723	.279
Corrosion Resisting Unhardened		
AISI 302	7.916	.286
AISI 316	7.972	.288
Silicon Molybdenum	7.723	.279
Carbon Steel	7.861	.284
Aluminum	2.796	.101
Aluminum Bronze	7.784	.274
Brass	8.470	.306
Bronze	8.415	.304
Monel Metal	8.830	.319
K-Monel Metal	8.470	.306
Tungsten Carbide	14.947	.540

For weight of ball or quantity of balls per kilogram or pound of these materials, see Tables 11 and 12.

TABLE 11, Part 1
NUMBER OF BALLS PER KILOGRAM

NOM DIA mm	MATERIAL DENSITY IN GRAMS PER CUBIC CENTIMETER												
	2.796	7.584	7.667	7.723	7.833	7.861	7.916	7.972	8.332	8.415	8.470	8.830	14.947
.3	25 300 000	9 330 000	9 230 000	9 160 000	9 030 000	9 000 000	8 940 000	8 870 000	8 490 000	8 410 000	8 350 000	8 010 000	4 730 000
.4	10 670 000	3 930 000	3 890 000	3 860 000	3 810 000	3 800 000	3 770 000	3 740 000	3 580 000	3 550 000	3 520 000	3 380 000	2 000 000
.5	5 470 000	2 010 000	1 990 000	1 980 000	1 950 000	1 940 000	1 930 000	1 920 000	1 830 000	1 820 000	1 800 000	1 730 000	1 020 000
.7	1 990 000	734 000	726 000	721 000	711 000	708 000	703 000	698 000	668 000	662 000	657 000	631 000	373 000
.8	1 330 000	492 000	487 000	483 000	476 000	475 000	471 000	468 000	448 000	443 000	440 000	422 000	250 000
1.0	683 000	252 000	249 000	247 000	244 000	243 000	241 000	240 000	229 000	227 000	225 000	216 000	128 000
1.2	395 000	146 000	144 000	143 000	141 000	141 000	140 000	139 000	133 000	131 000	130 000	125 000	73 900
1.5	202 000	74 600	73 800	73 300	72 200	72 000	71 500	71 000	67 900	67 200	66 800	64 100	37 900
2.0	85 400	31 500	31 100	30 900	30 500	30 400	30 200	29 900	28 700	28 400	28 200	27 000	16 000
2.5	43 700	16 100	15 900	15 800	15 600	15 500	15 400	15 300	14 700	14 500	14 400	13 800	8 180
3.0	25 300	9 330	9 230	9 160	9 030	9 000	8 940	8 870	8 490	8 410	8 350	8 010	4 730
3.5	15 900	5 870	5 810	5 770	5 690	5 670	5 630	5 590	5 350	5 290	5 260	5 040	2 980
4.0	10 700	3 930	3 890	3 860	3 810	3 800	3 770	3 740	3 580	3 550	3 520	3 380	2 000
4.5	7 500	2 760	2 730	2 710	2 680	2 670	2 650	2 630	2 520	2 490	2 470	2 370	1 400
5.0	5 470	2 010	1 990	1 980	1 950	1 940	1 930	1 920	1 830	1 820	1 800	1 730	1 020
5.5	4 110	1 510	1 500	1 490	1 470	1 460	1 450	1 440	1 380	1 360	1 360	1 300	768
6.0	3 160	1 170	1 150	1 140	1 130	1 120	1 120	1 110	1 060	1 050	1 040	1 000	592
6.5	2 490	917	907	901	888	885	878	872	835	826	821	788	465
7.0	1 990	734	726	721	711	708	703	698	668	662	657	631	373
7.5	1 620	597	590	586	578	576	572	568	543	538	534	513	303
