Designation: B438 – 08

StandardSpecification for Bronze-Base Powder Metallurgy (PM) Bearings (Oil-Impregnated)[1]

This standard is issued under the fixed designation B438; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification covers porous metallic sleeve, flange, thrust and spherical bronze-base bearings that are produced from mixed metal powders utilizing powder metallurgy (PM) technology and then impregnated with oil to supply operating lubrication.

1.2 Included are the specifications for the chemical, physical and mechanical requirements of those bronze-base PM materials that have been developed and standardized specifically for use in the manufacture of these self-lubricating bearings.

1.3 This specification is applicable to the purchase of bronze-base bearings (oil-impregnated) that were formerly covered by military specifications and are intended for government or military applications. Those additional government requirements that only apply to military bearings are listed in the Supplementary Requirements section of this specification.

1.4 This specification acccompanies Specification B439 that covers the requirements for Iron-Base Powder Metallurgy (PM) Bearings, (Oil-Impregnated).

1.5 Typical applications for bronze-base bearings are listed in Appendix X1.

1.6 Bearing dimensional tolerance data are shown in Appendix X2, while engineering information regarding installation and operating parameters of PM bearings is included in Appendix X3. Additional useful information on self-lubricating bearings can be found in MPIF Standard 35 and the technical literature.[2]

1.7 With the exception of density values for which the g/cm^3 unit is the industry standard, the values stated in inch-pound units are to be regarded as standard. The SI equivalents of inch-pound units, shown in parenthesis, have been converted in accordance with IEEE/ASTM SI 10, may be approximate and are only for information.

1.8 *The following safety hazards caveat pertains only to the test methods described in this specification. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

B243 Terminology of Powder Metallurgy

B328 Test Method for Density, Oil Content, and Interconnected Porosity of Sintered Metal Structural Parts and Oil-Impregnated Bearings (Withdrawn 2009)[4]

B439 Specification for Iron-Base Powder Metallurgy (PM) Bearings (Oil-Impregnated)

B939 Test Method for Radial Crushing Strength, ***K***, of Powder Metallurgy (PM) Bearings and Structural Materials

B946 Test Method for Surface Finish of Powder Metallurgy (PM) Products

E9 Test Methods of Compression Testing of Metallic Materials at Room Temperature

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

E1019 Test Methods for Determination of Carbon, Sulfur, Nitrogen, and Oxygen in Steel, Iron, Nickel, and Cobalt Alloys by Various Combustion and Fusion Techniques

2.2 *MPIF Standard:*

MPIF Standard 35 Materials Standards for PM Self-Lubricating Bearings[5]

[1] This specification is under the jurisdiction of ASTM Committee B09 on Metal Powders and Metal Powder Products and is the direct responsibility of Subcommittee B09.04 on Bearings.

Current edition approved June 1, 2008. Published July 2008. Originally approved in 1966. Last previous edition approved in 2005 as B438/B438M – 05. DOI: 10.1520/B0438-08.

[2] *Machine Design Magazine*, Vol 54, #14, June 17, 1982, pp. 130-142.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] The last approved version of this historical standard is referenced on www.astm.org.

[5] Available from MPIF, 105 College Road East, Princeton, NJ 08540, telephone (609) 452-7700.

***A Summary of Changes section appears at the end of this standard**

2.3 *IEEE/ASTM Standard:*

SI 10 American National Standard for Use of the International System of Units (SI): The Modernized Metric System[3]

2.4 *ISO Standard:*

ISO 2795 Plain Bearings Made from Sintered Metal—Dimensions and Tolerances[6]

2.5 *Government Standards:*

MIL-PRF-6085 Lubricating Oil: Instrument, Aircraft, Low Volatility[7]

QPL-6085 Lubricating Oil: Instrument, Aircraft, Low Volatility[7]

MIL-PRF-17331 Lubrication Oil, Steam Turbine and Gear, Moderate Service[7]

QPL-17331 Lubricating Oil, Steam Turbine and Gear, Moderate Service[7]

MIL-B-5687 Bearings, Sleeve, Washers, Thrust, Sintered, Metal Powder, Oil-Impregnated, General Specification For[7]

MS17795 Bearing, Sleeve, Plain, Sintered Bronze, Oil-Impregnated[7]

MS17796 Bearing, Sleeve, Flanged, Sintered Bronze, Oil-Impregnated[7]

MS21783 Bearing, Washer, Thrust, Sintered Bronze, Oil-Impregnated[7]

3. Terminology

3.1 *Definitions*—The definitions of the terms used in this specification are found in Terminology B243. Additional descriptive information is available in the Related Materials section of Volume 02.05 of the *Annual Book of ASTM Standards* .

4. Classification

4.1 This specification uses the established three-part alpha-numeric PM Material Designation Code to identify the non-ferrous materials used for self-lubricating PM bearings. The complete explanation of this classification system is presented in Annex A1.

4.2 The following standard oil-impregnated bronze-base bearing material compositions are contained in this specification:

4.2.1 *Prefix CT—Bronze:*

CT-1000-K19—Bronze with 24 % oil
CT-1000-K26—Bronze with 19 % oil
CT-1000-K37—Bronze with 12 % oil
CT-1000-K40—Bronze with 9 % oil

4.2.2 *Prefix CTG—Bronze-Graphite :*

CTG-1001-K17—Bronze, 1 % graphite with 22 % oil
CTG-1001-K23—Bronze, 1 % graphite with 17 % oil
CTG-1001-K30—Bronze, 1 % graphite with 9 % oil
CTG-1001-K34—Bronze, 1 % graphite with 7 % oil

4.2.3 *Prefix CTG—Bronze-High Graphite:*

CTG-1004-K10—Bronze, 4 % graphite with 11 % oil
CTG-1004-K15—Bronze, 4 % graphite with a trace or up to 8 % oil

4.2.4 *Prefix CTG-MOD—Bronze-Lead-Graphite (Military Grade):*

CTG-1001-K23-MOD—Bronze, 3 % lead, 1 % graphite with 17 % oil

4.2.5 *Prefix CFTG—Bronze-Iron-Graphite (Diluted Bronze):*

CFTG-3806-K14—Bronze, 40 % iron, 0.75 % graphite with 22 % oil
CFTG-3806-K22—Bronze, 40 % iron, 0.75 % graphite with 17 % oil

5. Ordering Information

5.1 Purchase orders or contracts for bronze-base, oil-impregnated bearings covered by this purchasing specification shall include the following information:

5.1.1 A copy of the bearing print showing dimensions and tolerances (Section 10),

5.1.2 Reference to this ASTM Standard, including date of issue,

5.1.3 Identification of bearing material by the PM Material Designation Code (section 4.2),

5.1.4 Request for Certification and Test Report documents, if required (Section 16),

5.1.5 Type and grade of special Lubricating Oil, if required (section 6.2 or S2.2),

5.1.6 Instructions for Special Packaging, if required (Section 17).

5.2 Those additional government requirements necessary on orders for military bearings are prescribed in the Supplementary Requirements section.

