Designation: B439 – 12

Standard Specification for Iron-Base Powder Metallurgy (PM) Bearings (Oil-Impregnated)[1]

This standard is issued under the fixed designation B439; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

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

1.2 Listed are the chemical, physical, and mechanical specifications for those standardized ferrous PM materials that have been developed specifically for the manufacture of self-lubricating bearings.

1.3 This standard is a companion to Specification B438 that covers the requirements for porous oil-imptegnated bronze-base bearings.

1.4 Typical applications for self-lubricating iron-base PM bearings are discussed in Appendix X1.

1.5 Commercial bearing dimensional tolerance data are shown in Appendix Appendix X2, while engineering information regarding installation and operating parameters of PM bearings is included in Appendix Appendix X3. Additional useful information on self-lubricating bearings can be found in MPIF Standard 35 (Bearings), ISO 5755 and the technical literature.[2]

1.6 *Units*—With the exception of density values for which the use of the g/cm^3 unit is the long-standing practice of the PM industry, the values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not to be regarded as standard

1.7 *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

B438 Specification for Bronze-Base Powder Metallurgy (PM) Bearings (Oil-Impregnated)

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

B962 Test Methods for Density of Compacted or Sintered Powder Metallurgy (PM) Products Using Archimedes' Principle

B963 Test Methods for Oil Content, Oil-Impregnation Efficiency, and Interconnected Porosity of Sintered Powder Metallurgy (PM) Products Using Archimedes' Principle

B966 Test Method for Permeability of Powder Metallurgy (PM) Bearings Using Nitrogen Gas

B970 Test Method for Cleanliness of Powder Metallurgy (PM) Bearings and Structural Parts

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:*[4]

MPIF Standard 35 Materials Standards for PM Self-Lubricating Bearings

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[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.

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[2] *Machine Design Magazine*, Vol 54, No. 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] Available from Metal Powder Industries Federations, 105 College Road East, Princeton, NJ 08540, http://www.info@mpif.org.

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

2.3 *ISO Standards:*[5]

ISO 2795 Plain bearings from sintered metal—Dimensions and tolerances

ISO 5755 Sintered Metal Materials – Specifications,

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 The following list of standardized iron-base oil-impregnated PM bearing material compositions classified by composition are included in this specification. Their complete chemical, physical and mechanical requirements can be found in the specification tables. Typical applications are discussed in Annex A1.

4.2 The three-part alphanumeric PM Material Designation Code, developed by the PM industry, is used to identify these materials. A complete explanation of this classification system is presented in Annex A1.

4.2.1 *Iron and Iron-Carbon Bearing Materials, (Prefix F)*

4.2.1.1 *Iron Materials*

F-0000-K15
F-0000-K23

4.2.1.2 Iron-Carbon Materials

F-0005-K20
F-0005-K28
F- 0008-K20
F -0008-K32

4.2.2 *Iron-Copper Bearing Materials (Prefix FC)*

4.2.2.1 *Low-Copper Materials*

FC-0200-K20
FC-0200-K34

4.2.2.2 *Medium-Copper Materials*

FC-1000-K20
FC-1000-K30
FC-1000-K40

4.2.2.3 *High-Copper Materials*

FC-2000-K25
FC-2000-K30
FC-2000-K40

4.2.3 *Iron-Copper-Carbon Bearing Materials (Prefix FC)*

4.2.3.1 *Low-Copper- Carbon Materials.*

FC-0205-K20
FC-0205-K35
FC-0208-K25
FC-0208-K40

4.2.3.2 *Medium-Copper-Carbon Materials.*

FC-0508-K35
FC-0508-K46

4.2.3.3 *High-Copper-Carbon Materials.*

FC-2008-K44
FC-2008-K46

4.2.4 *Iron-Graphite Bearing Materials (Prefix FG)*

FG-0303-K10
FG-0303-K12
FG-0308-K16
FG-0308-K22

4.2.5 *Iron-Bronze-Graphite (Diluted Bronze) Bearing Materials (Prefix FCTG)*

FCTG-3604-K16
FCTG-3604-K22

4.2.6 *Diffusion Alloyed Iron-Bronze Bearing Materials (Prefix FDCT)*

FDCT-1802- K22
FDCT-1802- K31
FDCT-1802- K39

5. Ordering Information

5.1 Purchase orders or contracts for iron-base oil-impregnated PM 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 specification, including date of issue,

5.1.3 Identification of bearing material by the *PM Material Designation Code* (Section 4),

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 (6.2.3), and

5.1.6 Instructions for special packaging, if required (Section 17).

6. Materials and Manufacture

6.1 *Porous Metallic Bearing:*

6.1.1 Porous iron-base bearings shall be processed from a mixture of elemental, prealloyed or diffusion-alloyed metal powders with or without the additions of copper, tin, bronze or graphite powder that together meet the specified chemical composition of the material.

6.1.2 The powder mixture shall be compacted to produce a green bearing of the required dimensions, shape and density

6.1.3 The green bearings shall then be sintered in a furnace having a protective atmosphere for a time and temperature cycle that will produce the required sintered ferrous-base PM material.

