PRECISION BALLS

July 2004

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THOMSON™

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Mechanical and Electro-Mechanical Product Solutions by Danaher Motion

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Danaher Motion's wide range of motion control systems and components offer customers an unprecedented choice in selecting the right solution to match their particular application requirements. Our product innovations have been improving the efficiency and productivity of complex manufacturing operations for over 60 years through trusted brand names such as Dover, Kollmorgen, Pacific Scientific, Portescap and Thomson in industries as diverse as semiconductor, aerospace and defense, mobile-off-highway, packaging, medical and robotics.

In addition, Danaher Motion, through Motion Engineering (MEI), offers powerful integrated motion control solutions with its industry-leading, multi-axis motion platforms and SynqNet" communications network for ultra-reliable machine performance. From software and controller, through the communications network to drives and I/O devices, to mechanical and electro-mechanical products, Danaher Motion differentiates itself in the marketplace by designing standard and custom solutions to satisfy the most demanding application requirements.

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- Broad & Innovative Motion Control Products and Systems
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- Customizable Products and Services
- Motion Control Pioneers with Global Staying Power
- Operational Excellence

Choose Danaher Motion as your Thomson Precision Ball Supplier.

THE ONLY BALL MANUFACTURER MEETING THESE CRITERIA:

- ISO 9002 Registered
- QS-9000 Certified
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- Three-Time GM Supplier of the Year
- Two-Time ITT Supplier Gold Award Recipient
- Hollow, Ceramic and Specialty Balls
- Worldwide Service and Support

The Most Complete Variety of Precision Balls, Ball Materials and Technologies

Quality Ball Technology from Danaher Motion

Expect only the finest in quality ball technology from Danaher Motion. Danaher Motion offers ball sphericity within 3 millionths of an inch (0.077 micron), 100% quality inspection, and a choice of 27 high performance materials—all guaranteed to meet or exceed the standards of the American Bearing Manufacturers Association (ANSI/ABMA Std. 10-1989).

The specifications for each Thomson quality ball are presented in this guide. Material characteristics are explained below. Each material's compositional analysis, mechanical properties and various testing standards are described with the ball engineering specifications within the guide.

In addition, a fraction - to - decimal - to - millimeter conversion chart is provided for your convenience. For more detailed information on Thomson quality ball technology, contact us directly at 1-800-554-8466.

Material Characteristics

52100 Chrome Steel: Found primarily in ball bearing designs and a variety of demanding industrial applications. A vacuum-degassed AISI E52100 chrome steel is used to obtain a superior ball with a fine surface finish, through-hardness and high load capacity. Also available in consumable electrode vacuum melt material.

Stainless Steels: Three quality stainless steels are available for applications in corrosive environments. AISI Type 440C offers the greatest hardness and surface finish, and is available in double vacuum melted materials. AISI Type 302 provides extreme toughness and corrosion resistance from oxidizing solutions and many organic chemicals in an unhardened state.

For resistance to sulfuric acid compounds and other severely corrosive environments, Type 316 austenitic steel with increased nickel is available. If required, Thomson can also provide a quality ball in Types 410, 420, and 430 stainless steels.

Monel: The ultimate in resistance to corrosion from steam, gas, salt water, ammonia, calcium chloride, acidic foods, high temperatures and other extreme environments. A low-hardness ball made from a special nickel-copper alloy.

K-Monel: A slightly harder material with corrosion resistance equal to Monel.

Bronze: A high quality alloy created for environments attacked by water, gasoline, and certain solvents.

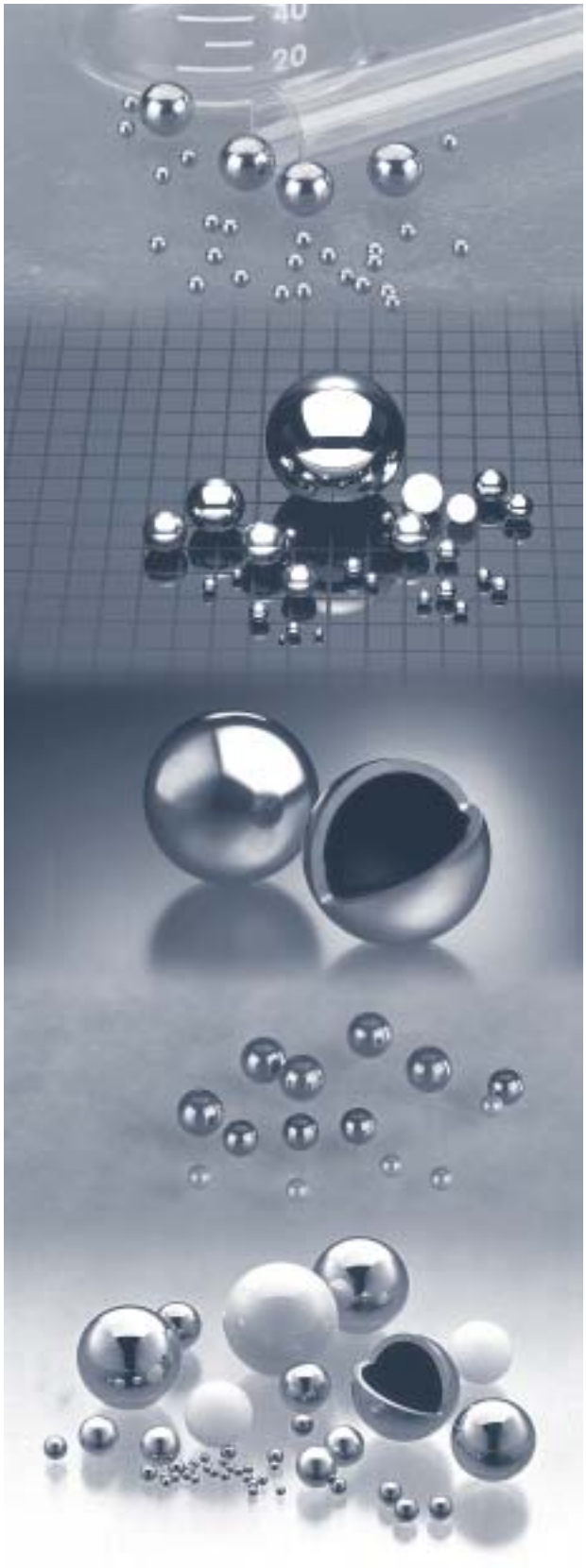
Brass: Corrosion resistant material similar to bronze, with greater tensile and yield strength.

Titanium Balls: This highly inert material is lightweight, offers exceptional anti-corrosive properties, operates effectively in high temperature applications, provides a high level of tensile/compression strength, and has expansion characteristics similar to steel. Titanium is used extensively in aerospace applications as well as in the chemical, food processing, and medical implant industries.

High Performance Ceramic Balls —
Diameters: 1/16" to 2 1/2": For extremely high temperature environments or applications exposed to harsh chemicals, balls made of engineered ceramics offer excellent performance characteristics. Danaher Motion manufactures a variety of precision ceramic balls, each providing its own unique corrosion and heat resistant qualities.