8.0	1 330	492	487	483	476	475	471	468	448	443	440	422	250
8.5	1 110	410	406	403	397	396	393	390	373	370	367	352	208
9.0	937	345	342	339	334	333	331	329	314	311	309	297	175
10.0	683	252	249	247	244	243	241	240	229	227	225	216	128
11.0	513.0	189.0	187.0	186.0	183.0	183.0	181.0	180.0	172.0	171.0	169.0	163.0	96.0
11.5	449.0	166.0	164.0	163.0	160.0	160.0	159.0	158.0	151.0	149.0	148.0	142.0	84.0
12.0	395.0	146.0	144.0	143.0	141.0	141.0	140.0	139.0	133.0	131.0	130.0	125.0	73.9
13.0	311.0	115.0	113.0	113.0	111.0	111.0	110.0	109.0	104.0	103.0	103.0	98.5	58.2
14.0	249.0	91.8	90.8	90.1	88.9	88.5	87.9	87.3	83.5	82.7	82.2	78.8	46.6
15.0	202.0	74.6	73.8	73.3	72.2	72.0	71.5	71.0	67.9	67.2	66.8	64.1	37.9
16.0	167.0	61.5	60.8	60.4	59.5	59.3	58.9	58.5	56.0	55.4	55.1	52.8	31.2
17.0	139.0	51.3	50.7	50.3	49.6	49.5	49.1	48.8	46.7	46.2	45.9	44.0	26.0
18.0	117.0	43.2	42.7	42.4	41.8	41.7	41.4	41.1	39.3	38.9	38.7	37.1	21.9
19.0	99.6	36.7	36.3	36.1	35.5	35.4	35.2	34.9	33.4	33.1	32.9	31.5	18.6
20.0	85.4	31.5	31.1	30.9	30.5	30.4	30.2	29.9	28.7	28.4	28.2	27.0	16.0
21.0	73.8	27.2	26.9	26.7	26.3	26.2	26.1	25.9	24.8	24.5	24.3	23.4	13.8
22.0	64.2	23.6	23.4	23.2	22.9	22.8	22.7	22.5	21.5	21.3	21.2	20.3	12.0
23.0	56.1	20.7	20.5	20.3	20.0	20.0	19.8	19.7	18.8	18.7	18.5	17.8	10.5
24.0	49.40	18.20	18.00	17.90	17.60	17.60	17.50	17.30	16.60	16.40	16.30	15.60	9.24
25.0	43.70	16.10	15.90	15.80	15.60	15.50	15.40	15.30	14.70	14.50	14.40	13.80	8.18
26.0	38.90	14.30	14.20	14.10	13.90	13.80	13.70	13.60	13.00	12.90	12.80	12.30	7.27
28.0	31.10	11.50	11.30	11.30	11.10	11.10	11.00	10.90	10.40	10.30	10.30	9.85	5.82
30.0	25.30	9.33	9.23	9.16	9.03	9.00	8.94	8.87	8.49	8.41	8.35	8.01	4.73
32.0	20.80	7.68	7.60	7.55	7.44	7.41	7.36	7.31	7.00	6.93	6.88	6.60	3.90
34.0	17.40	6.41	6.34	6.29	6.20	6.18	6.14	6.10	5.83	5.77	5.74	5.50	3.25
36.0	14.60	5.40	5.34	5.30	5.23	5.21	5.17	5.13	4.91	4.86	4.83	4.64	2.74
38.0	12.40	4.59	4.54	4.51	4.44	4.43	4.40	4.37	4.18	4.14	4.11	3.94	2.33
40.0	10.70	3.93	3.89	3.86	3.81	3.80	3.77	3.74	3.58	3.55	3.52	3.38	2.00
45.0	7.50	2.76	2.73	2.71	2.68	2.67	2.65	2.63	2.52	2.49	2.47	2.37	1.40
50.0	5.47	2.01	1.99	1.98	1.95	1.94	1.93	1.92	1.83	1.82	1.80	1.73	1.02
55.0	4.110	1.510	1.500	1.490	1.470	1.460	1.450	1.440	1.380	1.360	1.360	1.300	.768
60.0	3.160	1.170	1.150	1.140	1.130	1.120	1.120	1.110	1.060	1.050	1.040	1.000	.592
65.0	2.490	.917	.907	.901	.888	.885	.878	.872	835	.826	.821	.788	.465

For Density of Ball Materials see Table 10.