6.1.4 After sintering, the iron-base bearings are normally sized to achieve the density, dimensional characteristics, concentricity, and surface finish required of the finished 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 the lubricant used for most bearing applications, but extreme operating conditions such as elevated temperatures, intermittent rotation, extremely

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

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

7. Chemical Composition

7.1 *Chemical Composition Specifications*—Each iron-base PM bearing material shall conform to the chemical composition requirements prescribed in Table 1 when determined on a clean test sample obtained 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 2.

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 specified in Table 2 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 2.

TABLE 1 Compositional Specifications for Iron-Base PM Bearing Materials

Material Designation Code	Chemical Composition Requirements						
	Iron mass %	Total Carbon mass %	Combined Carbon [A] mass %	Graphitic Carbon [B] mass %	Copper mass %	Tin mass %	All Others mass %
Iron and Iron-Carbon							
F-0000-K15	bal.	0 to 0.3			0 to 1.5		0 to 2.0
F-0000-K23	bal.	0 to 0.3			0 to 1.5		0 to 2.0
F-0005-K20	bal.		0.3 to 0.6		0 to 1.5		0 to 2.0
F-0005-K28	bal.		0.3 to 0.6		0 to 1.5		0 to 2.0
F-0008-K20	bal.		0.6 to 0.9		0 to 1.5		0 to 2.0
F-0008-K32	bal.		0.6 to 0.9		0 to 1.5		0 to 2.0
Iron-Copper							
FC-0200-K20	bal.	0 to 0.3		1.5 to 3.9			0 to 2.0
FC--0200-K34	bal.	0 to 0.3		1.5 to 3.9			0 to 2.0
FC-1000-K20	bal.	0 to 0.3		9.0 to 11.0			0 to 2.0
FC-1000-K30	bal.	0 to 0.3		9.0 to 11.0			0 to 2.0
FC-1000-K40	bal.	0 to 0.3		9.0 to 11.0			0 to 2.0
FC-2000-K25	bal.	0 to 0.3		18.0 to 22.0			0 to 2.0
FC-2000-K30	bal.	0 to 0.3		18.0 to 22.0			0 to 2.0
FC-2000-K40	bal.	0 to 0.3		18.0 to 22.0			0 to 2.0
Iron-Copper-Carbon							
FC-0205-K20	bal.		0.3 to 0.6		1.5 to 3.9		0 to 2.0
FC-0205-K35	bal.		0.3 to 0.6		1.5 to 3.9		0 to 2.0
FC-0208-K25	bal.		0.6 to 0.9		1.5 to 3.9		0 to 2.0
FC-0208-K40	bal.		0.6 to 0.9		1.5 to 3.9		0 to 2.0
FC-0508-K35	bal.		0.6 to 0.9		4.0 to 6.0		0 to 2.0
FC-0508-K46	bal.		0.6 to 0.9		4.0 to 6.0		0 to 2.0
FC-2008-K44	bal.		0.6 to 0.9		18.0 to 22.0		0 to 2.0
FC-2008-K46	bal.		0.6 to 0.9		18.0 to 22.0		0 to 2.0
Iron-Graphite							
FG-0303-K10	bal.		0 to 0.5	2.0 to 3.0			0 to 2.0
FG-0303-K12	bal.		0 to 0.5	2.0 to 3.0			0 to 2.0
FG-0308-K16	bal.		0.5 to 1.0	1.5 to 2.5			0 to 2.0
FG-0308-K22	bal.		0.5 to 1.0	1.5 to 2.5			0 to 2.0
Iron-Bronze (Diluted Bronze)							
FCTG-3604-K16	bal.	0.5 to 1.3	0.5 max	[C]	34.0 to 38.0	3.5 to 4.5	0 to 2.0
FCTG-3604-K22	bal.	0.5 to 1.3	0.5 max	[C]	34.0 to 38.0	3.5 to 4.5	0 to 2.0
Diffusion Alloyed Iron-Bronze							
FDCT-1802-K22	bal.	0 to 0.1		[D]	17.0 to 19.0	1.5 to 2.5	0 to 1.0
FDCT-1802-K31	bal.	0 to 0.1		[D]	17.0 to 19.0	1.5 to 2.5	0 to 1.0
FDCT-1802-K39	bal.	0 to 0.1		[D]	17.0 to 19.0	1.5 to 2.5	0 to 1.0

[A]The combined carbon value listed is based on the mass percent of the iron content, not the mass percent of the alloy..
[B]Graphitic Carbon is also known as Free Graphite.
[C]These compositions usually contain 0.5 to 1.3% graphite.
[D]These compositions have no added graphite

TABLE 2 Physical and Mechanical Property Specifications for Iron-Base PM Bearing Materials