6. Materials and Manufacture

6.1 *Porous Metallic Bearing:*

6.1.1 Sintered bronze-base bearings shall be produced by first compacting pre-alloyed bronze or elemental copper and tin powders and any other additives appropriate for the composition to the proper density and bearing configuration.

6.1.2 The green bearings shall then be sintered in a protective atmosphere furnace for a time and temperature relationship that will produce the required sintered bronze-base PM material.

6.1.3 After sintering, the bronze-base bearings are normally sized to achieve the density, dimensional characteristics, concentricity and surface finish required of the metallic bearing.

6.2 *Oil for Operating Lubrication:*

6.2.1 The interconnected or open porosity in the bearings shall be filled to the required volume with lubricating oil, either by an extended soaking in the hot oil or preferably by a vacuum impregnation operation.

6.2.2 A medium viscosity petroleum oil is normally used for most bearing applications, but extreme operating conditions such as elevated temperatures, intermittent rotation, extremely low speeds or heavy loads may require a synthetic lubricant or an oil with a different viscosity.

6.2.3 Unless otherwise specified by the purchaser, a high-grade turbine oil with antifoaming additives and containing corrosion and oxidation inhibitors, having a kinematic viscosity of 280 to 500 SSU [(60 × 10^{-6} to 110 × 10^{-6} m^2/s), (60 to

[6] ISO standards are available from the American National Standards Institute (ANSI), 16 West 42nd Street, New York, NY 10036, (212) 642-4900.

[7] Available from Standardization Documents Order Desk, Bldg 4, Sec. D, 700 Robbins Ave, Philadelphia, PA 19111-5094. Electronic copies of military specifications may be obtained from http://assist.daps.dla.mil/.

TABLE 1 Specifications for Bronze-Base Materials used in PM Bearings

Material Designation Code	Chemical Requirements						Physical Requirements		Mechanical Requirements	
									Radial Crushing Strength, K	
	Copper mass %	Tin mass %	Lead mass %	Graphitic Carbon mass %	Iron mass %	All Others mass %	Impregnated Density g/cm^3	Content Oil vol %	10^3 psi	(MPa)
Bronze										
CT-1000-K19	bal	9.5-10.5	—	0.3 max	1.0 max	1.0 max	6.0-6.4	24 min[A]	19 min	(130 min)
CT-1000-K26	bal	9.5-10.5	—	0.3 max	1.0 max	1.0 max	6.4-6.8	19 min	26 min	(180 min)
CT-1000-K37	bal	9.5-10.5	—	0.3 max	1.0 max	1.0 max	6.8-7.2	12 min	37 min	(260 min)
CT-1000-K40	bal	9.5-10.5	—	0.3 max	1.0 max	1.0 max	7.2-7.6	9 min	40 min	(280 min)
Bronze-Graphite										
CTG-1001-K17	bal	9.5-10.5	—	0.5-1.8	1.0 max	1.0 max	6.0-6.4	22 min[B]	17 min	(120 min)
CTG-1001-K23	bal	9.5-10.5	—	0.5-1.8	1.0 max	1.0 max	6.4-6.8	17 min	23 min	(160 min)
CTG-1001-K30	bal	9.5-10.5	—	0.5-1.8	1.0 max	1.0 max	6.8.7.2	9 min	30 min	(210 min)
CTG-1001-K34	bal	9.5-10.5	—	0.5-1.8	1.0 max	1.0 max	7.2-7.6	7 min	34 min	(230 min)
Bronze-High Graphite										
CTG-1004-K10	bal	9.2-10.2	—	2.5-5.0	1.0 max	1.0 max	5.8-6.2	11 min	10 min	(70 min)
CTG-1004-K15	bal	9.2-10.2	—	2.5-5.0	1.0 max	1.0 max	6.2-6.6	[C]	15 min	(100 min)
Bronze-Lead-Graphite (Military Grade)										
CTG-1001-K23-MOD[D]	bal	9.5-10.5	2.0-4.0	0.5-1.75	1.0 max	0.5 max	6.4-6.8	17 min	23 min	(160 min)
Bronze-Iron-Graphite (Diluted Bronze)										
CFTG-3806-K14	bal	5.5-6.5	—	[E]	36.0-40.0[F]	2.0 max	5.6-6.0	22 min	14-35	(100-240)
CFTG-3806-K22	bal	5.5-6.5	—	[E]	36.0-40.0[F]	2.0 max	6.0-6.4	17 min	22-50	(150-340)

[A] For an oil content of 27 % min, density range shall be 5.8-6.2 g/cm^3 and radial crushing strength shall be 15 000 psi (100 MPa) minimum.
[B] For an oil content of 25 % min, density range shall be 5.8-6.2 g/cm^3 and radial crushing strength shall be 13 000 psi (90 MPa) minimum.
[C] At maximum graphite (5 %) and density (6.6 g/cm^3), this material will contain only a trace of oil. At 3 % graphite and 6.2-6.6 g/cm^3 density, it shall contain 8 vol% (min.) of oil.
[D] Additional chemical requirements are: Zinc–0.75 % max, Nickel–0.35 % max, Antimony–0.25 % max.
[E] Graphitic carbon content is typically 0.5-1.3 %; total carbon shall be 0.5-1.3 %.
[F] The iron portion may contain 0.5 % max metallurgically combined carbon.

110 cSt)] at 100°F (38°C) is normally used as a general purpose lubricating oil.

7. Chemical Composition

7.1 *Chemical Composition Specifications*—Each bronze-base PM bearing material shall conform to the chemical requirements prescribed in Table 1 when determined on a clean test sample from oil-free bearings.

7.2 *Limits on Nonspecified Elements*— By agreement between the purchaser and the supplier, limits may be established and chemical analyses required for elements or compounds not specified in Table 1.

8. Physical Properties

8.1 *Oil Content*—For each bearing material, the oil content of the as-received bearing shall not be less than the minimum percentage listed in Table 1.

8.2 *Impregnation Efficiency*—A minimum of 90 % of the interconnected porosity in the as-received bearings shall be impregnated with lubricating oil.

8.3 *Impregnated Density*—The density of the sample bearings, when fully impregnated with lubricating oil, shall meet the requirements prescribed in Table 1 for each bearing material.

9. Mechanical Properties

9.1 *Radial Crushing Strength*—The radial crushing strength of the oil-impregnated bearing material determined on a plain sleeve bearing or a test specimen prepared from a flange or spherical bearing shall meet the minimum and maximum (if required) strength values listed in Table 1.

10. Dimensions, Mass, and Permissible Variations

10.1 This standard is applicable to bronze-base PM sleeve and flange bearings having a 4 to 1 maximum length to inside diameter ratio and a 24 to 1 maximum length to wall thickness ratio.

10.2 Sleeve, flange, thrust and spherical PM bearings covered by this specification are illustrated by Figs. 1-4. Most PM bearings are small and weigh less than one-quarter pound (~100 g) but they can be produced in sizes that will accommodate shafts up to approximately 8 in. (200 mm) in diameter.