TABLE 11, Part 2
NUMBER OF BALLS PER POUND

NOM DIA Inches	MATERIAL DENSITY IN POUNDS PER CUBIC INCH												
	.101	.274	.277	.279	.283	.284	.286	.288	.301	.304	.306	.319	.540
1/32	620 000	228 000	226 000	224 000	221 000	220 000	219 000	217 000	208 000	206 000	205 000	196 000	116 000
1/16	77 500	28 600	28 200	28 000	27 600	27 500	27 400	27 200	26 000	25 700	25 600	24 500	14 500
3/32	22 900	8 460	8 370	8 310	8 190	8 160	8 100	8 050	7 700	7 620	7 570	7 270	4 290
1/8	9 680	3 570	3 530	3 500	3 460	3 440	3 420	3 400	3 250	3 220	3 200	3 070	1 810
5/32	4 960	1 830	1 810	1 790	1 770	1 760	1 750	1 740	1 660	1 650	1 640	1 570	927
3/16	2 870	1 060	1 050	1 040	1 020	1 020	1 010	1 010	963	953	947	908	537
7/32	1 810	666	659	654	645	642	638	634	606	600	596	572	338
1/4	1 210	446	441	438	432	430	427	424	406	402	399	383	226
9/32	850	313	310	308	303	302	300	298	285	282	281	269	159
5/16	620	228	226	224	221	220	219	217	208	206	205	196	116
11/32	466	172.	170.	169.	166.	166.	164.	163.	156.	155.	154.	147.	87.1
3/8	359	132.	131.	130.	128.	128.	127.	126.	120.	119.	118.	114.	67.1
13/32	282	104.	103.	102.	101.	100.	99.6	98.9	94.6	93.7	93.1	89.3	52.8
7/16	226	83.2	82.3	81.7	80.6	80.3	79.7	79.2	75.8	75.0	74.5	71.5	42.2
15/32	184	67.7	66.9	66.5	65.5	65.3	64.8	64.4	61.6	61.0	60.6	58.1	34.3
1/2	151	55.8	55.2	54.8	54.0	53.8	53.4	53.1	50.8	50.3	49.9	47.9	28.3
17/32	126	46.5	46.0	45.7	45.0	44.9	44.5	44.2	42.3	41.9	41.6	39.9	23.6
9/16	106	39.2	38.7	38.5	37.9	37.8	37.5	37.3	35.7	35.3	35.1	33.6	19.9
19/32	90 3	33.3	32.9	32.7	32.2	32.1	31.9	31.7	30.3	30.0	29.8	28.6	16.9
5/8	77 5	28.6	28.2	28.0	27.6	27.5	27.4	27.2	26.0	25.7	25.6	24.5	14.5
21/32	66 9	24.7	24.4	24.2	23.9	23.8	23.6	23.5	22.5	22.2	22.1	21.2	12.5
11/16	58 2	21.5	21.2	21.1	20.8	20.7	20.6	20.4	19.5	19.3	19.2	18.4	10.9
23/32	50 9	18.8	18.6	18.4	18.2	18.1	18.0	17.9	17.1	16.9	16.8	16.1	9.53
3/4	44 8	16.5	16.3	16.2	16.0	15.9	15.8	15.7	15.0	14.9	14.8	14.2	8.38
25/32	39 7	14.6	14.5	14.4	14.2	14.1	14.0	13.9	13.3	13.2	13.1	12.6	7.42
13/16	35 3	13.0	12.9	12.8	12.6	12.5	12.5	12.4	11.8	11.7	11.6	11.2	6.59
27/32	31 5	11.6	11.5	11.4	11.2	11.2	11.1	11.0	10.6	10.5	10.4	9.97	5.89
7/8	28 2	10.4	10.3	10.2	10.1	10.0	9.97	9.90	9.47	9.38	9.32	8.94	5.2