Material Designation Code	Physical Requirements		Mechanical Requirements[A]			
	Oil Content vol %	Impregnated Density g/cm^3	Radical Crushing Strength, (K)			
			10^3 psi		MPa	
			min	max	min	max
Iron and Iron-Carbon						
F-0000-K15	21	5.6 to 6.0	12		100	
F-0000-K23	17	6.0 to 6.4	23		160	
F-0005-K20	21	5.6 to 6.0	20		140	
F-0005-K28	17	6.0 to 6.4	28		190	
F-0008-K20	21	5.6 to 6.0	20		140	
F-0008-K32	17	6.0 to 6.4	32		220	
Iron-Copper						
FC-0200-K20	22	5.6 to 6.0	20		140	
FC--0200-K34	17	6.0 to 6.4	34		230	
FC-1000-K20	22	5.6 to 6.0	20		140	
FC-1000-K30	19	5.8 to 6.2	30		210	
FC-1000-K40	17	6.0 to 6.4	40		280	
FC-2000-K25	22	5.6 to 6.0	25		170	
FC-2000-K30	19	5.8 to 6.2	30		210	
FC-2000-K40	17	6.0 to 6.4	40		280	
Iron-Copper-Carbon						
FC-0205-K20	22	5.6 to 6.0	20		140	
FC-0205-K35	17	6.0 to 6.4	35		240	
FC-0208-K25	22	5.6 to 6.0	25		170	
FC-0208-K40	17	6.0 to 6.4	40		28/0	
FC-0508-K35	22	5.6 to 6.0	35		240	
FC-0508-K46	17	6.0 to 6.4	46		320	
FC-2008-K44	22	5.6 to 6.0	44		300	
FC-2008-K46	17	6.0 to 6.4	46		320	
Iron-Graphite						
FG-0303-K10	18	5.6 to 6.0	10	25	70	170
FG-0303-K12	12	6.0 to 6.4	12	35	80	240
FG-0308-K16	18	5.6 to 6.0	16	45	110	310
FG-0308-K22	12	6.0 to 6.4	22	55	150	380
Iron-Bronze (Diluted Bronze)						
FCTG-3604-K16	22	5.6 to 6.0	16	36	110	250
FCTG-3604-K22	17	6.0 to 6.4	22	50	150	340
Diffusion Alloyed Iron-Bronze						
FDCT-1802-K22	24	5.6 to 6.0	22		150	
FDCT-1802-K31	19	6.0 to 6.4	31		215	
FDCT-1802-K39	13	6.4 to 6.8	39		270	

[A] These requirements are based on bearings in the finished, oil-impregnated condition.

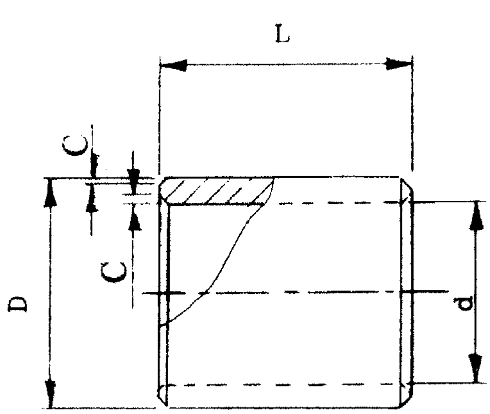

FIG. 1 Standard Sleeve Bearing

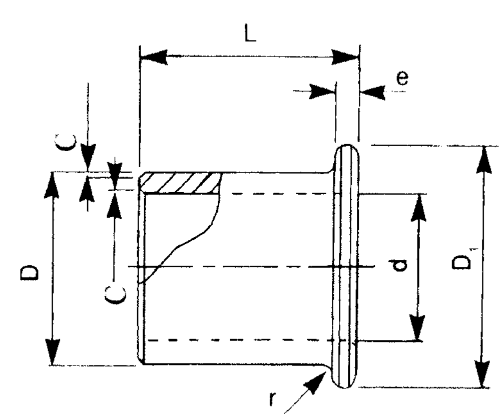

FIG. 2 Standard Flange Bearing

10. Dimensions, Mass, and Permissible Variations

10.1 This specification is applicable to iron-base PM sleeve and flange bearings having a 3 to 1 maximum length to inside diameter ratio and a 20 to 1 maximum length to wall thickness ratio.

10.2 Standard 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.

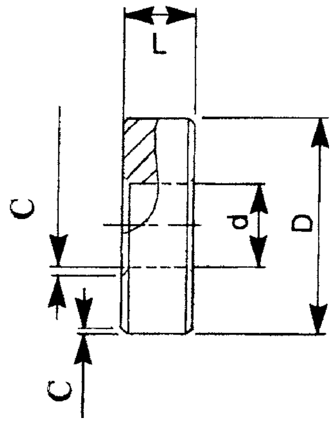

FIG. 3 Standard Thrust Bearing

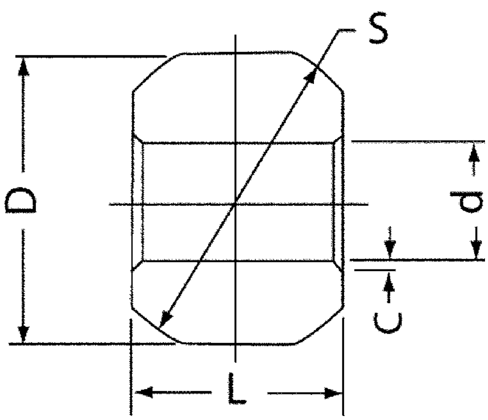

FIG. 4 Standard Spherical Bearing

10.3 Permissible variations in dimensions shall be within the limits specified on the bearing drawing accompanying the order or shall be within the limits specified in the purchase order or contract.