10.3 Permissible variations in dimensions shall be within the tolerance limits shown on the bearing print accompanying the order or shall be within the limits specified in the purchase order or contract. Dimensional tolerances of bearings for military or government applications shall meet the requirements specified in the Supplementary Requirements section.

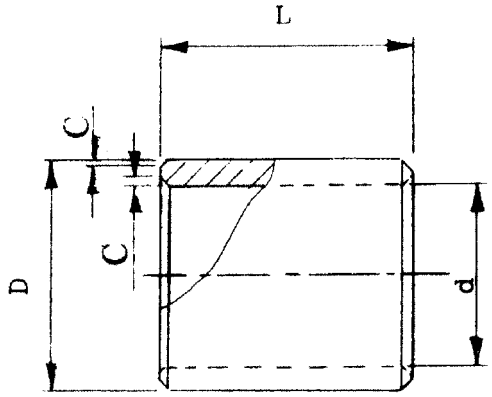

FIG. 1 Standard Sleeve Bearing

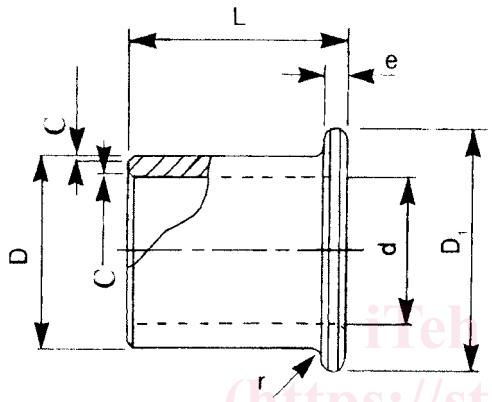

FIG. 2 Standard Flange Bearing

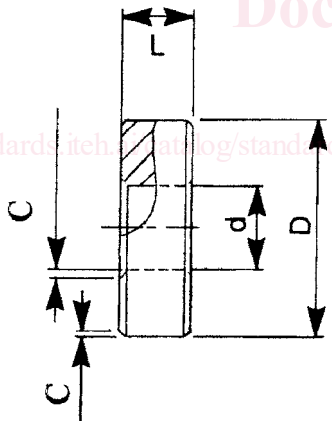

FIG. 3 Standard Thrust Bearing

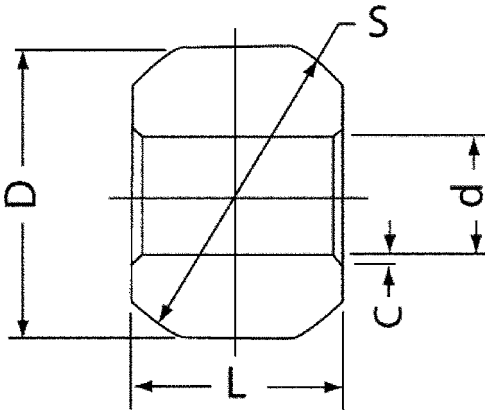

FIG. 4 Standard Spherical Bearing

10.4 Recommended commercial tolerances for bronze-base PM bearings are referenced throughout the tables in Appendix X2.

10.5 Chamfers of 30-45° are generally used on PM bearings to break the corners.

11. Workmanship, Finish, and Appearance

11.1 The bearings should have a matte surface and not show oxidation. The surfaces of sized bearings should have a smooth, bright finish.

11.2 When cut or fractured, the exposed surface of the bearings should exhibit a uniform visual appearance.

11.3 If metallographic examination is performed to determine degree of sintering, it should be done at 200-400× magnification. In 90Cu-10Sn bronze bearings, the microstructure should be alpha bronze with no silver-gray tin-rich copper compounds and with a minimum of reddish copper-rich areas. The structure should have a very minimum number of original particle boundaries. Diluted Bronze material should show a bronze phase with no visible free tin, dispersed throughout an iron matrix.

11.4 To verify that oil is present, heat the bearing to about 300°F (150°C) for 5 minutes. If oil is present, the bearing surfaces exhibit beads of oil being exuded from the pores.

11.5 When bearings are ordered as being “dry-to-the-touch” to allow automated handling by the purchaser, the excess surface oil is normally removed by a centrifugal operation. It is important that the Oil Content test (13.3.2) be performed after the surface drying treatment to make certain that the required volume of lubricating oil is present.

12. Sampling

12.1 *Lot*—Unless otherwise specified, a lot shall be defined as a specific quantity of bearings manufactured under traceable, controlled conditions as agreed to between the producer and user (Terminology B243).

12.2 *Sampling Plan*—The number of sample bearings, agreed to between the manufacturer and the purchaser, to be used for inspections shall be taken randomly from locations throughout the lot.

13. Test Methods

13.1 *Dimensional Measurements:*

13.1.1 Using suitable measuring equipment, the inside diameter of the bearings shall be measured to the nearest 0.0001 in. (0.0025 mm). The other bearing dimensions only require instrumentation capable of measuring to the tolerances specified on the bearing drawing.

13.2 *Chemical Analysis:*

13.2.1 *Oil Extraction*—Bearings must be dry and free of oil before running chemical tests. To remove oil, a Soxhlet Apparatus as specified in Test Method B328 may be used. However, upon agreement between purchaser and supplier, a low-temperature furnace treatment [1000 to 1200°F (540 to 650°C)] with a flowing nitrogen or inert atmosphere may be used to volatilize any lubricant that may be present.

13.2.2 *Metallic Elements*—The chemical analysis of metallic elements shall be performed on an oil-free sample in accordance with the test methods prescribed in Volume 03.05 of the *Annual Book of ASTM Standards* or by another approved method agreed upon between the manufacturer and the purchaser.

13.2.3 *Combined Carbon*—To determine the amount of carbon metallurgically combined with the iron in the diluted bronze materials, a metallographic estimate may be made.

13.2.4 *Graphitic Carbon*—Determine the total carbon content in accordance with Test Method E1019 with the exception that a sample as small as 0.25 g may be used upon agreement between customer and supplier. With the exception of diluted bronze, the graphitic carbon provides an estimate of the total carbon. For diluted bronze, the graphitic carbon is approximately equal to the total carbon minus the combined carbon as determined in 13.2.3.

13.3 *Physical Properties:*

13.3.1 *Oil Content*—The oil content of the as-received bearing shall be determined following the procedure for *Oil Content by Volume as Received* in Test Method B328.

13.3.2 *Impregnation Efficiency*—The efficiency of the oil-impregnation process in volume percent units shall be calculated as the ratio of the *Oil Content by Volume as Received to the Interconnected Porosity* using the procedures and formulas in Test Method B328.

13.3.3 *Impregnated Density*—The impregnated density of the sample bearings in g/cm^3 units, measured after they have been fully impregnated, shall be determined following the procedure for *Wet Density* in Test Method B328.