29/32	25 4	9.37	9.26	9.20	9.07	9.04	8.97	8.91	8.53	8.44	8.39	8.04	4.75
15/16	22 9	8.46	8.37	8.31	8.19	8.16	8.10	8.05	7.70	7.62	7.57	7.27	4.29
31/32	20.8	7.67	7.58	7.53	7.42	7.40	7.35	7.29	6.98	6.91	6.87	6.59	3.89
1	18.9	6.97	6.89	6.85	6.75	6.72	6.68	6.63	6.35	6.28	6.24	5.99	3.54
1-1/8	13.3	4.90	4.84	4.81	4.74	4.72	4.69	4.66	4.46	4.41	4.38	4.20	2.48
1-1/4	9.68	3.57	3.53	3.50	3.46	3.44	3.42	3.40	3.25	3.22	3.20	3.07	1.81
1-3/8	7.27	2.68	2.65	2.63	2.60	2.59	2.57	2.55	2.44	2.42	2.40	2.30	1.36
1-1/2	5.60	2.07	2.04	2.03	2.00	1.99	1.98	1.96	1.88	1.86	1.85	1.77	1.05
1-5/8	4 41	1.62	1.61	1.60	1.57	1.57	1.56	1.55	1.48	1.46	1.45	1.40	.824
1-3/4	3.53	1.30	1.29	1.28	1.26	1.25	1.25	1.24	1.18	1.17	1.16	1.12	.660
1-7/8	2.87	1.06	1.05	1.04	1.02	1.02	1.01	1.01	.963	.953	.947	.908	.537
2	2.36	.871	.862	.856	.844	.841	.835	.829	.793	.785	.780	.748	.442
2-1/8	1.97	.726	.719	.713	.703	.701	.696	.691	.661	.655	.650	.624	.369
2-1/4	1.66	.612	.605	.601	.592	.590	.586	.582	.557	.552	.548	.526	.311
2-3/8	1.41	.520	.515	.511	.504	.502	.498	.495	.474	.469	.466	.447	.264
2-1/2	1.21	.446	.441	.438	.432	.430	.427	.424	.406	.402	.399	.383	.226
2-5/8	1.05	.385	.381	.378	.373	.372	.369	.367	.351	.347	.345	.331	.196
2-3/4	.909	.335	.332	.329	.325	.323	.321	.319	.305	.302	.300	.288	.170
2-7/8	.796	.293	.290	.288	.284	.283	.281	.279	.267	.264	.263	.252	.149
3	.700	.258	.255	.254	.250	.249	.247	.246	.235	.233	.231	.222	.131
3-1/8	.620	.228	.226	.224	.221	.220	.219	.217	.208	.206	.205	.196	.116
3-1/4	.551	.203	.201	.199	.197	.196	.195	.193	.185	.183	.182	.174	.103
3-3/8	.492	.181	.179	.178	.176	.175	.174	.173	.165	.163	.162	.156	.092
3-1/2	.441	.163	.161	.160	.157	.157	.156	.155	.148	.147	.146	.140	.082
3-5/8	.397	.146	.145	.144	.142	.141	.140	.139	.133	.132	.131	.126	.074
3-3/4	.359	.132	.131	.130	.128	.128	.127	.126	.120	.119	.118	.114	.067
3-7/8	.325	.120	.118	.118	.116	.116	.115	.114	.109	.108	.107	.103	.061
4	.295	.109	.108	.107	.105	.105	.104	.104	.099	.098	.097	.093	.055
4-1/8	.269	.099	.098	.097	.096	.096	.095	.094	.090	.089	.089	.085	.050
4-1/4	.246	.091	.090	.089	.088	.088	.087	.086	.083	.082	.081	.078	.046
4-3/8	.226	.083	.082	.082	.081	.080	.080	.079	.076	.075	.074	.071	.042
4-1/2	.208	.076	.076	.075	.074	.074	.073	.073	.070	.069	.068	.066	.039