Silicon Nitride: Popular choice in bearing designs and other high precision product applications. When compared to steel, this material offers 46% reduction in weight, up to twice the material hardness, a coefficient of thermal expansion that is 70% less than steel, and a temperature operating range up to 1800° F. Silicon Nitride balls are non-corrosive, anti-magnetic and excel In low noise, high rigidity, and high load carrying applications. These balls can be run dry in a vacuum environment and up to 500°F without lubrication.

Zirconia: A high-strength material that operates well in environments such as molten metals, organic solvents, caustics and most acids. Because of its good resistance to abrasion and corrosion, it is often used as check valves for flow control. Zirconia undergoes “transformation toughening” when stressed by impact. This tends to stop cracks from spreading and increases the ball's strength in the stressed area.



Special Materials: A variety of non-metallic materials are offered for lightweight, corrosion-resistant applications. Standard non-metallics include Nylon®, Delrin® and Lexan® for applications subject to common solvents, dilute mineral acids, most organic acids, alkalis, oils and greases up to 300° F.

Ceramics: When extremely high temperature, high loads, and harsh operating environments are present, quality Thomson ceramics are available from Danaher Motion in a variety of precision grades. Call our Inside Sales Staff for assistance with your specific application.

How to Order:
When ordering balls, please specify the following:

- Nominal ball diameter
- Type of material
- Grade
- Ball Gage† (if applicable)

All standard balls are always in stock and ready for immediate off-the-shelf delivery. If your application calls for custom balls, send us your specifications and we'll gladly meet them.

To place your order, call us toll-free: 1-800-554-8466 or fax 516-883-8050 / Toll Free Fax 1-800-445-0329.

Or write:
Danaher Motion
43-45 Channel Drive
Port Washington, NY 11050

E-mail: DMAC@danahermotion.com

†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 -).

Hardness Correction Table

Corrections to be added to Rockwell "C" readings taken on the spherical surface for equivalent measure on parallel flats. These correction factors apply only to chrome and AISI-Type 440 stainless steel balls.

Hardness readings of balls taken on spherical surfaces are affected by the curvature and hardness of the ball. Because of these factors, corrections are necessarily added to the hardness read on ball surface to obtain the equivalent hardness on a flat surface. For ball sizes not shown, interpolate between values at right.

Rockwell "C" Readings (Curved surface)	Ball Diameters											
	5/16"	3/8"	7/16"	1/2"	9/16"	5/8"	11/16"	3/4"	13/16"	7/8"	15/16"	1"
55	3.1	2.5	2.1	1.8	1.6	1.4	1.3	1.1	1.0	1.0	.8	.8
56	2.9	2.4	2.0	1.6	1.5	1.3	1.2	1.0	.9	.9	.7	.7
57	2.7	2.2	1.8	1.5	1.4	1.2	1.1	.9	.8	.8	.7	.6
58	2.6	2.1	1.7	1.4	1.2	1.1	1.0	.8	.7	.7	.6	.5
59	2.4	1.9	1.6	1.3	1.1	1.0	.9	.7	.7	.6	.5	.4
60	2.2	1.8	1.5	1.2	1.0	.9	.8	.7	.6	.5	.5	.4
61	2.0	1.6	1.3	1.0	.9	.8	.7	.6	.5	.5	.4	.3
62	1.8	1.5	1.2	.9	.8	.7	.6	.5	.4	.4	.4	.3
63	1.7	1.3	1.0	.8	.7	.5	.5	.4	.4	.3	.3	.2
64	1.5	1.2	.9	.6	.5	.4	.3	.3	.3	.2	.2	.2
65	1.3	1.0	.7	.5	.4	.3	.2	.2	.2	.2	.1	.1
66	1.1	.8	.6	.4	.3	.2	.1	.1	.1	.1	–	–

Hardness Conversion Table: (Conversions are only valid for readings taken on parallel flats.)

Rockwell "C" Scale	Brinell† 3000 Kilogram Load	Rockwell "C" Scale	Rockwell "B" Scale	Brinell† 3000 Kilogram Load	Rockwell "B"Scale	Brinell† 3000 Kilogram Load
66	–	40	–	371	94	205
65	739	39	–	362	93	200
64	722	38	–	353	92	195
63	705	37	–	344	91	190
62	688	36	–	336	90	185
61	670	35	–	327	89	180
60	654	34	–	319	88	176
59	634	33	–	311	87	172
58	615	32	–	301	86	169
57	595	31	–	294	85	165
56	577	30	–	286	84	162
55	560	29	–	279	83	159
54	543	28	–	271	82	156
53	525	27	–	264	81	153
52	500	26	–	258	80	150
51	487	25	–	253	79	147
50	475	24	–	247	78	144
49	464	23	100.0	243	77	141
48	451	22	99.0	237	76	139
47	442	21	98.5	231	75	137
46	432	20	97.8	226	74	135
45	421	(19)	97.0	222	73	132
44	409	(18)	96.7	219	72	130
43	400	(17)	96.1	215	71	127
42	390	(16)	95.5	212	70	125
41	381	(15)	94.7	208	–	–

†For Rockwell "C" values under 20, as indicated in parentheses, it is recommended that the Rockwell "B" scale be used.

BALL MATERIALS	Industrial Atmosphere	Hydraulic Oils (Petroleum)	Fresh Water	Salt Water	Food Products	Fruit & Veg. Juices	Milk	Alcohol	HCl-40%	Sulfuric Acid-40%	Phosphoric Acid-40%	Nitric Acid-50%	Citric Acid	Ammonia Liquids
52100 CHROME	C	A	D	D	–	–	–	C	–	–	–	–	C	B
440C STAINLESS	B	A	C	C	B	–	A	A	D	D	A	A	A	A
302 STAINLESS	B	A	B	B	A	–	A	–	–	–	A	–	–	–
316 STAINLESS	B	A	A	A	A	A	A	A	D	D	A	A	A	A
BRASS	C	B	C	C	D	–	C	C	–	D	D	–	D	–
MONEL	C	A	A	B	D	C	C	A	D	–	C	–	–	A
NYLON	A	A	A	A	–	A	A	A	D	D	D	D	C	–
VITON®	A	A	A	A	A	A	A	A	A	A	A	A	A	D
CERAMIC	A	A	A	A	A	A	A	A	C	D	C	A	A	A
TITANIUM	–	–	–	–	–	–	–	A	C	C	–	A	A	–

Numbers indicating order of preference

A = excellent B = good C = fair D = poor – = test data not available

Grades and Tolerances (ABMA STD-10)

(2.12) Grade: A specific combination of dimensional form and surface roughness tolerance. A ball grade is designated by a grade number.

(2.4) Ball Diameter Variation: The difference between the largest and the smallest actual single diameter of one ball.

(2.8) Lot Diameter Variation: The difference between the mean diameter of the largest ball and that of the smallest ball in the lot.

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

Mechanical Characteristics

Hardness: The measure of resistance to penetration of the ball surface or truncated flat of the ball by a specific indenting shape.

Ball Diameter (ABMA STD-10)

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

(2.13) Ball Gage: 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.

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

(2.10) Container Marking Increment: The standard unit steps in micrometers or in millionths of an inch, used to express the specific diameter.