13.4 *Mechanical Properties:*

13.4.1 *Radial Crushing Strength*—Radial crushing strength in psi (MPa) is the mechanical property by which the strength of oil-impregnated PM bearing material is characterized and evaluated. It is determined by breaking plain thin-walled bearings or hollow cylindrical test specimens under diametrical loading, following the procedures described in Test Method B939, and calculating the radial crushing strength according to the material strength formula contained therein.

13.4.1.1 Plain sleeve bearings and thrust bearings are tested in the oil-impregnated condition. For acceptance, the radial crushing strength, determined on the test bearings, shall not be less than the minimum nor more than the maximum (if applicable) strength specification values listed in Table 1 for the bearing material.

13.4.1.2 Flanged oil-impregnated bearings shall be tested by cutting off the flange and crushing the body as a plain sleeve bearing. For acceptance, the radial crushing strength so determined shall meet the minimum and maximum (if applicable) material strength requirements prescribed in Table 1. The testing procedure and material strength requirements of the flange shall be a matter of agreement between manufacturer and purchaser.

13.4.1.3 To evaluate spherical, or bearings of other configuration, a number of sample bearings from the lot shall first be machined to a right circular cylinder, measured, and then crushed to determine the radial crushing strength of the oil-impregnated bearing material. This value shall not be less than the minimum nor more than the maximum (if applicable) radial crushing strength specified in Table 1 for the material in the sample bearings.

13.4.2 *Bearing Breaking Load*—If agreed to by the manufacturer and the purchaser, an acceptance specification for the minimum (maximum) bearing breaking load, $P_{min,}$ (P_{max}) in lbf (N), may be established for any specific standard oil-impregnated bearing. This simplifies acceptance testing because the decision is now based solely upon reading the output of the testing machine without a need for further calculations. This acceptance procedure can be very useful when evaluating multiple or repeat shipments of the same bearing.

13.4.2.1 The minimum (maximum) breaking load, $P_{min,} (P_{max})$ required for acceptance of any specific plain sleeve or thrust bearing is calculated using the breaking load formula:

$$P_{min,} (P_{max}) = \frac{K \times L \times t^2}{D - t} \quad (1)$$

where:

$P_{min,} (P_{max})$ = minimum (maximum) bearing breaking load, lbf (N),
K = minimum (maximum) radial crushing strength, psi (MPa),
L = length of bearing, in. (mm),
t = wall thickness, [$t = (D - d) / 2$], in. (mm),
D = outside diameter, in. (mm), and
d = inside diameter, in. (mm).

13.4.2.2 Use the minimum (maximum) radial crushing strength value specified for the oil-impregnated bearing material from Table 1 for K, use the actual D, d and L dimensions of the as-received bearing and solve for $P_{min,} (P_{max})$. This calculated value will be the minimum (maximum) acceptable breaking load for that specific plain bearing. Using the allowable print dimensions that minimize (maximize) the volume of the bearing for the calculations will result in a breaking load specification(s) that will be applicable to any lot of that specific bearing.

13.4.2.3 The minimum (maximum) acceptable breaking load for a specific flanged bearing shall be calculated by first cutting off the flange and measuring the D, d and L of the body. Then, using the minimum (maximum) radial crushing strength for the oil-impregnated bearing material in Table 1 for K in the breaking load formula and the measured dimensions of the body, a $P_{min,}$ (P_{max}) value may be calculated. This will be the minimum (maximum) bearing breaking load required for the body of that specific flanged bearing. The test procedure and breaking load requirements for the flange shall be a matter of agreement between purchaser and manufacturer.

13.4.2.4 For acceptance testing of whole spherical bearings, a minimum (maximum) bearing breaking load specification,

$P_{min,}$ (P_{max}) may be established on a specific whole spherical oil-impregnated bearing. First, the radial crushing strength, K_a, is determined on that specific spherical bearing machined to a plain cylinder as in 13.4.1.3. Second, whole spherical bearings from the same lot are crushed, keeping their axes horizontal, to determine the breaking load of the whole bearing. Then, using the correlation formula, the specifications for the breaking load, $P_{a,}$ of that whole spherical bearing are calculated as follows:

$$P_{min,}\,(P_{max}) = \frac{K \times P_a}{K_a} \tag{2}$$

where:

$P_{min,}\,(P_{max})$ = specification for the minimum (maximum) bearing breaking load of a specific whole spherical bearing, lbf (N),

K_a = radial crushing strength of the machined test spherical bearings according to 13.4.1.3, psi (MPa),

K = minimum (maximum) radial crushing strength for the bearing material, (Table 1), psi (MPa), and

P_a = breaking load of whole test spherical bearings, lbf (N).

13.5 *Conformance:*

13.5.1 *Dimensional Measurements*—For purposes of determining conformance with the dimensional specifications, the tolerance limits specified on the bearing print are considered absolute limits as defined in Practice E29.

13.5.2 *Chemical, Physical, Mechanical Test Results*—For purposes of determining conformance with these specifications, an observed value or calculated value shall be rounded "to the nearest unit" in the last right-hand digit used in expressing the specification limit, in accordance with the rounding-off method of Practice E29.

13.5.3 *Measurement Uncertainty*—The precision and bias of the test result values shall be considered by the purchaser and supplier in determining conformance.

14. Inspection

14.1 The manufacturer has the primary responsibility to conduct the necessary measurements and tests to ensure that the bearings meet the requirements of the purchase order or contract and this specification before they are shipped to the customer.

14.2 Provided the manufacturer notifies the purchaser, all or a portion of the required conformance tests may be contracted to a qualified third party.

14.3 Upon receipt of the shipment, the purchaser may conduct whatever quality control inspections that he feels are necessary to confirm compliance to the purchasing requirements.

15. Rejection and Rehearing

15.1 Rejection based on tests made in accordance with this specification shall be reported in writing to the manufacturer within 30 days of receipt of the shipment; the rejected bearings, however, shall not be returned or disposed of without written authorization from the producer.

15.2 In case of dissatisfaction with the test results, either the purchaser or manufacturer may make a claim for rehearing.

16. Certification and Test Report

16.1 The purchaser may require in the purchase order or contract that the manufacturer shall supply a Certificate of Compliance stating that the bearings were produced and tested in accordance with this specification and met all requirements.

16.2 In addition, when required by the purchase order or contract, the manufacturer shall furnish a Test Report that lists the results of the chemical, physical, mechanical and functional tests performed on the sample bearings.

16.3 When required, the Certificate of Compliance or the Test Report, or both may be transmitted by electronic service.

17. Packaging

17.1 Unless specific packaging requirements are included in the purchase order or contract, the finished oil-impregnated PM bearings shall be packaged and shipped in containers of a nonabsorbent material to prevent loss of lubricating oil.

18. Keywords

18.1 bearing breaking load; bronze bearings; impregnated density; interconnected porosity; oil content; oil-impregnated bearings; open porosity; porous metallic bearings; radial crushing strength; self-lubricating bearings; PM bearings; PV Factor; PV Limit

SUPPLEMENTARY REQUIREMENTS

MILITARY BEARINGS, SINTERED BRONZE, OIL-IMPREGNATED

The following supplementary requirements shall apply to purchase orders or contracts from all agencies of the United States Government or where specified by a purchaser as part of the purchase order or contract with a government agency.