For Density of Ball Materials see Table 10.

TABLE 12, Part 1
WEIGHT OF BALLS, KILOGRAMS PER THOUSAND BALLS

NOM DIA mm	MATERIAL DENSITY IN GRAMS PER CUBIC CENTIMETER												
	2.796	7.584	7.667	7.723	7.833	7.861	7.916	7.972	8.332	8.415	8.470	8.830	14.947
.3	.000 04	.000 11	.000 11	.000 11	.000 11	.000 11	.000 11	.000 11	.000 12	.000 12	.000 12	.000 12	.000 21
.4	.000 09	.000 25	.000 26	.000 26	.000 26	.000 26	.000 27	.000 27	.000 28	.000 28	.000 28	.000 30	.000 50
.5	.000 18	.000 50	.000 50	.000 51	.000 51	.000 51	.000 52	.000 52	.000 55	.000 55	.000 55	.000 58	.000.98
.7	.000 50	.001 36	.001 38	.001 39	.001 41	.001 41	.001 42	.001 43	.001 50	.001 51	.001 52	.001 59	.002 68
.8	.000 75	.002 03	.002 06	.002 07	.002 11	.002 11	.002 12	.002 14	.002 23	.002 26	.002 27	.002 37	.004 01
1.0	.001 46	.003 97	.004 01	.004 04	.004 12	.004 12	.004 15	.004 17	.004 36	.004 41	.004 43	.004 62	.007 83
1.2	.002 5	.006 9	.006 9	.007 0	.007 1	.007 1	.007 2	.007 2	.007 5	.007 6	.007 7	.008 0	.013 5
1.5	.004 9	.013 4	.013 5	.013 6	.013 9	.013 9	.014 0	.014 1	.014 7	.014 9	.015 0	.015 6	.026 4
2.0	.011 7	.031 8	.032 1	.032 3	.032 9	.032 9	.033 2	.033 4	.034 9	.035 2	.035 5	.037 0	.062 6
2.5	.023	.062	.063	.063	.064	.065	.065	.065	.068	.069	.069	.072	.122
3.0	.040	.107	.108	.109	.111	.111	.112	.113	.118	.119	.120	.125	.211
3.5	.063	.170	.172	.173	.176	.176	.178	.179	.187	.189	.190	.198	.336
4.0	.094	.254	.257	.259	.263	.263	.265	.267	.279	.282	.284	.296	.501
4.5	.133	.362	.366	.368	.375	.375	.378	.380	.398	.401	.404	.421	.713
5.0	.183	.496	.502	.505	.515	.515	.518	.522	.545	.551	.554	.578	.978
5.5	.24	.66	.67	.67	.68	.68	.69	.69	.73	.73	.74	.77	1.30
6.0	.32	.86	.87	.87	.89	.89	.90	.90	.94	.95	.96	1.00	1.69
6.5	.40	1.09	1.10	1.11	1.13	1.13	1.14	1.15	1.20	1.21	1.22	1.27	2.15
7.0	.50	1.36	1.38	1.39	1.41	1.41	1.42	1.43	1.50	1.51	1.52	1.59	2.68
7.5	.62	1.68	1.69	1.71	1.74	1.74	1.75	1.76	1.84	1.86	1.87	1.95	3.30
8.0	.75	2.03	2.06	2.07	2.11	2.11	2.12	2.14	2.23	2.26	2.27	2.37	4.01
8.5	.90	2.44	2.47	2.48	2.53	2.53	2.55	2.56	2.68	2.71	2.72	2.84	4.81
9.0	1.07	2.89	2.93	2.95	3.00	3.00	3.02	3.04	3.18	3.21	3.23	3.37	5.71
10.0	1.46	3.97	4.01	4.04	4.12	4.12	4.15	4.17	4.36	4.41	4.43	4.62	7.83