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

10.5 Chamfers of 30 to 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 shall exhibit a uniform appearance.

11.3 If metallographic examination is performed to determine degree of sintering, it should be done at 200 to 400× magnification. The iron materials should show a predominantly ferritic or pearlitic phase with uniformly dispersed graphitic carbon (if present). High copper content Iron-Copper materials should show evidence of melted copper as a copper rich skeletal network around a ferrous interior structure. Diluted Bronze material should show a bronze phase with no visible free tin, dispersed throughout an iron matrix. The structure should not show an excessive number of original particle boundaries.

11.4 To verify the presence of oil in the bearing, the as-received bearing may be heated to approximately 300 °F (150 °C) for approximately 5 min. If oil is present, the surfaces will show beads of oil being exuded from the open porosity.

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 tumbling operation. It is important that the Oil Content test (13.3.1) 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" (see Terminology B243).

12.2 *Sampling Plan*—The number of sample bearings agreed to between the manufacturer and the purchaser to be used for dimensional inspection (13.1), chemical analysis (13.2), physical tests (13.3), and mechanical tests (13.4) 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 and test samples must be dry and free of oil before performing chemical tests. The preferred method of oil removal is by use of the Soxhlet Apparatus specified in Test Method B963. 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 other inert gas atmosphere may be used to volatilize any oil or lubricant that may be present.

13.2.2 *Test Sample*—An oil-free test sample of chips shall then be obtained by milling, drilling, filing, or crushing the bearings using clean dry tools without lubrication.

13.2.3 *Metallic Elements*—The chemical analysis for specified metallic elements shall then be performed 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.

13.2.4 *Carbon Analysis*—Carbon analysis is a set of procedures for determining the total carbon, the graphitic carbon, and the combined carbon in iron-base PM bearings. Total carbon is the sum of graphitic carbon and the total combined carbon.

13.2.4.1 *Total Carbon*—Determine the total carbon in accordance with Test Method E1019 with the exception that a sample size as small as 0.25 g may be used upon agreement between customer and supplier.

13.2.4.2 *Combined Carbon (Preferred Method)*—The combined carbon content in the iron portion is most easily determined by a metallographic estimate. The etched cross section of the iron matrix is viewed at 200 to 400× magnification and the combined carbon in the iron is estimated from the relative amounts of ferrite and pearlite in the structure. 100 % pearlite is equal to approximately 0.8 % combined carbon in the iron portion. The total combined carbon in the composition is then determined by multiplying the estimated combined carbon in the iron by the percentage of iron in the material.

13.2.4.3 *Graphitic Carbon (Preferred Method)*—Subtract the calculated total combined carbon from the total carbon as determined by Test Method E1019 (13.2.4.1) to obtain the graphitic carbon in the bearing.

13.2.4.4 *Graphitic Carbon (Alternative Method)*—This wet chemical analytical procedure may be used to determine graphitic carbon content but it is time-consuming and has been found to lack precision. Weigh and transfer a 0.25 g sample of chips to a 400 mL beaker. Add 25 mL of distilled water, then carefully add 25 mL of concentrated nitric acid and gently boil until all the iron is in solution. At this point, add five to ten drops of 48 mass % hydrofluoric acid to ensure complete solubility of all carbides, silicates, and other compounds. Filter the solution through a porous combustion crucible, wash with hot water until free of acid, then rinse with ethyl alcohol. Dry at 212 °F (100 °C) for 1 h. After drying, add approximately 1 g of carbon-free iron chips and 1 g of copper chips (or another approved accelerator) and follow Test Method E1019 for determining the total carbon.

13.2.4.5 *Combined Carbon (Alternative Method)*—If the graphitic carbon has been determined by wet chemical analysis (13.2.4.4) then the amount of total combined carbon is obtained by subtracting the amount of the graphitic carbon from the total carbon obtained in accordance with Test Method E1019 (13.2.4.1) Divide this total combined carbon value by the percentage of iron in the composition to determine the amount of combined carbon in the iron portion.

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 B963.

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 B963.

13.3.3 *Impregnated Density*—The impregnated density in g/cm^3 units ,measured after they have been fully impregnated, shall be determined following the procedure for *Impregnated Density* in Test Method B962.

13.3.4 *Permeability*—The ability of fluids to flow through the interconnected porosity of the finished bearing may be quantitatively measured by Test Method B966.

13.3.5 *Cleanliness*—The amount of metallic and non-metallic contamination on the finished bearings may be measured by Test Method B970.

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 as-received 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 2 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 2. 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 2 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 following formula is used to calculate the breaking load, P, for a hollow cylinder or bearing test specimen.

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

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 The minimum (maximum) breaking load, P_{min} (P_{max}) required for acceptance of any specific plain sleeve or thrust bearing is calculated using the minimum (maximum) radial crushing strength value specified for that specific bearing material from Table 1and the actual D, d and L dimensions of the as-received bearing

NOTE 1—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 outside diameter, *D*, the inside diameter, *d* and the length, *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, P_a, of the whole bearing. Then, using the correlation formula, the specifications for the breaking load of that whole spherical bearing are calculated as follows:

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

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, (from 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 manufacturer and purchaser when determining conformance.

14. Inspection

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

14.2 Upon notification to the purchaser by the manufacturer, 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 without written authorization from the supplier.

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 numerical results obtained from the chemical, physical, and mechanical tests performed on the sample bearings.