S1. Introduction

S1.1 The B438 purchasing specification incorporates and updates the applicable portions of specifications from MIL-B-5687 (revision D, dated 21 February 1984), MS17795 (revision A dated 14 February 1962), MS17796 (revision B w/Amendment 1, dated 14 Jul 2004) and MS21783 (basic document, dated 21 February 1984) bringing the military requirements into alignment with the rest of this consensus specification. The type and grade designations from MIL-B-5687 have been converted to the industry accepted material designation codes from MPIF Standard 35 (Bearings) (see Table A2.1 for conversion information). In addition to meeting the primary specifications, the purchaser of bearings for military or government applications must comply with additional specific requirements. This Supplementary Requirements section details those additional governmental requirements.

S1.2 The bearings referred to within this specification are not intended for reaming on assembly.

S1.3 The bearings referred to within this specification are not recommended for military airframe applications.

S2. Government Requirements

S2.1 *Chemical, Physical and Mechanical Requirements*—Refer to Section 1 and Table 1 for the specifications for bearing materials that shall conform to material designation codes CTG-1001-K23 (sleeve, flange and thrust washer) or CTG-1001-K23-MOD (sleeve and flange only). The contractor shall furnish a chemical composition analysis on an oil-free basis for each lot showing the weight percentage for each element as specified in Table 1. Bearings shall conform to this specification.

S2.1.1 *Compressive Yield Strength*—The yield strength in compression shall be 11 000 psi (75 MPa) (minimum) for 0.1 percent permanent offset in accordance with section X3.2.1.

S2.1.2 *Surface Finish*—For thrust washer bearings, all surfaces shall have a surface finish of 125 µin. maximum except as noted on a print or drawing. Surface finish shall be measured in accordance with Test Method B946.

S2.2 *Oil-Impregnation*—High-grade non-gumming petroleum lubricants purchased in accordance with the applicable Qualified Products Lists (QPLs), such as MIL-PRF-17331 (Military Symbol 2190–TEP, NATO Code O-250 and QPL-17331) for sleeve and flange bearings and MIL-PRF-6085 (Military Symbol OAI, NATO Code No. 0-147 and QPL-6085) for thrust washer bearings, or as specified on referenced military standard specification sheets shall be used to impregnate the bearings.

S2.3 *First Article Tests (FAT)*—When specified in the contract, FATs shall be performed on a number of samples (four minimum). The tests performed shall conform to 12.2, Sampling Plan and shall include testing for interconnected porosity. Testing shall be as specified within this specification, Test Method B328 or in another document as specified in the contract. Any defect or failure shall be cause for rejection of the lot. Waivers for minor defects may be addressed to the contracting officer.

Note—In order to perform all the tests on a single bearing, the following order of tests is suggested: dimensional, impregnated density, interconnected porosity, oil content, oil exudation, radial crushing strength and chemical analysis.

S2.4 *Oil Exudation Test*— During the test period for oil exudation, beads shall exude from the bearing surface. Lack of appreciable sweating of the lubricant on the bearing surface will be cause for rejection (see 11.4).

S2.5 *COQC*—When procured from a dealer or distributor versus the actual manufacturer, a certificate of quality conformance (COQC) supplied by the manufacturer of the bearing may be furnished in lieu of actual performance of such testing by the dealer or distributor, provided lot identity is traceable, has been maintained and can be demonstrated to the Government. The certificate shall include the name of the dealer or distributor, dealer or distributor number, name of manufacturer, national stock number (NSN), item identification, name of the component or material, lot number, lot size, dimensions, date of testing, test method, individual test results, and specification requirements.

S2.6 *Records*—Records of examination and tests performed by or for the contractor shall be maintained and made available to the Government by the contractor for a period of three years after delivery of the products and associate material.

S2.7 *Inspection*— Unless otherwise specified, the manufacturer is responsible for testing. The manufacturer may use their own or any other suitable facility for the performance of testing and inspection, unless an exception is stated. The Government reserves the right to perform an inspection as set forth herein to assure supplies and sources conform to the prescribed requirements.

S2.8 *Packaging*—Special packaging and marking requirements shall be included in the contract or will conform to Section 17, Packaging.

S2.9 *Requirements*—All requirements shall be as specified herein. Referenced military standard specification sheets shall take precedence unless otherwise specified in the purchase order or contract.

S3. Ordering Information

S3.1 *Purchase Order or Contract*—Ordering information shall be in accordance with Section 5 of this specification and shall also include:

S3.1.1 PIN from S3.3, Table S3.1, Table S3.2 or Table S3.3,

S3.1.2 National Stock Number (NSN),

S3.1.3 Quantity,

S3.1.4 Requirements for testing including FAT,

S3.1.15 COQC if required, and

S3.1.6 Packaging requirements, if different from Section 17.

S3.2 *PIN*—The military PIN shall consist of the letters and numbers representing the old MS documents and taken from the titles of Table S3.1 (for sleeve), Table S3.2 (for flange) or Table S3.3 (for thrust washer), a dash number from either Table S3.1 (for sleeve), Table S3.2 (for flange) or Table S3.3 (for thrust washer) and a suffix of Y or Z representing the material designation code.

Example: MS17796 − 104 − Y

where:

MS17796 = the number from Table S3.1 or Table S3.2 or Table S3.3 representing the old MS document,

104 = Dash number, from Table S3.1 or Table S3.2 or Table S3.3,

Y = Material Designation Code:
Y = CTG-1001-K23
Z = CTG-1001-K23 MOD

Note—The MS17796–104–Y part identification number (PIN) equates to the old MS17796-104 designation where the MS17796 represented the military standard number for flange bearings (sleeve and thrust bearings are described in MS17795 and MS21783 respectively), the 104 was the dash number; as for the suffix Y, it is new; in MS17796, the material designation code was called out separately as a Grade and Type and was not a part of the PIN but was part of the required ordering information. The dash numbers themselves remain unchanged from those in MS17795, MS17796 and MS21783.

S3.3 *Dimensions and Dash Numbers:*

S3.3.1 *Sleeve Bearings*—Refer to Fig. 1 and Table S3.1—Standard Military Bronze Sleeve Bearings–Dimensions and Dash Numbers.

S3.3.2 *Flange Bearings*—Refer to Fig. 2 and Table S3.2—Standard Military Bronze Flange Bearings–Dimensions and Dash Numbers.

S3.3.3 *Thrust Washer Bearings*— Refer to Fig. 3 and Table S3.3—Standard Military Bronze Thrust Washer Bearings–Dimensions and Dash Numbers.

S3.4 *Tolerances*—Refer to Table S3.4—Required Dimensional Tolerances.

S3.5 *Chamfers*—Refer to Table S3.5—Chamfers.

S3.6 *Documents*— Referenced documents shall be of the issue in effect on the date of invitations for bids or request for proposals, except that referenced, adopted industry documents shall give the date of the issue adopted. In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence.