How Ball Diameter Is Indicated

Example:

Nominal Ball Diameter . . . . . .1/2"
Ball Gage . . . . . .1/2" + .0003
Specific Diameter . . . . . .1/2" + .000325

Surface Qualities

Surface Roughness: 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.

Waviness: The more widely spaced circumferential component of surface texture.

Danaher Motion Statement of Standard Measurement Conditions:

Diameter: Between two parallel flat carbide gage surfaces under 4 oz. gage force with size corrected to zero gage pressure per ABMA Std. 10.

Deviation from Spherical Form: Determined by rotation of the ball against a linear transducer with less than 4 grams gage force. The resulting polar chart is interpreted using the minimum circumscribed circle method (MCC) per ABMA Std. 10, Appendix A1.1 and AMS 889.3.

Surface Roughness: Determined by a stylus type instrument with the ball stationary. Compliance with Ra limits specified in ABMA Std. 10, Table 3 will be interpreted using a cutoff of .003 for ball radii up to .050, .01 for ball radii up to .130, and .03 over .130, with filtration to optimize the number of cutoffs used to calculate the results.

†American Bearing Manufacturers Association (ABMA); formerly the Anti Friction Bearing Manufactures Association (AFBMA)
††DIN 5401 and ISO 3290 are European originated precision ball specifications similar to the ABMA specifications referencing tolerance specifications

Grades and Tolerances – Inches

Grade	Size Range	Deviation from Spherical Form	Lot Diameter Variation	Allowable Ball Gage Variation	Nominal Ball Diameter Tolerance	Marking Increments	Maximum Surface Roughness† in Microinches "Ra"
3	.006-1/2"	.000003	±.000003	±.00003	–	0.00001	.5
5	.006-1/2"	.000005	±.000005	±.00005	–	0.00001	.8
10	.006-7/8"	.00001	±.000010	±.00005	–	0.00001	1.0
25	.006-1"	.000025	±.000025	±.00010	–	0.00001	2.0
50	.006-1"	.000050	±.000050	–	±.0002	0.00005	3.0
100	.006-1"	.0001	±.0001	–	±.0005	–	5.0
200	.006-1"	.0002	±.0002	–	±.001	–	8.0
1000	.006-1"	.001	±.001	–	±.005	–	–

† Maximum surface roughness arithmetic average.

Grades and Tolerances – Metric (Millimeter)

DIN Grade	ABMA Grade	Deviation from Spherical Form	Lot Diameter Variation	Allowable Ball Gage Variation	Nominal Ball Diameter Tolerance	Marking Increments	Maximum Surface Roughness† in Micrometers "Ra"
–	3	.00008	±.00008	±.0008	–	.00025	0.012
–	5	.00013	±.000013	±.0013	–	.00025	0.020
I	10	.00025	±.00025	±.0013	–	.00025	0.025
II	25	.0006	±.0006	±.0025	–	.00025	0.051
III	50	.0012	±.0012	–	±.0051	.00127	0.076
IV	100	.0025	±.0025	–	±.0381	–	0.127
–	200	.005	±.005	–	±.025	–	0.203
V	1000	.025	±.025	–	±.127	–	–

† Maximum surface roughness arithmetic average.

Hardness

Our modern heat treating facilities, complete with controlled atmosphere and temperature, allow us to maintain Rockwell hardness within three (3) points in any production run and to attain any specific hardness designated by the customer. AISI E52100 Chrome Steel Balls are made with a through hardness of RC 60 to 67†, depending on requirements.
(A table correcting Rockwell "C" values for the curved surface to parallel flats appears on page 6.)

†Per ABMA Std 10, Table 1

Material Analysis†

Carbon	0.98 to 1.10%
Manganese	0.25 to 0.45%
Silicon	0.15 to 0.35%
Phosphorus	Maximum of .025%
Sulphur	Maximum of .025%
Chromium	1.30 to 1.60%
Nickel	Maximum of 0.25%
Molybdenum	Maximum of 0.10%
Copper	Maximum of 0.35%

†Per AMS 6440

Mechanical Properties

Tensile Strength	325,000 psi
Yield Strength	295,000 psi
Elongation in two inches	5%
Reduction in area	8%
Modulus of Elasticity	29,500,000 psi
Density	283 lb./cubic inch

Material Conversion

Material	AISI	Federal	Military	ASTM	JIS	UNS	DIN	AMS	Military and Gov't Stds.
52100 Chrome	E52100	FED-STD-66D	MIL-B-1083	A295	SUJ-2	G-52986	100Cr6	6440 6444† 6444††	MS 19059

† Premium aircraft quality, consumable electrode vacuum melted.

†† Balls, low chromium, high-carbon steel, hardened and tempered.

Size in Inches	Metric Sizes	Minimum Crushing Load in Pounds	Balls per Pound	Balls per Carton†	Metric Balls per Carton	Weight per Carton Pounds
.006		–	45,045,000	–		–
.008		–	13,192,612	–		–
.01		–	6,802,721	–		–
.015		–	1,996,007	–		–
.02		–	841,751	–		–
.025		–	431,406	–		–
1/32	1mm	–	221,141	–	400,000	–
3/64		–	65,496	–		–
1/16		275	27,600	300,000		10.9
5/64	2mm	345	14,286	150,000	150,000	10.5
3/32		618	8,200	100,000		12.2
7/64	3mm	842	5,150	60,000	50,000	11.6
1/8		1,100	3,460	40,000		11.6
9/64		1,392	2,425	30,000		12.4
5/32	4mm	1,718	1,770	20,000	20,000	11.3
11/64		2,080	1,330	15,000		11.3
3/16	5mm	2,475	1,020	12,500	10,000	12.2
13/64		2,905	805	10,000		12.4
7/32		3,368	645	8,000		12.4
15/64	6mm	3,867	524	6,000	6,000	11.4
1/4		4,400	432	5,000		11.6
17/64	7mm	4,730	360	4,000	4,000	11.1
9/32		5,568	303	3,500		11.5
5/16	8mm	6,875	221	2,500	2,500	11.3
11/32	9mm	8,318	166	2,000	1,750	12.0
3/8	10mm	9,900	128	1,500	1,250	11.7
13/32	11mm	11,618	101	1,250	1,000	12.4
7/16		13,475	81	1,000		12.4
15/32	12mm	15,468	66	750	750	11.4
1/2		17,600	54	600		11.1
17/32		18,062	45	500		11.1
9/16		20,250	38	450		11.9
19/32		22,562	32	350		10.9
5/8		25,000	28	300		10.9
21/32		27,562	24	250		10.5
11/16		30,250	21	250		12
23/32		33,062	18	200		11
3/4		36,000	16	200		12.5
13/16		42,250	13	150		11.9
7/8		49,000	10	100		9.9
15/16		56,250	8	75		9.2
1		64,000	6.7	70		10.4

† Grade 10 and better packed in smaller quantities in bubble pack.

Hardness

Our modern heat treating facilities, complete with controlled atmosphere and temperature, allow us to maintain Rockwell hardness within three (3) points in any production run and to attain any specific hardness designated by the customer. AISI 440C corrosion resistant, hardened steel balls are made with a through hardness from RC 58 to 65†, depending on requirements. (A table correcting Rockwell "C" values for the curved surface to Rockwell "C" for parallel flats may be found on page 6).