16.3 Either the Certificate of Compliance or the Test Report 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; impregnated density; interconnected porosity; oil content; oil-impregnated bearings; open porosity; PM bearings; porous metallic bearings; PV factor; PV limit; radial crushing strength; self-lubricating bearings

ANNEXES

(Mandatory Information)

A1. PM MATERIAL DESIGNATION CODE

A1.1 Introduction

A1.1.1 The *PM Material Designation Code* is a three-part alphanumeric array that was developed by the Metal Powder Industries Federation (MPIF) to identify any powder metallurgy material and present fundamental chemical and strength requirement information and is used herein with their permission. It is applicable to all standardized powder metallurgy structural and bearing materials. The array consists of a one to four letter prefix code identifying the base material, a four or five digit chemical composition code giving numeric information about the composition and a suffix code that specifies the minimum strength of the material. The identification system defines a specific standard PM material.

A1.1.2 This system offers a convenient means of designating both the chemical composition and the mechanical strength requirements of any standard PM material. For oil-impregnated bearings, the mechanical strength is listed as the minimum radial crushing strength in 10^3 psi units and the value preceded by the letter "K" to distinguish bearing material from structural material.

A1.1.3 Physical properties are not indicated within the *PM Material Designation Code*. Rather, the material specifications for oil content, interconnected porosity, and impregnated density are listed in the Physical Requirements table shown for each standardized material.

A1.1.4 Code designations in this specification and revisions thereof apply only to PM materials for which specifications have been formally adopted. In order to avoid confusion, the PM designation coding system is intended for use only with such materials, and it should not be used to designate nonstandard compositions. The explanatory notes, property values and other contents of this specification have no application to any other materials.

A1.2 Prefix Material Letter Code

A1.2.1 In this PM coding system, the prefix letters denote the elements or alloy of the bearing material with the first letter always designating the dominant metallic element present. For example, the prefix FC represents iron (F) as the base element and copper (C) as the major alloying constituent. The code for iron-base bearing materials always begins with the letter (F). The letter codes used in the prefix of PM bearing materials are listed in Table A1.1.

TABLE A1.1 Prefix Material Code

Letter Code	Material
C	Copper
F	Iron and Iron-Carbon or Steel
G	Free Graphite
T	Tin
CT	Copper-Tin or Bronze
CTG	Bronze with Graphite
FC	Iron-Copper and Iron-Copper-Carbon
FCTG	Iron-Base Diluted Bronze with Graphite
FDCT	Diffusion-Alloyed Iron-Bronze
FG	Iron-Graphite

A1.3 Four-Digit Chemical Composition Code

A1.3.1 All PM bearing materials use a four digit chemical composition code following the prefix letter code to define the primary chemical composition of the material.

A1.3.2 In Iron-Base bearing materials, the added elements (except combined carbon) are included in the prefix letter code in order of decreasing percentage. The first two numbers of the four-digit chemical composition code indicate the percentage of the major added constituent. The percentage of other added elements are excluded from the code but are represented in the "Chemical Composition Requirements" table which lists the complete chemical specifications for each standard material.

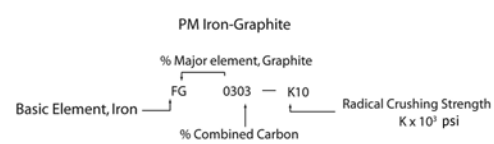

FIG. A1.1 Illustration of an Iron-Graphite PM Bearing Material Designation Code

A1.3.3 The last two numbers in the four-digit series for any ferrous PM material always designate the metallurgically combined carbon. Combined carbon content up to and including 0.3 % is listed as zero. The carbon that is combined in the iron portion of ferrous bearing material is coded as shown in Table A1.2. An exception to this rule are the iron-base diluted bronze materials in which the last two digits represent the tin content.

TABLE A1.2 Designation Codes for Combined Carbon Iron-Base Bearings

Combined Carbon Range	Code Designation
Iron-Base Bearings	
0.0 to 0.3 %	00
0.3 to 0.6 %	05
0.6 to 0.9 %	08
Iron-Graphite Bearings (Only)	
0.0 to 0.5 %	03
0.5 to 1.0 %	08

A1.3.4 An illustration of an iron-graphite PM bearing material designation code is shown in Fig. A1.1.

A1.4 Minimum Strength Suffix Code

A1.4.1 The suffix code designates the minimum mechanical strength of the PM material. For PM bearing materials the suffix starts with the letter "K" to designate radial crushing strength. The two digits that follow indicate the minimum radial crushing strength of the bearing material in 10^3 psi (6.895 MPa) that the user can expect from the finished oil-impregnated bearing material.

A1.5 Data Source

A1.5.1 Information used in compiling this specification was contributed by the membership of the Standards Committee of the Metal Powder Industries Federation and the ASTM Committee B09 on Metal Powders and Metal Powder Products. These technical data are reproduced in this specification with the permission of the Metal Powder Industries Federation, Princeton, NJ, 08540.