11.0	1.95	5.29	5.34	5.38	5.48	5.48	5.52	5.56	5.81	5.86	5.90	6.15	10.40
11.5	2.23	6.04	6.11	6.15	6.26	6.26	6.30	6.35	6.63	6.70	6.74	7.03	11.90
12.0	2.53	6.86	6.94	6.99	7.11	7.11	7.16	7.21	7.54	7.61	7.66	7.99	13.50
13.0	3.22	8.72	8.82	8.88	9.04	9.04	9.11	9.17	9.58	9.68	9.74	10.20	17.20
14.0	4.02	10.90	11.00	11.10	11.30	11.30	11.40	11.50	12.00	12.10	12.20	12.70	21.50
15.0	4.94	13.40	13.50	13.60	13.90	13.90	14.00	14.10	14.70	14.90	15.00	15.60	26.40
16.0	6.00	16.30	16.40	16.60	16.90	16.90	17.00	17.10	17.90	18.00	18.20	18.90	32.10
17.0	7.19	19.50	19.70	19.90	20.20	20.20	20.40	20.50	21.40	21.60	21.80	22.70	38.50
18.0	8.54	23.20	23.40	23.60	24.00	24.00	24.20	24.30	25.40	25.70	25.90	27.00	45.60
19.0	10.0	27.20	27.50	27.70	28.20	28.20	28.40	28.60	29.90	30.20	30.40	31.70	53.70
20.0	11.70	31.80	32.10	32.30	32.90	32.90	33.20	33.40	34.90	35.20	35.50	37.00	62.60
21.0	13.60	36.80	37.20	37.40	38.10	38.10	38.40	38.70	40.40	40.80	41.10	42.80	72.50
22.0	15.60	42.30	42.70	43.10	43.80	43.80	44.10	44.40	46.50	46.90	47.20	49.20	83.30
23.0	17.80	48.30	48.80	49.20	50.10	50.10	50.40	50.80	53.10	53.60	54.00	56.30	95.20
24.0	20.2	54.9	55.5	55.9	56.9	56.9	57.3	57.7	60.3	60.9	61.3	63.9	108.0
25.0	22.9	62.0	62.7	63.2	64.3	64.3	64.8	65.2	68.2	68.8	69.3	72.2	122.0
26.0	25.7	69.8	70.6	71.1	72.3	72.3	72.9	73.4	76.7	77.4	77.9	81.3	138.0
28.0	32.1	87.2	88.1	88.8	90.4	90.4	91.0	91.6	95.8	96.7	97.4	101.0	172.0
30.0	39.5	107.0	108.0	109.0	111.0	111.0	112.0	113.0	118.0	119.0	120.0	125.0	211.0
32.0	48.0	130.0	132.0	132.0	135.0	135.0	136.0	137.0	143.0	144.0	145.0	151.0	256.0
34.0	57.5	156.0	158.0	159.0	162.0	162.0	163.0	164.0	171.0	173.0	174.0	182.0	308.0
36.0	68.3	185.0	187.0	189.0	192.0	192.0	193.0	195.0	204.0	206.0	207.0	216.0	365.0
38.0	80.3	218.0	220.0	222.0	226.0	226.0	227.0	229.0	239.0	242.0	243.0	254.0	429.0
40.0	93.7	254.0	257.0	259.0	263.0	263.0	265.0	267.0	279.0	282.0	284.0	296.0	501.0
45.0	133.0	362.0	366.0	368.0	375.0	375.0	378.0	380.0	398.0	401.0	404.0	421.0	713.0
55.0	244	661	668	673	685	685	690	694	726	733	738	769	1300
60.0	316	858	867	873	889	889	895	902	942	952	958	999	1690
65.0	402	1090	1100	1110	1130	1130	1140	1150	1200	1210	1220	1270	2150