†Per ABMA Std 10, Table 1

Material Analysis†

Carbon	0.95 to 1.20%
Manganese	Maximum of 1.00%
Silicon	Maximum of 1.00%
Phosphorus	Maximum of .040%
Sulphur	Maximum of .030%
Chromium	16.00 to 18.00%
Molybdenum	Maximum of 0.75%
Nickel	Maximum of 0.75%
Copper	Maximum of 0.50%

†Per AMS 5630

Mechanical Properties

Tensile Strength	285,000 psi
Yield Strength	275,000 psi
Elongation in two inches	2%
Reduction in area	10%
Modulus of Elasticity	29,000,000 psi
Density	.277 lb./cubic inch

NOTE: All stainless steel balls are passivated. 420 stainless steel balls available on request.

Material Conversion

Material	AISI	Federal	Military	ASTM	JIS	UNS	DIN	AMS	Military and Gov't Stds.
Type 440C	440C	QQ-S-763	–	A276	SUS440C	S-44004	X105CrMo17	5630	
								5618†	MS 19060
		CL 440C						7445††	

† Consumable electrode vacuum melted
†† Balls, corrosion resistant steel, 17Cr, hardened.

Size in Inches	Metric Sizes	Balls per Pound	Balls per Carton†	Metric Balls per Carton	Carton in Approximate Pounds
.006		45,871,000	–		–
.008		13,477,082	–		–
.010		6,944,444	–		–
.015		2,040,816	–		–
.020		861,326	–		–
.025		440,723	–		–
1/32	1mm	225,938	–	400,000	–
3/64		66,916	–		–
1/16	2mm	28,200	100,000	150,000	9.0
3/32		8,380	100,000		12.2
7/64	3mm	5,263	60,000	50,000	11.6
1/8		3,530	40,000		11.6
9/64		2,481	30,000		12.4
5/32	4mm	1,810	20,000	20,000	11.3
11/64		1,359	15,000		11.3
3/16	5mm	1,050	12,500	10,000	12.2
13/64		822	10,000		12.4
7/32		659	8,000		12.4
15/64	6mm	536	6,000	6,000	11.4
1/4		441	5,000		11.6
17/64	7mm	368	4,000	4,000	11.1
9/32		310	3,500		11.5
5/16	8mm	226	2,500	2,500	11.3
11/32		170	2,000		12.0
3/8	9mm	131	1,500	1,750	11.7
13/32	10mm	103	1,250	1,250	12.4
7/16	11mm	82	1,000	1,000	12.4
15/32	12mm	67	750	750	11.4
1/2		51	600		11.1
17/32		46	500		11.1
9/16		39	450		11.9
5/8		28	300		10.6
11/16		21	250		11.8
3/4		16	200		12.5
13/16		13	150		11.9
7/8		10	100		9.9
15/16		8	75		9.2
1		7	70		10.4

† Grade 10 and better packed in smaller quantities in bubble pack.

Hardness

Non-annealed hardness, uniform throughout, as measured on parallel flats, is typically Rockwell "C" 25 to 39†. Annealed hardness, available on request, is typically Rockwell "B" 75 to 90. (A table converting Rockwell "C" to Rockwell "B" and Brinell ratings may be found on page 6.)

†Per ABMA Std 10, Table 1

Material Analysis† – 302/302HQ

Carbon	Maximum of 0.15%
Manganese	Maximum of 2.00%
Phosphorus	Maximum of 0.045%
Sulphur	Maximum of 0.030%
Silicon	Maximum of 1.00%
Chromium	17.00 to 19.00%
Nickel	8.00 to 10.00%
Nitrogen	Maximum of 0.10%
Copper††	3.00 to 4.00%

†Per ASTM A276-89 ††Type HQ

Material Analysis† – 316/316L

Carbon	Maximum of 0.08% (0.03%)††
Manganese	Maximum of 2.00%
Phosphorus	Maximum of 0.045%
Sulphur	Maximum of 0.030%
Silicon	Maximum of 1.00%
Chromium	16.00 to 18.00%
Nickel	10.00 to 14.00%
Nitrogen	Maximum of 0.10%
Molybdenum	2.00 to 3.00%

†Per ASTM A276-89 ††Type 316L

Mechanical Properties (Type 302) (At Rockwell "B" 75-90)

Tensile Strength	100,000 to 180,000 psi
Yield Strength	50,000 to 150,000 psi
Elongation in two inches	55 to 60%
Reduction in area	55 to 65%
Modulus of Elasticity	29,000,000 psi
Density	.286 lb./cubic inch

Mechanical Properties (Type 316)

Tensile Strength	90,000 psi
Yield Strength	45,000 psi
Elongation in two inches	35%
Reduction in area	60%
Modulus of Elasticity	28,000,000 psi
Density	.29 lb./cubic inch

NOTE: All stainless steel balls are passivated. 420 stainless steel balls available on request.

Material Conversion

Material	AISI	Federal	ASTM	DIN	UNS	JIS	AMS
Stainless Steel	Type 302	QQ-S-763 CL 302	A276	—	S-30200	—	5636
	Type 316	QQ-S-763 CL 316	A276	X5CrNiMo17122	S-31603	SUS316	5648

Hardness: Monel 400

Typical hardness, as measured on parallel flats, is:
Rockwell "B" 85 to 95†.

†Per ABMA Std 10, Table I

Hardness: K-Monel 500

Typical hardness, as measured on parallel flats, is:
Rockwell "C" 27 minimum†.

†Per ABMA Std 10, Table I

Material Analysis† – Monel

Nickel	Minimum of 63.0%
Copper	28.0 to 34.0%
Iron	Maximum of 2.50%
Manganese	Maximum of 0.20%
Carbon	Maximum of 0.30%
Silicon	Maximum of 0.50%

†Per ASM Metals Handbook

Material Analysis† – K-Monel

Nickel	Minimum of 63.0%
Copper	27.0 to 33.0%
Iron	Maximum of 2.00%
Manganese	Maximum of 1.50%
Carbon	Maximum of 0.25%
Silicon	Maximum of 0.50%
Aluminum	2.0 to 4.0%

†Per ASM Metals Handbook

Material Conversion

Material	AISI	Federal	ASTM	UNS	AMS
Monel 400	—	QQ-N-281 Class A	B164	N-04400	4730
K-Monel 500	—	QQ-N-286 Class B	—	N-05500	4676

General Data

Size in Inches	Metric Sizes	Balls per Pound	Balls per Carton	Metric Balls per Carton	Weight per Carton in Pounds
1/16		25,564	250,000		9.8
3/32		7,574	100,000		13.2
7/64	3mm	4,762	60,000	50,000	12.6
1/8		3,195	40,000		12.5
9/64		2,247	30,000		13.4
5/32	4mm	1,636	20,000	20,000	12.2
11/64		1,228	15,000		12.2
3/16	5mm	946	12,500	10,000	13.2
13/64		745	10,000		13.4
7/32		596	8,000		13.4
15/64	6mm	485	6,000	6,000	12.4
1/4		399	5,000		12.5
17/64	7mm	333	4,000	4,000	12.0
9/32		280	3,500		12.5
5/16	8mm	204	2,500	2,500	12.2
11/32	9mm	153	2,000	1,750	13.0
3/8	10, 11, 12mm	118	1,500	1,250, 1,000, 750	12.7
7/16		74	1,000		13.4
1/2		50	500		10.0
9/16		35	300		8.6
5/8		25	250		9.8
3/4		15	150		10.1

Hardness: Brass

Typical hardness, as measured on parallel flats, is approximately Rockwell "B" 75 to 87†.