A2. CROSS INDEX OF BEARING MATERIALS

TABLE A2.1 Bearing Material Designation Cross-Reference

Previous ASTM Designation	New PM Material Code
B439, Iron-Base, Grade 1, 5.6 to 6.0 g/cm^3 impregnated density	F-0000-K15
B439, Iron-Carbon, Grade 2, 5.6 to 6.0 g/cm^3 impregnated density	F-0005-K20
B439, Iron-Copper, Grade 3 5.8 to 6.2 g/cm^3 impregnated density	FC-1000-K20
B439, Iron-Copper, Grade 4, 5.8 to 6.2 g/cm^3 impregnated density	FC-2000-K25
B612, Iron-Bronze-Graphite, 6.0 to 6.4 g/cm^3 impregnated density	FCTG-3604-K22
B782, Iron-Graphite, Grade 1, 5.6 to 6.0 g/cm^3 impregnated density	FG-0303-K10
B782, Iron-Graphite, Grade 2, 5.6 to 6.0 g/cm^3 impregnated density	FG-0308-K16

A2.1 The bearing designation information presented in Table A2.1 permits cross-reference between the former ASTM material designations and the replacement *PM Material Designation Code* identifications.

APPENDIXES

(Nonmandatory Information)

X1. IRON-BASE PM BEARINGS—APPLICATIONS

X1.1 *Introduction*—PM bearings are categorized as "metallic hydrodynamic journal bushings" as the bearings are fixed in the housing while the shaft rotates on a lubricant film supplied by the oil-impregnated bearing. The bearing materials are engineered to have the compressive strength to support the shaft load, porosity to store the lubricating oil, composition designed for minimum wear and quiet operation and additives to supply start-up lubrication. Iron-base PM bearings are generally used at higher loads and slower speeds than bronze-base bearings. Strength and ductility are directly related to density. Within each iron-base composition, the lower density materials are better for faster speeds and lighter loads while the higher densities are just the opposite. Density must be considered in the material selection process.

X1.2 *Iron Material*—Bearings of 100 % iron are widely used for light to medium load applications in toys, small machine tools, automotive accessories, garden equipment, consumer electronics and kitchen household appliances operating at low to medium speeds. Bearing materials of lower density will contain more oil leading to an increase in service life but at a sacrifice in strength. Unalloyed iron bearings have the lowest raw material cost of any PM bearing.

X1.3 *Iron-Carbon Materials*—Alloying carbon with the iron produces a steel bearing with higher radial crushing strength, higher hardness, improved wear resistance and greater compressive strength. They are used in applications similar to those where unalloyed iron is used but are more highly loaded such as portable industrial power tools. These materials have a coefficient of expansion that is of the same order as the shaft. Iron-Carbon bearings should be used with hardened and ground steel shafts.

X1.4 *Iron-Copper Materials*—The addition of copper improves strength and hardness. These materials have a balanced combination of both strong structural properties and good bearing characteristics. Iron-Copper bearings have good shock loading ability but a speed limit lower than bronze. They are the oldest and most widely used of the iron-base PM bearing materials.

X1.5 *Iron-Copper-Carbon Materials*—The addition of combined carbon in the amounts of 0.3 to 0.9 % greatly increases the strength of iron-copper bearing material. These copper steels have the highest strength of the iron-base materials. In addition, these materials can be hardened by a heat treatment. Iron-copper-carbon materials offer high wear resistance and a high compressive strength. They are selected over iron-copper when the application requires a higher hardness bearing that is subjected to heavy loading such as trucks, farm vehicles, earth-moving tractors and heavy construction equipment. Hardened bearings require the use of hardened shafts. The material is often selected for applications that require a part to serve both as a bearing and a structural component.

X1.6 *Iron-Bronze-Graphite Materials*—These are similar in appearance to 90 Cu-10 Sn bronze but the 60 % iron content substantially lowers the raw material cost. They are commonly referred to as "Diluted Bronze" and can replace bronze in moderately loaded fractional horsepower motors, appliances and business equipment running at medium speeds. They exhibit the best corrosion resistance of any of the iron-base materials. The addition of graphitic carbon is beneficial for oscillatory or intermittent applications and reduces start-up friction.

X1.7 Diffusion-Alloyed Iron-Bronze Materials Bearings made of these 80/20 Iron-Bronze materials are characterized by fine interconnected porosity, smooth bearing surface, high radial crushing strength, quiet operation and low cost. The material is used for applications requiring good hydrodynamic lubrication at light loads and relatively fast operating speeds.

X1.8 *Iron-Graphite Materials* —These copper free bearings are manufactured so that most of the graphitic carbon is not combined but is available to aid in lubrication. They are excellent for intermittent operating conditions at medium to high loads. The Iron-Graphite materials have excellent damping characteristics and produce a very quiet running bearing.

X2. IRON-BASE PM BEARINGS—COMMERCIAL TOLERANCES

X2.1 *Introduction*—The dimensional accuracy of iron-base PM bearings requires control of all processing steps from raw material to secondary operations. Dimensions critical to control with the PM process are the wall thickness and the length of the bearing. Wall thickness should be a minimum of one-eighth of the inside diameter Normal production practice involves sizing after sintering to achieve the tolerances shown. The tolerances for iron-base bearings are somewhat wider than bronze-base bearings. As-sintered bearings have broader tolerances and are used for applications having less demanding dimensional requirements.