TABLE S3.1 MS17795 Bronze Sleeve Bearings—Dimensions and Dash Numbers

Dash No.	Static Capacity (lb)	Length, L (in.)	Nominal ID (in.)	Inner Diameter, d (in.)	Outer Diameter, D (in.)
1	97	3/32	1/8	0.127	0.1905
2	129	1/8	1/8	0.127	0.1905
3	194	3/16	1/8	0.127	0.1905
4	258	1/4	1/8	0.127	0.1905
5	129	1/8	1/8	0.127	0.253
6	194	3/16	1/8	0.127	0.253
7	258	1/4	1/8	0.127	0.253
8	323	5/16	1/8	0.127	0.253
9	193	1/8	3/16	0.1895	0.253
10	290	3/16	3/16	0.1895	0.253
11	387	1/4	3/16	0.1895	0.253
12	483	5/16	3/16	0.1895	0.253
13	580	3/8	3/16	0.1895	0.253
14	677	7/16	3/16	0.1895	0.253
15	290	3/16	3/16	0.1895	0.3155
16	387	1/4	3/16	0.1895	0.3155
17	483	5/16	3/16	0.1895	0.3155
18	580	3/8	3/16	0.1895	0.3155
19	677	7/16	3/16	0.1895	0.3155
20	774	1/2	3/16	0.1895	0.3155
21	386	3/16	1/4	0.252	0.378
22	516	1/4	1/4	0.252	0.378
23	645	5/16	1/4	0.252	0.378
24	773	3/8	1/4	0.252	0.378
25	902	7/16	1/4	0.252	0.378
26	1031	1/2	1/4	0.252	0.378
27	1289	5/8	1/4	0.252	0.378
28	386	3/16	1/4	0.252	0.4405
29	516	1/4	1/4	0.252	0.4405
30	645	5/16	1/4	0.252	0.4405
31	773	3/8	1/4	0.252	0.4405
32	902	7/16	1/4	0.252	0.4405
33	1031	1/2	1/4	0.252	0.4405
34	1289	5/8	1/4	0.252	0.4405
35	1547	3/4	1/4	0.252	0.4405
36	645	1/4	5/16	0.3145	0.4405
37	806	5/16	5/16	0.3145	0.4405
38	967	3/8	5/16	0.3145	0.4405
39	1128	7/16	5/16	0.3145	0.4405
40	1289	1/2	5/16	0.3145	0.4405
41	1611	5/8	5/16	0.3145	0.4405
42	1934	3/4	5/16	0.3145	0.4405
43	773	1/4	3/8	0.377	0.503
44	967	5/16	3/8	0.377	0.503
45	1160	3/8	3/8	0.377	0.503
46	1354	7/16	3/8	0.377	0.503
47	1547	1/2	3/8	0.377	0.503
48	1934	5/8	3/8	0.377	0.503
49	2320	3/4	3/8	0.377	0.503
50	2707	7/8	3/8	0.377	0.503
51	3094	1	3/8	0.377	0.503
52	773	1/4	3/8	0.377	0.628
53	967	5/16	3/8	0.377	0.628
54	1160	3/8	3/8	0.377	0.628
55	1354	7/16	3/8	0.377	0.628
56	1547	1/2	3/8	0.377	0.628
57	1934	5/8	3/8	0.377	0.628
58	2320	3/4	3/8	0.377	0.628
59	2707	7/8	3/8	0.377	0.628
60	3094	1	3/8	0.377	0.628
61	3867	1-1/4	3/8	0.377	0.628
62	1354	3/8	7/16	0.439	0.565
63	1579	7/16	7/16	0.439	0.565
64	1805	1/2	7/16	0.439	0.565
65	2256	5/8	7/16	0.439	0.565
66	2707	3/4	7/16	0.439	0.565
67	3158	7/8	7/16	0.439	0.565
68	3609	1	7/16	0.439	0.565
69	4512	1-1/4	7/16	0.439	0.565
70	1547	3/8	1/2	0.502	0.628
71	1805	7/16	1/2	0.502	0.628
72	2063	1/2	1/2	0.502	0.628

TABLE S3.1 *Continued*

Dash No.	Static Capacity (lb)	Length, L (in.)	Nominal ID (in.)	Inner Diameter, d (in.)	Outer Diameter, D (in.)
73	2578	5/8	1/2	0.502	0.628
74	3094	3/4	1/2	0.502	0.628
75	3609	7/8	1/2	0.502	0.628
76	4125	1	1/2	0.502	0.628
77	5156	1-1/4	1/2	0.502	0.628
78	1547	3/8	1/2	0.502	0.753
79	2063	1/2	1/2	0.502	0.753
80	2578	5/8	1/2	0.502	0.753
81	3094	3/4	1/2	0.502	0.753
82	3609	7/8	1/2	0.502	0.753
83	4125	1	1/2	0.502	0.753
84	5156	1-1/4	1/2	0.502	0.753
85	6188	1-1/2	1/2	0.502	0.753
86	2320	1/2	9/16	0.565	0.695
87	2900	5/8	9/16	0.565	0.695
88	3480	3/4	9/16	0.565	0.695
89	4061	7/8	9/16	0.565	0.695
90	4641	1	9/16	0.565	0.695
91	5801	1-1/4	9/16	0.565	0.695
92	6961	1-1/2	9/16	0.565	0.695
93	2578	1/2	5/8	0.627	0.753
94	3223	5/8	5/8	0.627	0.753
95	3867	3/4	5/8	0.627	0.753
96	4518	7/8	5/8	0.627	0.753
97	5156	1	5/8	0.627	0.753
98	6445	1-1/4	5/8	0.627	0.753
99	7734	1-1/2	5/8	0.627	0.753
100	2578	1/2	5/8	0.627	0.879
101	3223	5/8	5/8	0.627	0.879
102	3867	3/4	5/8	0.627	0.879
103	4518	7/8	5/8	0.627	0.879
104	5156	1	5/8	0.627	0.879
105	6445	1-1/4	5/8	0.627	0.879
106	7734	1-1/2	5/8	0.627	0.879
107	9023	1-3/4	5/8	0.627	0.879
108	3094	1/2	3/4	0.752	0.879
109	3867	5/8	3/4	0.752	0.879
110	4640	3/4	3/4	0.752	0.879
111	5414	7/8	3/4	0.752	0.879
112	6188	1	3/4	0.752	0.879
113	7734	1-1/4	3/4	0.752	0.879
114	9281	1-1/2	3/4	0.752	0.879
115	10828	1-3/4	3/4	0.752	0.879
116	3094	1/2	3/4	0.752	1.004
117	3867	5/8	3/4	0.752	1.004
118	4640	3/4	3/4	0.752	1.004
119	5414	7/8	3/4	0.752	1.004
120	6188	1	3/4	0.752	1.004
121	7734	1-1/4	3/4	0.752	1.004
122	9281	1-1/2	3/4	0.752	1.004
123	10828	1-3/4	3/4	0.752	1.004
124	12375	2	3/4	0.752	1.004
125	4512	5/8	7/8	0.877	1.004
126	5414	3/4	7/8	0.877	1.004
127	6316	7/8	7/8	0.877	1.004
128	7219	1	7/8	0.877	1.004
129	9023	1-1/4	7/8	0.877	1.004
130	10828	1-1/2	7/8	0.877	1.004
131	12633	1-3/4	7/8	0.877	1.004
132	6188	3/4	1	1.003	1.129
133	7219	7/8	1	1.003	1.129
134	8250	1	1	1.003	1.129
135	10313	1-1/4	1	1.003	1.129
136	12375	1-1/2	1	1.003	1.129
137	14438	1-3/4	1	1.003	1.129
138	16500	2	1	1.003	1.129
139	6188	3/4	1	1.003	1.254
140	7219	7/8	1	1.003	1.254
141	8250	1	1	1.003	1.254
142	10313	1-1/4	1	1.003	1.254
143	12375	1-1/2	1	1.003	1.254
144	14438	1-3/4	1	1.003	1.254
145	16500	2	1	1.003	1.254