†Per ABMA Std 10, Table I

Hardness: Bronze

Typical hardness, as measured on parallel flats, is approximately Rockwell "B" 75-98†.

†Per ABMA Std 10, Table I

Material Analysis† – (Brass) CDA 270

Copper . . . . . .63.0 to 68.5%
Zinc . . . . . .33.5 to 36.5%
Other Elements . . . . . .Trace, Max.

†Per ASM Metals Handbook

Material Analysis† – (Bronze) CA 220

Copper . . . . . .89.0 to 91.0%
Zinc . . . . . .08.5 to 10.5%
Other Elements . . . . . .Trace, Max.

†Per ASM Metals Handbook

NOTE: Brass balls available in CDA 260

Material Conversion

Material	AISI	Federal	ASTM	UNS	AMS
Yellow Brass	–	QQ-W-321	B134	C-27000	4712
Commercial Bronze	–	AA-W-321	B134	C-22000	–

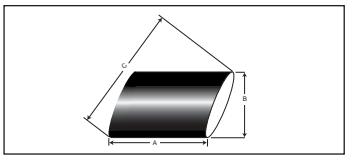
General Data (Brass Balls)†

Size in Inches	Metric Sizes	Balls per Pound	Balls per Carton	Metric Balls per Carton	Weight per Carton in Pounds
1/16		25,600	250,000		9.7
3/32		7,570	100,000		13.1
7/64	3mm	4,800	60,000	50,000	12.5
1/8		3,200	40,000		12.4
9/64		2,225	30,000		13.3
5/32	4mm	1,630	20,000	20,000	12.2
11/64		1,235	15,000		12.1
3/16	5mm	947	12,500	10,000	13.1
13/64		749	10,000		13.4
7/32		596	8,000		13.3
15/64	6mm	487	6,000	6,000	12.3
1/4		400	5,000		12.4
17/64	7mm	335	4,000	4,000	11.9
9/32		281	3,500		12.4
5/16	8mm	205	2,500	2,500	12.2
11/32	9mm	154	2,000	1,750	12.9
3/8	10, 11, 12mm	118	1,500	1,250, 1,000, 750	12.6
7/16		74	1,000		13.3
1/2		50	500		10.0
9/16		35	300		8.5
5/8		26	250		9.7
11/16		19	200		10.4
3/4		15	150		10.1
1		–	50		8.0

† Note: Other analyses of Brass and Bronze available upon request.

Diagonals

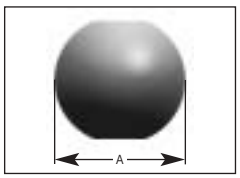
Diagonally-cut ends are effective for burnishing into fairly sharp angles and figured surfaces. Available in sizes 3/32" through 1". Materials include stainless steels, 52100 chrome steel, and ceramics.



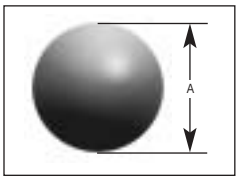
	3/32"	1/8"	5/32"	3/16"	7/32"	1/4"	5/16"
"A" Flat to Flat	.093	.125	.156	.187	.218	.250	.312
"B" Dia. (Equal to "A")	–	–	–	–	–	–	–
"C" Long Diagonal.155	.210	.260	.300	.340	.410	.470	

Burnishing Balls

Both types of Thomson Burnishing Balls are hardened polishing tools made like high grade bearing balls, but not held within close precision limits.



Regular
Commercial type with slight flats at poles – specified for most burnishing applications. Available in sizes 1/16" through 5/8".



Special
Round, free from flats. Preferred for applications where truer sphericity is required. Available in sizes 1/16" through 5/8".

Actual dimensions are given in this section: allowable tolerance ± .015. All types weigh approximately 180 pounds/cubic foot.

Zytel® Nylon 101 Balls

Made in sizes from 3/32" to 3/4"
Size Tolerance . . . . . .± .001 (SPH) .0005
. . . . . .± .002 (SPH) .001

Physical Properties

Coefficient of linear thermal expansion in./in./°F . . . . . .4.5 x 10^{-5}
Heat Distortion temp. at 264 psi . . . . . .170° F
. . . . . .at 66 psi . . . . . .400° F
Water Absorption (24 hrs.)1.5%
Specific Gravity 1.14
Hardness . . . . . .(Rockwell R118)
Tensile strength at 77° F 10,900 psi
Modulus of elasticity at 77° F . . . . . .400,000 psi
Shear strength . . . . . .9,600 psi

Delrin® Acetal Balls

Acetal Resin
Sizes 1/8" to 3/4"
SPH . . . . . .± .001
Tolerance . . . . . .± .002

Physical Properties

Color . . . . . .Natural (white)
Specific Gravity 1.425
Rockwell Hardness M94, R120
Tensile strength . . . . . .7,500 to 10,000 psi
Water Absorption (24 hrs.) 0.12%
Heat Distortion temp. at 66 psi . . . . . .338° F
Tabor abrasion (CS-17 Wheel) . . . . . .20 mg/1000 cycles
Flammability . . . . . Flammable
Impact Strength . . . . . .Izod 1.2-1.4 ft. lb./in.

Lexan® Balls

Polycarbonate Resin
Sizes 1/8" to 3/4"
SPH .± 001
Tolerance± 002

Physical Properties

Color . . . . . .Light Amber
Specific Gravity 1.20
Rockwell Hardness M70, R118
Tensile strength . . . . . .8,000 to 9,000 psi
Water Absorption (24 hrs.) 0.2%
Heat Distortion temp. at 66 psi . . . . . .283° F
Tabor abrasion (C5-17 Wheel) . . . . . .7-11/1000 cycle
Flammability . . . . . .Self-Extinguishing
Impact Strength . . . . . .Izod 12-16 ft. lb./in.

Available Grades and Tolerances

Grade†	Tolerance††	Sphericity
0	±.0005"	.0005"
I	±.001	.0005
II	±.002	.001
III	±.005	.005
IV	±.015	—

†Tolerance to +/-.0005 inches is possible for certain materials such as Nylon® and Acetal®. Surfaces can be tailored from rough to highly polished finishes. ††Grades apply to plastic balls only.