For Density of Ball Materials see Table 10.

TABLE 12, Part 2
WEIGHT OF BALLS, POUNDS PER THOUSAND BALLS

NOM DIA Inches	MATERIAL DENSITY IN POUNDS PER CUBIC INCH												
	.101	.274	.277	.279	.283	.284	.286	.288	.301	.304	.306	.319	.540
1/32	.002	.004	.004	.004	.005	.005	.005	.005	.005	.005	.005	.005	.009
1/16	.013	.035	.035	.036	.036	.036	.037	.037	.038	.039	.039	.041	.069
3/32	.044	.118	.120	.120	.122	.123	.123	.124	.130	.131	.132	.138	.233
1/8	.103	.280	.283	.285	.289	.290	.292	.295	.308	.311	.313	.326	.552
5/32	.202	.547	.553	.557	.565	.567	.571	.575	.601	.607	.611	.637	1.08
3/16	.349	.946	.956	.963	.977	.980	.987	.994	1.04	1.05	1.06	1.10	1.86
7/32	.554	1.50	1.52	1.53	1.55	1.56	1.57	1.58	1.65	1.67	1.68	1.75	2.96
1/4	.826	2.24	2.27	2.28	2.32	2.32	2.34	2.36	2.46	2.49	2.50	2.61	4.42
9/32	1.18	3.19	3.23	3.25	3.30	3.31	3.33	3.35	3.51	3.54	3.56	3.72	6.29
5/16	1.61	4.38	4.43	4.46	4.52	4.54	4.57	4.60	4.81	4.86	4.89	5.10	8.63
11/32	2.15	5.83	5.89	5.93	6.02	6.04	6.08	6.13	6.40	6.47	6.51	6.78	11.5
3/8	2.79	7.57	7.65	7.70	7.81	7.84	7.90	7.95	8.31	8.39	8.45	8.81	14.9
13/32	3.55	9.62	9.72	9.79	9.93	9.97	10.0	10.1	10.6	10.7	10.7	11.2	19.0
7/16	4.43	12.0	12.1	12.2	12.4	12.5	12.5	12.6	13.2	13.3	13.4	14.0	23.7
15/32	5.45	14.8	14.9	15.0	15.3	15.3	15.4	15.5	16.2	16.4	16.5	17.2	29.1
1/2	6.61	17.9	18.1	18.3	18.5	18.6	18.7	18.8	19.7	19.9	20.0	20.9	35.3
17/32	7.93	21.5	21.7	21.9	22.2	22.3	22.5	22.6	23.6	23.9	24.0	25.0	42.4
9/16	9.41	25.5	25.8	26.0	26.4	26.5	26.7	26.8	28.0	28.3	28.5	29.7	50.3
19/32	11.1	30.0	30.4	30.6	31.0	31.1	31.3	31.6	33.0	33.3	33.5	35.0	59.2
5/8	12.9	35.0	35.4	35.7	36.2	36.3	36.6	36.8	38.5	38.9	39.1	40.8	69.0
21/32	14.9	40.5	41.0	41.3	41.9	42.0	42.3	42.6	44.5	45.0	45.3	47.2	79.9
11/16	17.2	46.6	47.1	47.5	48.1	48.3	48.7	49.0	51.2	51.7	52.1	54.3	91.9
23/32	19.6	53.3	53.9	54.2	55.0	55.2	55.6	56.0	58.5	59.1	59.5	62.0	105.
3/4	22.3	60.5	61.2	61.6	62.5	62.7	63.2	63.6	66.5	67.2	67.6	70.5	119.
25/32	25.2	68.4	69.2	69.7	70.7	70.9	71.4	71.9	75.1	75.9	76.4	79.6	135.
13/16	28.4	77.0	77.8	78.4	79.5	79.8	80.3	80.9	84.5	85.4	85.9	89.6	152
27/32	31.8	86.2	87.1	87.7	89.0	89.3	89.9	90.6	94.7	95.6	96.2	100.	170
7/8	35.4	96.1	97.2	97.9	99.3	99.6	100.	101.	106.	107.	107.	112.	189
29/32	39.4	107.	108.	109.	110.	111.	111.	112.	117.	118.	119.	124.	210
15/16	43.6	118.	120.	120.	122.	123.	123.	124.	130.	131.	132.	138	233
31/32	48.1	130	132	133	135	135	136	137	143	145	146	152	257
1	52.9	143	145	146	148	149	150	151	158	159	160	167	283
1-1/8	75.3	204	207	208	211	212	213	215	224	227	228	238	403
1-1/4	103.	280	283	285	289	290	292	295	308	311	313	326	552
1-3/8	137.	373	377	380	385	387	389	392	410	414	417	434	735
1-1/2	178	484	489	493	500	502	505	509	532	537	541	564	954
1-5/8	227	616	622	627	636	638	643	647	676	683	687	717	1 210
1-3/4	283	769	777	783	794	797	803	808	845	853	859	895	1 520
1-7/8	349	946	956	963	977	980	987	994	1 040	1 050	1 060	1 100	1 860
2	423	1 150	1 160	1 170	1 190	1 190	1 200	1 210	1 260	1 270	1 280	1 340	2 260
2-1/8	507	1 380	1 390	1 400	1 420	1 430	1 440	1 450	1 510	1 530	1 540	1 600	2 710
2-1/4	602	1 630	1 650	1 660	1 690	1 690	1 710	1 720	1 800	1 810	1 820	1 900	3 220
2-3/8	708	1 920	1 940	1 960	1 990	1 990	2 010	2 020	2 110	2 130	2 150	2 240	3 790
2-1/2	826	2 240	2 270	2 280	2 320	2 320	2 340	2 360	2 460	2 490	2 500	2 610	4 420