TABLE S3.1 *Continued*

Dash No.	Static Capacity (lb)	Length, L (in.)	Nominal ID (in.)	Inner Diameter, d (in.)	Outer Diameter, D (in.)
146	18563	2-1/4	1	1.003	1.254
147	20625	2-1/2	1	1.003	1.254
148	9281	1	1-1/8	1.128	1.378
149	11602	1-1/4	1-1/8	1.128	1.378
150	13922	1-1/2	1-1/8	1.128	1.378
151	16242	1-3/4	1-1/8	1.128	1.378
152	18563	2	1-1/8	1.128	1.378
153	20883	2-1/4	1-1/8	1.128	1.378
154	23203	2-1/2	1-1/8	1.128	1.378
155	10313	1	1-1/4	1.2535	1.504
156	12891	1-1/4	1-1/4	1.2535	1.504
157	15469	1-1/2	1-1/4	1.2535	1.504
158	18047	1-3/4	1-1/4	1.2535	1.504
159	20625	2	1-1/4	1.2535	1.504
160	23203	2-1/4	1-1/4	1.2535	1.504
161	25781	2-1/2	1-1/4	1.2535	1.504
162	28359	2-3/4	1-1/4	1.2535	1.504
163	30938	3	1-1/4	1.2535	1.504
164	11344	1	1-3/8	1.378	1.629
165	14180	1-1/4	1-3/8	1.378	1.629
166	17016	1-1/2	1-3/8	1.378	1.629
167	19852	1-3/4	1-3/8	1.378	1.629
168	22688	2	1-3/8	1.378	1.629
169	25523	2-1/4	1-3/8	1.378	1.629
170	28359	2-1/2	1-3/8	1.378	1.629
171	31195	2-3/4	1-3/8	1.378	1.629
172	34031	3	1-3/8	1.378	1.629
173	12375	1	1-1/2	1.504	1.755
174	15469	1-1/4	1-1/2	1.504	1.755
175	18563	1-1/2	1-1/2	1.504	1.755
176	21656	1-3/4	1-1/2	1.504	1.755
177	24750	2	1-1/2	1.504	1.755
178	27844	2-1/4	1-1/2	1.504	1.755
179	30938	2-1/2	1-1/2	1.504	1.755
180	34031	2-3/4	1-1/2	1.504	1.755
181	37125	3	1-1/2	1.504	1.755
182	21656	1-1/2	1-3/4	1.753	2.005
183	25266	1-3/4	1-3/4	1.753	2.005
184	28875	2	1-3/4	1.753	2.005
185	32484	2-1/4	1-3/4	1.753	2.005
186	36094	2-1/2	1-3/4	1.753	2.005
187	39703	2-3/4	1-3/4	1.753	2.005
188	43313	3	1-3/4	1.753	2.005
189	28875	1-3/4	2	2.004	2.38
190	33000	2	2	2.004	2.38
191	37125	2-1/4	2	2.004	2.38
192	41250	2-1/2	2	2.004	2.38
193	45375	2-3/4	2	2.004	2.38
194	49500	3	2	2.004	2.38
195	57750	3-1/2	2	2.004	2.38
196	66000	4	2	2.004	2.38
197	37125	2	2-1/4	2.254	2.631
198	46406	2-1/2	2-1/4	2.254	2.631
199	55688	3	2-1/4	2.254	2.631
200	64969	3-1/2	2-1/4	2.254	2.631
201	74250	4	2-1/4	2.254	2.631
202	41250	2	2-1/2	2.505	3.006
203	51563	2-1/2	2-1/2	2.505	3.006
204	61875	3	2-1/2	2.505	3.006
205	72188	3-1/2	2-1/2	2.505	3.006
206	82500	4	2-1/2	2.505	3.006
207	323	5/16	1/8	0.127	0.1905
208	387	3/8	1/8	0.127	0.1905
209	451	7/16	1/8	0.127	0.1905
210	516	1/2	1/8	0.127	0.1905
211	387	3/8	1/8	0.127	0.253
212	451	7/16	1/8	0.127	0.253
213	516	1/2	1/8	0.127	0.253
214	161	1/8	5/32	0.158	0.253
215	242	3/16	5/32	0.158	0.253
216	322	1/4	5/32	0.158	0.253
217	403	5/16	5/32	0.158	0.253
218	483	3/8	5/32	0.158	0.253