Special Balls (Available on Request)

1. Haynes Star-J
2. Haynes® 25
3. Hastelloy® Alloys
4. Haynes Stellite®
5. Tungsten Carbide

High Performance Ceramic Balls — Diameters: 1/16" to 2 1/2"

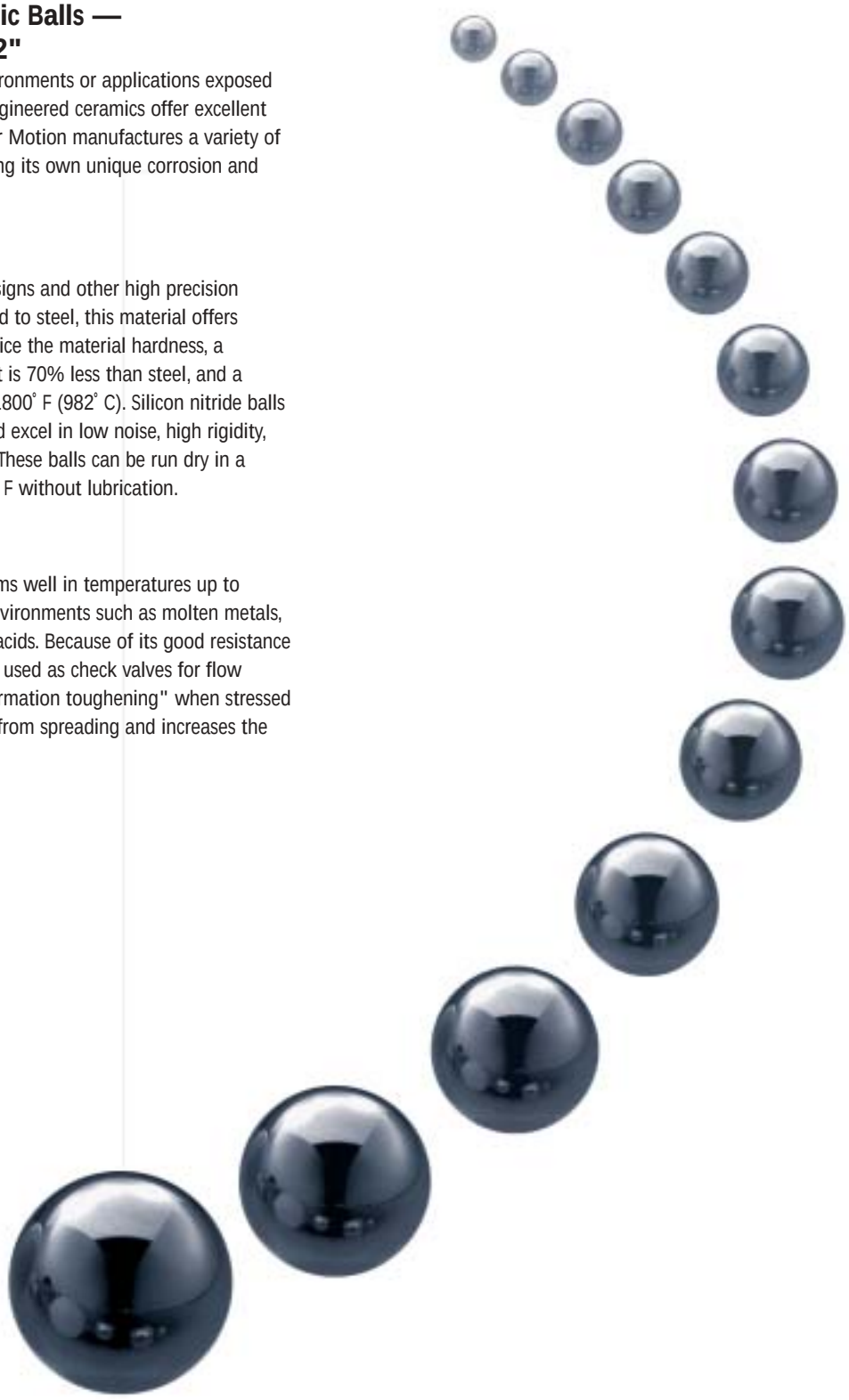
For extremely high temperature environments or applications exposed to harsh chemicals, balls made of engineered ceramics offer excellent performance characteristics. Danaher Motion manufactures a variety of precision ceramic balls, each providing its own unique corrosion and heat resistant qualities.

Silicon Nitride

A popular choice among bearing designs and other high precision product applications. When compared to steel, this material offers a 60% reduction in weight, up to twice the material hardness, a coefficient of thermal expansion that is 70% less than steel, and a temperature operating range up to 1800˚ F (982˚ C). Silicon nitride balls are non-corrosive, anti-magnetic, and excel in low noise, high rigidity, and high load carrying applications. These balls can be run dry in a vacuum environment and up to 500˚ F without lubrication.

Zirconia

A high-strength material that performs well in temperatures up to 1000˚ F (538˚ C). Operates well in environments such as molten metals, organic solvents, caustics and most acids. Because of its good resistance to abrasion and corrosion, it is often used as check valves for flow control. Zirconia undergoes "transformation toughening" when stressed by impact. This tends to stop cracks from spreading and increases the ball's strength in the stressed area.



Titanium Balls

This highly inert material is lightweight, offers exceptional anti-corrosive properties, operates effectively in high temperature applications, provides a high level of tension/compression strength, and has expansion characteristics similar to steel. Titanium is used extensively in aerospace applications as well as in the chemical, food processing, and medical implant industries.

Precision 440A Stainless Steel Hollow Balls

The one-inch hollow ball is utilized in weight sensitive applications requiring a combination of high surface hardness with material fracture toughness. Minimum crush strength is 6,000 lbs. Typical weight is 23 grams as compared to 65 grams for a solid ball, a reduction in weight of over 60%. Available in Grade 1000 tolerance or higher. Typical applications include aircraft ball transfer units, liquid float systems, and custom ball valves.

Hardness

440A stainless steel hardness as measured on parallel flats is Rockwell "C" 52-60.

Material Analysis – (Type 440A Stainless Steel)

Carbon	0.60 to 0.75%
Manganese	Maximum of 1.00%
Phosphorus	Maximum of 0.040%
Sulphur	Maximum of 0.030%
Silicon	Maximum of 1.00%
Chromium	16.00 to 18.00%
Molybdenum	Maximum of 0.75%

430 Stainless Steel Balls

Type 430 stainless steel is an economical stainless material that provides corrosion resistance at low cost. Typical applications for this product include cosmetic mixing media, decorative trim, and light duty ball valves.

Hardness

430 stainless steel is a non-hardenable stainless steel.