SLEEVE BEARINGS

X2.2 *Sleeve Bearing Tolerances*—The recommended commercial tolerances for standard plain sleeve bearings, as-sized (Section 10, Fig. 1), are shown in Table X2.1. A listing of standard sleeve bearings in inch sizes is shown as Table X2.2.

FLANGE BEARINGS

X2.3 *Flange Bearing Tolerances*—The inside and outside diameter tolerances for the body of flange bearings (Section 10, Fig. 2) are the same as for sleeve bearings. Commercial flange diameter and flange thickness tolerances are shown in Table X2.3. Normally, flange tolerance are not critical, therefore they should only be specified as close as is required for the application.

THRUST WASHERS

X2.4 *Thrust Washer Tolerances* —The commercial inside diameter tolerances for thrust washers, (Section 10, Fig. 3), are the same as those for plain cylindrical bearings. The outside diameter tolerances are the same as for the flange diameter of flanged bearings. The commercial tolerances for thickness and parallelism are shown in Table X2.4.

SPHERICAL BEARINGS

X2.5 *Spherical Bearing Tolerances*—The commercial tolerances recommended for spherical bearings, (Section 10, Fig. 4), are shown in Table X2.5.

TABLE X2.1 Recommended Tolerances for Iron-Base PM Sleeve Bearings

Inside and Outside Diameter Tolerances[A]			
Inside, d, and Outside, D, Diameters		Total Diametrical Tolerances	
in.	(mm)	in.	(mm)
up to 0.760	(up to 19)	0.001	(0.025)
0.761 to 1.010	(19 to 25)	0.0015	(0.038)
1.011 to 1.510	(25 to 38)	0.0015	(0.038)
1.511 to 2.010	(38 to 50)	0.002	(0.050)
2.011 to 2.510	(50 to 63)	0.0025	(0.063)
2.511 to 3.010	(63 to 75)	0.003	(0.075)
3.011 to 4.010	(75 to 100)	0.004	(0.100)
4.011 to 5.010	(100 to 125)	0.005	(0.125)
5.011 to 6.010	(125 to 150)	0.006	(0.150)
Length Tolerances			
Length of Bearing, L		Total Length Tolerances	
in.	(mm)	in.	(mm)
up to 1.495	(up to 38)	0.010	(0.25)
1.496 to 1.990	(38 to 50)	0.015	(0.38)
1.991 to 2.990	(50 to 75)	0.020	(0.50)
2.991 to 4.985	(75 to 125)	0.030	(0.75)

Concentricity Tolerances[B]					
Outside Diameter, D		Wall Thickness, t		Concentricity Tolerance, (TIR)	
in.	(mm)	in.	(mm)	in.	(mm)
up to 1.000	(up to 25)	up to 0.255	(up to 6)	0.003	(0.075)
1.001 to 1.510	(25 to 38)	up to 0.355	(up to 9)	0.003	(0.075)
1.511 to 2.010	(38 to 50)	up to 0.505	(up to 13)	0.004	(0.100)
2.011 to 3.010	(50 to 75)	up to 0.760	(up to 19)	0.005	(0.125)
3.011 to 4.010	(75 to 100)	up to 1.010	(up to 25)	0.005	(0.125)
4.011 to 5.010	(100 to 125)	up to 1.510	(up to 38)	0.006	(0.150)
5.011 to 6.010	(125 to 150)	up to 2.010	(up to 50)	0.007	(0.175)

[A] Values are for bearings up to 2 in. (50 mm) in length. For greater lengths increase the diametrical tolerances by 0.0005 in. (0.013 mm) for each 1 in. (25 mm) of added length.

[B] Values are for bearings up to 1 in. (25 mm) in length. For greater lengths, increase the concentricity tolerance by 0.0005 in. (0.013 mm) for each 1 in. (25 mm) of added length.