TABLE S3.1 *Continued*

Dash No.	Static Capacity (lb)	Length, L (in.)	Nominal ID (in.)	Inner Diameter, d (in.)	Outer Diameter, D (in.)
219	564	7/16	5/32	0.158	0.253
220	645	1/2	5/32	0.158	0.253
221	774	1/2	3/16	0.1895	0.253
222	967	5/8	3/16	0.1895	0.253
223	1160	3/4	3/16	0.1895	0.253
224	967	5/8	3/16	0.1895	0.3155
225	1160	3/4	3/16	0.1895	0.3155
226	1354	7/8	3/16	0.1895	0.3155
227	1546	1	3/16	0.1895	0.3155
228	1547	3/4	1/4	0.252	0.378
229	1805	7/8	1/4	0.252	0.378
230	2063	1	1/4	0.252	0.378
231	2320	1-1/8	1/4	0.252	0.378
232	2578	1-1/4	1/4	0.252	0.378
233	1805	7/8	1/4	0.252	0.4405
234	2063	1	1/4	0.252	0.4405
235	2320	1-1/8	1/4	0.252	0.4405
236	2578	1-1/4	1/4	0.252	0.4405
237	3094	1-1/2	1/4	0.252	0.4405
238	2256	7/8	5/16	0.3145	0.4405
239	2578	1	5/16	0.3145	0.4405
240	2900	1-1/8	5/16	0.3145	0.4405
241	3223	1-1/4	5/16	0.3145	0.4405
242	3867	1-1/2	5/16	0.3145	0.4405
243	645	1/4	5/16	0.3145	0.503
244	806	5/16	5/16	0.3145	0.503
245	967	3/8	5/16	0.3145	0.503
246	1128	7/16	5/16	0.3145	0.503
247	1289	1/2	5/16	0.3145	0.503
248	1611	5/8	5/16	0.3145	0.503
249	1934	3/4	5/16	0.3145	0.503
250	2256	7/8	5/16	0.3145	0.503
251	2578	1	5/16	0.3145	0.503
252	2900	1-1/8	5/16	0.3145	0.503
253	3223	1-1/4	5/16	0.3145	0.503
254	3867	1-1/2	5/16	0.3145	0.503
255	3480	1-1/8	3/8	0.377	0.503
256	3867	1-1/4	3/8	0.377	0.503
257	4641	1-1/2	3/8	0.377	0.503
258	3480	1-1/8	3/8	0.377	0.628
259	4061	1-1/8	7/16	0.439	0.565
260	5414	1-1/2	7/16	0.439	0.565
261	4641	1-1/8	1/2	0.502	0.628
262	6188	1-1/2	1/2	0.502	0.628
263	6703	1-5/8	1/2	0.502	0.628
264	4641	1-1/8	1/2	0.502	0.753
265	6703	1-5/8	1/2	0.502	0.753
266	7219	1-3/4	1/2	0.502	0.753
267	8250	1-7/8	1/2	0.502	0.753
268	5221	1-1/8	9/16	0.565	0.695
269	5801	1-1/8	5/8	0.627	0.753
270	5801	1-1/8	5/8	0.627	0.879
271	8379	1-5/8	5/8	0.627	0.879
272	9668	1-7/8	5/8	0.627	0.879
273	10313	2	5/8	0.627	0.879
274	6961	1-1/8	3/4	0.752	0.879
275	10055	1-5/8	3/4	0.752	0.879
276	6961	1-1/8	3/4	0.752	1.004
277	10055	1-5/8	3/4	0.752	1.004
278	11602	1-7/8	3/4	0.752	1.004
279	13922	2-1/4	3/4	0.752	1.004
280	15469	2-1/2	3/4	0.752	1.004
281	8121	1-1/8	7/8	0.877	1.004
282	11730	1-5/8	7/8	0.877	1.004
283	9281	1-1/8	1	1.003	1.129
284	13406	1-5/8	1	1.003	1.129
285	15469	1-7/8	1	1.003	1.129
286	9281	1-1/8	1	1.003	1.254
287	13406	1-5/8	1	1.003	1.254
288	15469	1-7/8	1	1.003	1.254
289	22681	2-3/4	1	1.003	1.254
290	24750	3	1	1.003	1.254
291	6188	3/4	1	1.003	1.379

TABLE S3.1 *Continued*

Dash No.	Static Capacity (lb)	Length, L (in.)	Nominal ID (in.)	Inner Diameter, d (in.)	Outer Diameter, D (in.)
292	7219	7/8	1	1.003	1.379
293	8250	1	1	1.003	1.379
294	9281	1-1/8	1	1.003	1.379
295	10313	1-1/4	1	1.003	1.379
296	12375	1-1/2	1	1.003	1.379
297	13406	1-5/8	1	1.003	1.379
298	14438	1-3/4	1	1.003	1.379
299	15469	1-7/8	1	1.003	1.379
300	16500	2	1	1.003	1.379
301	18563	2-1/4	1	1.003	1.379
302	20625	2-1/2	1	1.003	1.379
303	22681	2-3/4	1	1.003	1.379
304	10441	1-1/8	1-1/8	1.128	1.378
305	15082	1-5/8	1-1/8	1.128	1.378
306	17402	1-7/8	1-1/8	1.128	1.378
307	25523	2-3/4	1-1/8	1.128	1.378
308	27800	3	1-1/8	1.128	1.378
309	11602	1-1/8	1-1/4	1.2535	1.504
310	16758	1-5/8	1-1/4	1.2535	1.504
311	19336	1-7/8	1-1/4	1.2535	1.504
312	10313	1	1-1/4	1.2535	1.630
313	11602	1-1/8	1-1/4	1.2535	1.630
314	12891	1-1/4	1-1/4	1.2535	1.630
315	15469	1-1/2	1-1/4	1.2535	1.630
316	16758	1-5/8	1-1/4	1.2535	1.630
317	18047	1-3/4	1-1/4	1.2535	1.630
318	19336	1-7/8	1-1/4	1.2535	1.630
319	20625	2	1-1/4	1.2535	1.630
320	23203	2-1/4	1-1/4	1.2535	1.630
321	25781	2-1/2	1-1/4	1.2535	1.630
322	28359	2-3/4	1-1/4	1.2535	1.630
323	30938	3	1-1/4	1.2535	1.630
324	12762	1-1/8	1-3/8	1.378	1.629
325	18434	1-5/8	1-3/8	1.378	1.629
326	21270	1-7/8	1-3/8	1.378	1.629
327	13922	1-1/8	1-1/2	1.504	1.755
328	20109	1-5/8	1-1/2	1.504	1.755
329	23203	1-7/8	1-1/2	1.504	1.755
330	12375	1	1-1/2	1.504	1.880
331	13922	1-1/8	1-1/2	1.504	1.880
332	15469	1-1/4	1-1/2	1.504	1.880
333	18563	1-1/2	1-1/2	1.504	1.880
334	20109	1-5/8	1-1/2	1.504	1.880
335	21656	1-3/4	1-1/2	1.504	1.880
336	23203	1-7/8	1-1/2	1.504	1.880
337	24750	2	1-1/2	1.504	1.880
338	27844	2-1/4	1-1/2	1.504	1.880
339	30938	2-1/2	1-1/2	1.504	1.880
340	34031	2-3/4	1-1/2	1.504	1.880
341	37125	3	1-1/2	1.504	1.880
342	23461	1-5/8	1-3/4	1.753	2.005
343	27070	1-7/8	1-3/4	1.753	2.005
344	30938	1-7/8	2	2.004	2.380
345	28875	1-3/4	2	2.004	2.505
346	30938	1-7/8	2	2.004	2.505
347	33000	2	2	2.004	2.505
348	37125	2-1/4	2	2.004	2.505
349	41250	2-1/2	2	2.004	2.505
350	45375	2-3/4	2	2.004	2.505
351	49500	3	2	2.004	2.505
352	57750	3-1/2	2	2.004	2.505
353	66000	4	2	2.004	2.505
354	41766	2-1/4	2-1/4	2.254	2.631
355	51047	2-3/4	2-1/4	2.254	2.631
356	60328	3-1/4	2-1/4	2.254	2.631
357	69609	3-3/4	2-1/4	2.254	2.631
358	46406	2-1/4	2-1/2	2.505	3.006
359	56719	2-3/4	2-1/2	2.505	3.006
360	67031	3-1/4	2-1/2	2.505	3.006
361	77344	3-3/4	2-1/2	2.505	3.006
362	49500	2	3	3.006	3.507
363	55688	2-1/4	3	3.006	3.507
364	61875	2-1/2	3	3.006	3.507