Material Analysis – (Type 430 Stainless Steel)

Carbon	Maximum of 0.12%
Manganese	Maximum of 1.00%
Phosphorus	Maximum of 0.040%
Sulphur	Maximum of 0.030%
Silicon	Maximum of 1.00%
Chromium	14.00 to 18.00%

Millimeter / Decimal / Fraction Conversion Chart†

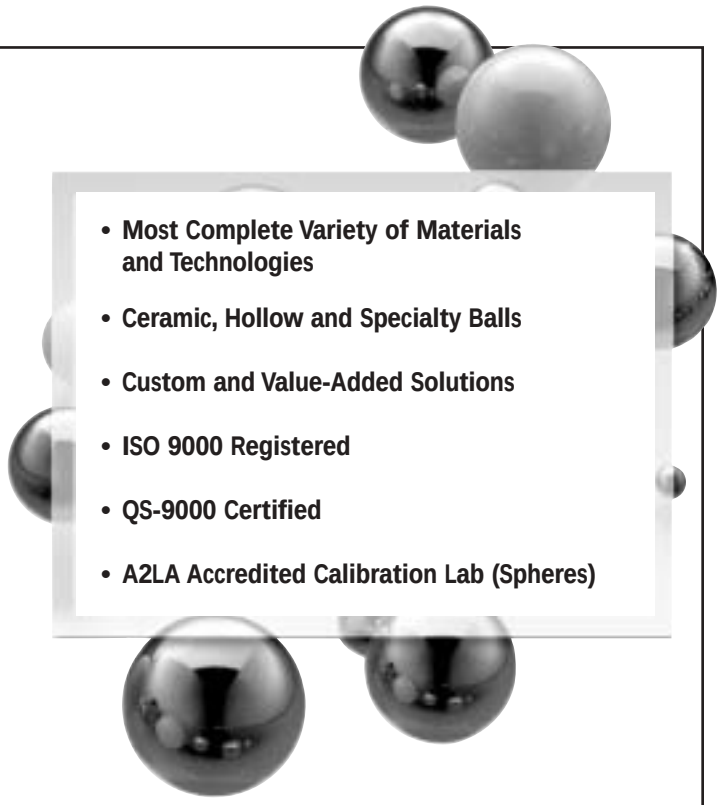
Milli-Meter	Decimal	Fraction (inches)	Milli-Meter	Decimal	Fraction (inches)	Milli-Meter	Decimal	Fraction (inches)	Milli-Meter	Decimal	Fraction (inches)	Milli-Meter	Decimal	Fraction (inches)	Milli-Meter	Decimal	Fraction (inches)
0.1	.0039		**4.366**	**.1719**	**11/64**	8.6	.3386		12.9	.5079		17.1	.6732		21.4	.8425	
0.2	.0079		4.4	.1732		8.7	.3425		13.0	.5118		17.2	.6772		**21.431**	**.8438**	**27/32**
0.3	.0118		4.5	.1772		**8.731**	**.3438**	**11/32**	**13.097**	**.5156**	**33/64**	17.3	.6811		21.5	.8465	
0.397	**.0156**	**1/64**	4.6	.1811		8.8	.3465		13.1	.5157		17.4	.6850		21.6	.8504	
0.4	.0157		4.7	.1850		8.9	.3504		13.2	.5197		**17.463**	**.6875**	**11/16**	21.7	.8543	
0.5	.0197		**4.763**	**.1875**	**3/16**	9.0	.3543		13.3	.5236		17.5	.6890		21 8	.8583	
0.6	.0236		4.8	.1890		9.1	.3583		13.4	.5276		17.6	.6929		**21.828**	**.8594**	**55/64**
0.7	.0276		4.9	.1929		**9.128**	**.3594**	**23/64**	**13.494**	**.5313**	**17/32**	17.7	.6968		21.9	.8622	
0.794	**.0313**	**1/32**	5.0	.1969		9.2	.3622		13.5	.5315		17.8	.7008		22.0	.8661	
0.8	.0315		5.1	.2008		9.3	.3661		13.6	.5354		**17.859**	**.7031**	**45/64**	22.1	.8701	
0.9	.0354		**5.159**	**.2031**	**13/64**	9.4	.3701		13.7	.5394		17.9	.7047		22.2	.8740	
1.0	.0394		5.2	.2047		9.5	.3740		13.8	.5433		18.0	.7087		**22.225**	**.8750**	**7/8**
1.1	.0433		5.3	.2087		**9.525**	**.3750**	**3/8**	**13.891**	**.5469**	**35/64**	18.1	.7126		22.3	.8780	
1.191	**.0469**	**3/64**	5.4	.2126		9.6	.3780		13.9	.5472		18.2	.7165		22.4	.8819	
1.12	.0472		5.5	.2165		9.7	.3819		14.0	.5512		**18.256**	**.7188**	**23/32**	22.5	.8858	
1.3	.0512		**5.556**	**.2188**	**7/32**	9.8	.3858		14.1	.5551		18.3	.7205		22.6	.8898	
1.4	.0551		5.6	.2205		9.9	.3898		14.2	.5591		18.4	.7244		**22.622**	**.8906**	**57/64**
1.5	.0591		5.7	.2244		**9.922**	**.3906**	**25/64**	**14.288**	**.5625**	**9/16**	18.5	.7283		22.7	.8937	
1.588	**.0625**	**1/16**	5.8	.2283		10.0	.3937		14.3	.5630		**18.563**	**.7323**	**47/64**	22.8	.8976	
1.6	.0630		5.9	.2323		10.1	.3976		14.4	.5669		18.6	.7344		22.9	.9016	
1.7	.0669		**5.953**	**.2344**	**15/64**	10.2	.4016		14.5	.5709		18.7	.7362		23.0	.9055	
1.8	.0709		6.0	.2362		10.3	.4055		14.6	.5748		18.8	.7402		**23.019**	**.9063**	**29/32**
1.9	.0748		6.1	.2402		**10.319**	**.4063**	**13/32**	**14.684**	**.5781**	**37/64**	18.9	.7441		23.1	.9094	
1.984	**.0781**	**5/64**	6.2	.2441		10.4	.4094		14.7	.5787		19.0	.7480		23.2	.9134	
2.0	.0787		6.3	.2480		10.5	.4134		14.8	.5827		**19.050**	**.7500**	**3/4**	23.3	.9173	
2.1	.0827		**6.350**	**.2500**	**1/4**	10.6	.4173		14.9	.5866		19.1	.7520		23.4	.9213	
2.2	.0866		6.4	.2520		10.7	.4213		15.0	.5906		19.2	.7559		**23.416**	**.9219**	**59/64**
2.3	.0906		6.5	.2559		**10.716**	**.4219**	**27/64**	**15.081**	**.5938**	**19/32**	19.3	.7598		23.5	.9252	
2.381	**.0938**	**3/32**	6.6	.2598		10.8	.4252		15.1	.5945		19.4	.7638		23.6	.9291	
2.4	.0945		6.7	.2638		10.9	.4291		15.2	.5984		**19.447**	**.7656**	**49/64**	23.7	.9331	
2.5	.0984		**6.747**	**.2656**	**17/64**	11.0	.4331		15.3	.6024		19.5	.7677		23.8	.9370	
2.6	.1024		6.8	.2677		11.1	.4370		15.4	.6063		19.6	.7717		**23.813**	**.9375**	**15/16**
2.7	.1063		6.9	.2717		**11.113**	**.4375**	**7/16**	**15.478**	**.6094**	**39/64**	19.7	.7756		23.9	.9409	
2.778	**.1094**	**7/64**	7.0	.2756		11.2	.4409		15.5	.6102		19.8	.7795		24.0	.9449	
2.8	.1102	71	7.1	.2795		11.3	.4449		15.6	.6142		**19.844**	**.7813**	**25/32**	24.1	.9488	
2.9	.1142		**7.144**	**.2813**	**9/32**	11.4	.4488		15.7	.6181		19.9	.7835		24.2	.9567	
3.0	.1181		7.2	.2835		11.5	.4528		15.8	.6220		20.0	.7874		**24.209**	**.9531**	**61/64**
3.1	.1220		7.3	.2874		**11.509**	**.4531**	**29/64**	**15.875**	**.6250**	**5/8**	20.1	.7913		24.3	.9567	
3.175	**.1250**	**1/8**	7.4	.2913		11.6	.4567		15.9	.6260		20.2	.7953		24.4	.9606	
3.2	.1260		7.5	.2953		11.7	.4606		16.0	.6299		**20.241**	**.7969**	**51/64**	24.5	.9646	
3.3	.1299		**7.541**	**.2969**	**19/64**	11.8	.4646		16.1	.6339		20.3	.7992		24.6	.9685	
3.4	.1339		7.6	.2992		11.9	.4685		16.2	.6378		20.4	.8031		**24.606**	**.9688**	**31/32**
3.5	.1378		7.7	.3031		**11.906**	**.4688**	**15/32**	**16.272**	**.6406**	**41/64**	20.5	.8071		24.7	.9724	
3.572	**.1406**	**9/64**	7.8	.3071		12.0	.4724		16.3	.6417		20.6	.8110		24.8	.9764	
3.6	.1417		7.9	.3110		12.1	.4764		16.4	.6457		**20.638**	**.8125**	**13/16**	24.9	.9803	
3.7	.1457		**7.938**	**.3125**	**5/16**	12.2	.4803		16.5	.6496		20.7	.8150		25.0	.9843	
3.8	.1496		8.0	.3150		12.3	.4843		16.6	.6535		20.8	.8189		**25.003**	**.9844**	**63/64**
3.9	.1535		8.1	.3189		**12.303**	**.4844**	**31/64**	**16.669**	**.6563**	**21/32**	20.9	.8228		25.1	.9882	
3.969	**.1563**	**5/32**	8.2	.3228		12.4	.4882		16.7	.6575		21.0	.8268		25.2	.9921	
4.0	.1575		8.3	.3268		12.5	.4921		16.8	.6614		**21.034**	**.8281**	**53/64**	25.3	.9961	
4.1	.1614		**8.334**	**.3281**	**21/64**	12.6	.4961		16.9	.6654		21.1	.8307		**25.400**	**1.00001**	
4.2	.1654		8.4	.3307		**12.7**	**.5000**	**1/2**	17.0	.6693		21.2	.8346				
4.3	.1693		8.5	.3346		12.8	.5039		**17.066**	**.6719**	**43/64**	21.3	.8386				