2-5/8	957	2 590	2 620	2 640	2 680	2 690	2 710	2 730	2 850	2 880	2 900	3 020	5 110
2-3/4	1 100	2 980	3 020	3 040	3 080	3 090	3 110	3 140	3 280	3 310	3 330	3 470	5 880
2-7/8	1 260	3 410	3 450	3 470	3 520	3 530	3 560	3 580	3 750	3 780	3 810	3 970	6 720
3	1 430	3 870	3 920	3 940	4 000	4 010	3 040	4 070	4 260	4 300	4 330	4 510	7 630
3-1/8	1 610	4 380	4 430	4 460	4 520	4 540	4 570	4 600	4 810	4 860	4 890	5 100	8 630
3-1/4	1 820	4 920	4 980	5 010	5 090	5 100	5 140	5 180	5 410	5 460	5 500	5 730	9 710
3-3/8	2 030	5 520	5 580	5 620	5 700	5 720	5 760	5 800	6 060	6 120	6 160	6 420	10 900
3-1/2	2 270	6 150	6 220	6 260	6 350	6 380	6 420	6 470	6 760	6 820	6 870	7 160	12 100
3-5/8	2 520	6 830	6 910	6 960	7 060	7 080	7 130	7 180	7 510	7 580	7 630	7 960	13 500
3-3/4	2 790	7 570	7 650	7 700	7 810	7 840	7 900	7 950	8 310	8 390	8 450	8 810	14 900
3-7/8	3 080	8 350	8 440	8 500	8 620	8 650	8 710	8 770	9 170	9 260	9 320	9 720	16 500
4	3 380	9 180	9 280	9 350	9 480	9 520	9 580	9 650	10 100	10 200	10 300	10 700	18 100
4-1/8	3 710	10 100	10 200	10 300	10 400	10 400	10 500	10 600	11 100	11 200	11 200	11 700	19 800
4-1/4	4 060	11 000	11 100	11 200	11 400	11 400	11 500	11 600	12 100	12 200	12 300	12 800	21 700
4-3/8	4 430	12 000	12 100	12 200	12 400	12 500	12 500	12 600	13 200	13 300	13 400	14 000	23 700
4-1/2	4 820	13 100	13 200	13 300	13 500	13 600	13 600	13 700	14 400	14 500	14 600	15 200	25 800

For Density of Ball Materials see Table 10.

American National Standards

The standard in this booklet is one of more than 10,000 standards approved to date by the American National Standards Institute.

The Standards Institute provides the machinery for creating voluntary standards. It serves to eliminate duplication of standards activities and to weld conflicting standards into single, nationally accepted standards under the designation "American National Standards."

Each standard represents general agreement among maker, seller, and user groups as to the best current practice with regard to some specific problem. Thus the completed standards cut across the whole fabric of production, distribution, and consumption of goods and services. American National Standards, by reason of Institute procedures, reflect a national consensus of manufacturers, consumers, and scientific, technical, and professional organizations, and governmental agencies. The completed standards are used widely by industry and commerce and often by municipal, state, and federal governments.

The Standards Institute, under whose auspices this work is being done, is the United States clearinghouse and coordinating body for voluntary standards activity on the national level. It is a federation of trade associations, technical societies, professional groups, and consumer organizations. Some 1000 companies are affiliated with the Institute as company members.

The American National Standards Insitute is the United States member of the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC). Through these channels U.S. standards interests make their positions felt on the international level. American National Standards are on file in the libraries of the national standards bodies of more than 60 countries.

American National Standards Institute, Inc
1430 Broadway
New York, N.Y. 10018