† All millimeter and decimal equivalents have been rounded off to the next higher digit when following digit is 5 (five) or more.

Thomson Precision Ball Quick Quote Fax Form

Note: All standard balls are always in stock and ready for immediate, off-the-shelf delivery. If your application calls for custom balls, fax us your specifications for a free quotation.

To receive your quote, complete this form and fax it to us at: 516-883-8050 or Toll Free: 1-800-445-0329.



- **Most Complete Variety of Materials and Technologies**
- **Ceramic, Hollow and Specialty Balls**
- **Custom and Value-Added Solutions**
- **ISO 9000 Registered**
- **QS-9000 Certified**
- **A2LA Accredited Calibration Lab (Spheres)**

Nominal Ball Diameter _____

Type of Material:

❑ 52100 Chrome Steel
❑ Monel
❑ Titanium
❑ Non-Metallic _____ (Specify)

❑ Bronze
❑ Brass
❑ Ceramic
❑ Other _____ (Specify)

Stainless Steel

❑ 302 ❑ 316
❑ 316L ❑ 430
❑ 440C ❑ Other _____ (Specify)

Grade _____ Ball Gage(1) _____

Quantity Required _____ Estimated Annual Usage _____

(1) 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 –) in 0.0001" or micron increments.

For immediate assistance, call us Toll-Free at 1-800-554-8466

Name _____

Title _____

Company _____

Address _____

City _____ State _____ Zip _____

Phone _____

Fax _____ E-mail _____

Danaher Motion's A2LA Certified Calibration Lab

The Danaher Motion A2LA accredited calibration laboratory offers a unique blend of the finest environment of metrology for the calibration of spheres and forty-five years of experience manufacturing Thomson precision balls. The experience assures our customers that the spheres we calibrate for them do not contain any hidden damage which might go undetected by a calibration lab inexperienced in working with spheres.

How Can Our Lab Help You?

If a company is required to be QS-9000 compliant, calibration facilities of that company must meet the requirements of QS-9000 4.10.6.1 and 4.10.6.6. If this is not the case, then their standards must be calibrated by an ISO 17025 accredited calibration laboratory.

For example: suppose a facility uses a coordinate axis-measuring machine and the check standard is a ball bar. An ISO 17025 accredited calibration laboratory, whose scope of accreditation includes spheres, must calibrate that sphere.

The manufacturer of the ball bar may have supplied a calibration for that sphere. However, unless the manufacturer is ISO 17025 compliant and their scope of accreditation includes spheres, their certificate does not meet the requirements of QS-9000.

Danaher Motion's calibration laboratory management system has been audited and found to comply with QS-9000, ISO 9002, AISI/ISO/ASQ9002 and in accordance with QS's Appendix B Code of Practice.

How To Determine Competency

A good indicator of competency for a calibration laboratory is the degree of uncertainty that lab is able to demonstrate. Danaher Motion's metrology lab demonstrates an uncertainty of:

- 8 microinches for diameter calibration
- 0.56 microinches for roundbess calibration
- a dead band of less than 4 nanometers for surface finish calibration.

How Do We Achieve These Results?

Our laboratory comparison masters are Tungsten Carbide and have been calibrated by the National Institute of Standards and Technology (NIST) for minimum uncertainty and maximum accuracy. Our gage environment is controlled to be between Class 1000 and Class 10,000 cleanliness levels and temperature is regulated to +/- 0.5 degrees Fahrenheit.

Calibrating Diameter

We measure diameter in accordance with the requirements of ABMA Standard 10.

The instrumentation system consists of proprietary gage amplifiers operating at a range of +/- 0.001 inches with a resolution of +/- 0.000001 inches. The gage heads are mounted on precision comparator stands with a capacity of over 9 inches. The stands have rugged bases for stability and the gage heads are mounted units which allow friction free straight-line motion.

The specimen balls are positioned in custom crafted fixtures that assure the ball will return to the same gage location for each reading. This minimizes any adverse effect of surface condition or parallelism.

Calibrating Ball Roundness

We measure ball roundness on our proprietary geometrical gage system. This system uses a design specifically engineered to gage spheres.The holding system for this measurement will accommodate balls from 0.020 inch diameter to 10.00-inch diameter, with the appropriate fixturing. The active elements of the gage system are engineered to minimize any vibration.

Calibrating Surface Finish

We calibrate surface finish on our state of the art surface finish measuring equipment. This equipment is mounted on a vibration isolation table. The standard stylus is conical diamond. However, surface finish metrology is limited only by the ingenuity of the holding fixture. Our gage travel is limited to 50mm. The wavelength of the roughness filter can be as small as 0.0001 inches or as large as 1.0 inches. We are able to evaluate surface finish in as many as 27 different surface finish parameters.

The resolution is approximately four nm, which is only one nm less than the resolution NIST uses to measure surface finish. A NIST calibrated Tungsten Carbide check standard is used to verify the continued performance of the instrument.

THOMSON™

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