TABLE X2.2 Standard PM Sleeve Bearings

Shaft Diameter	Bearing Inside Diameter, d		Wall Thickness, t	Bearing Outside Diameter, D			Bearing Length, L	
Nominal, in.	Decimal		Nominal, in.	Nominal, in.	Decimal		Decimal	
	in.	(mm)			in.	(mm)	in.	(mm)
1/8	0.127	(3.23)	1/32	3/16	0.1905	(4.83)	0.250	(6.35)
1/8	0.127	(3.23)	1/16	1/4	0.253	(6.43)	0.250	(6.35)
5/32	0.158	(4.01)	3/64	1/4	0.253	(6.43)	0.312	(7.92)
3/16	0.1895	(4.80)	1/32	1/4	0.253	(6.43)	0.375	(9.525)
3/16	0.1895	(4.80)	1/16	5/16	0.3155	(8.01)	0.375	(9.525)
1/4	0.252	(6.40)	1/16	3/8	0.378	(9.60)	0.500	(12.70)
1/4	0.252	(6.40)	3/32	7/16	0.4405	(11.19)	0.500	(12.70)
5/16	0.3145	(7.99)	1/16	7/16	0.4405	(11.19)	0.562	(14.275)
5/16	0.3145	(7.99)	3/32	1/2	0.503	(12.78)	0.562	(14.275)
3/8	0.377	(9.58)	1/16	1/2	0.503	(12.78)	0.625	(15.875)
3/8	0.377	(9.58)	3/32	1/2	0.5655	(14.36)	0.625	(15.875)
1/2	0.502	(12.75)	1/16	5/8	0.628	(15.95)	0.750	(19.05)
1/2	0.502	(12.75)	1/8	3/4	0.753	(19.13)	0.750	(19.05)
5/8	0.627	(15.925)	1/16	3/4	0.753	(19.13)	0.750	(19.05)
5/8	0.627	(15.925)	1/8	7/8	0.879	(22.33)	0.937	(23.80)
3/4	0.752	(19.1)	1/16	7/8	0.879	(22.33)	1.125	(28.575)
3/4	0.752	(19.10)	1/8	1	1.004	(25.50)	1.125	(28.575)
1	1.003	(25.48)	1/8	1 1/4	1.254	(31.85)	1.500	(38.10)
1	1.003	(25.48)	3/16	1 3/8	1.379	(35.03)	1.500	(38.10)
1 1/4	1.2535	(31.84)	1/8	1 1/2	1.504	(38.20)	1.500	(38.10)
1 1/4	1.2535	(31.84)	3/16	1 5/8	1.630	(41.40)	1.875	(47.625)
1 1/2	1.504	(38.20)	1/8	1 3/4	1.755	(44.58)	1.500	(38.10)
1 1/2	1.504	(38.20)	3/16	1 7/8	1.880	(47.75)	2.250	(57.15)
2	2.004	(50.90)	1/4	2 1/2	2.505	(63.63)	2.000	(50.80)
2 1/2	2.505	(63.63)	1/4	3	3.006	(76.35)	2.500	(63.50)
3	3.006	(76.35)	1/4	3 1/2	3.507	(89.08)	3.000	(76.20)

TABLE X2.3 Recommended Tolerances for Iron-Base PM Flange Bearings

Flange Diameter Tolerances					
Flange Diameter, D_1		Flange Diameter Tolerances			
		Sized		As-Sintered	
in.	(mm)	in.	(mm)	in.	(mm)
0 to 1.5	(0 to 38)	±0.0025	(±0.06)	±0.005	(±0.13)
1.5 to 3.0	(38 to 75)	±0.005	(±0.13)	±0.010	(±0.25)
3.0 to 6.0	(75 to 150)	±0.010	(±0.25)	±0.025	(±0.63)
Flange Thickness Tolerances					
Flange Diameter, D_1		Flange Thickness Tolerances			
		Sized		As-Sintered	
in.	(mm)	in.	(mm)	in.	(mm)
0 to 1.5	(0 to 38)	±0.0025	(±0.06)	±0.005	(±0.13)
1.5 to 3.0	(38 to 75)	±0.007	(±0.18)	±0.010	(±0.25)
3.0 to 6.0	(75 to 150)	±0.010	(±0.25)	±0.015	(±0.38)
Flange Parallelism Tolerances					
Flange Diameter, D_1		Maximum Parallelism of Faces			
		Sized		As-Sintered	
in.	(mm)	in.	(mm)	in.	(mm)
0 to 1.5	(0 to 38)	0.003	(0.075)	0.005	(0.125)
1.5 to 3.0	(38 to 75)	0.005	(0.125)	0.007	(0.175)
3.0 to 6.0	(75 to 150)	0.007	(0.175)	0.010	(0.250)

TABLE X2.4 Recommended Tolerances for Iron-Base PM Thrust Washers

Thrust Washer Thickness Tolerances					
Thrust Washer Thickness, L		Thickness Tolerance for All Diameters			
		Sized		As-Sintered	
in.	(mm)	in.	(mm)	in.	(mm)
0 to 0.25	(0 to 6)	±0.0025	(±0.06)	±0.005	(±0.13)
Thrust Washer Parallelism Tolerances					
Thrust Washer Diameter, D		Maximum Parallelism of Faces			
		Sized		As-Sintered	
in.	(mm)	in.	(mm)	in.	(mm)
0 to 1.5	(0 to 38)	0.003	(0.075)	0.005	(0.125)
1.5 to 3.0	(38 to 75)	0.005	(0.125)	0.007	(0.175)
3.0 to 6.0	(75 to 150)	0.007	(0.175)	0.010	(0.250)

TABLE X2.5 Recommended Tolerances for Iron-Base PM Spherical Bearings

Inside Diameter Tolerances			
Inside Diameter, d		Total Diametrical Tolerance	
in.	(mm)	in.	(mm)
0 to 1.00	(0 to 25)	0.0010	(0.025)
1.00 to 2.00	(25 to 50)	0.0015	(0,038)
2.00 to 3.00	(50 to 75)	0.0020	(0.051)
Outside Diameter Tolerances			
Outside Diameter, D		Total Diametrical Tolerance	
in.	(mm)	in.	(mm)
0 to 4.00	(0 to 100)	0.02	(0.6)
Sphere Diameter Tolerances			
Sphere Diameter, S		Total Diametrical Tolerance	
in.	(mm)	in.	(mm)
0 to 1.00	(0 to 25)	0.006	(0.15)
1.00 to 1.50	(25 to 40)	0.008	(0.20)
1.50 to 3.00	(40 to 75)	0.014	(0.36)
3.00 to 4.00	(75 to 100)	0.018	(0.46)
over 4.00	over 100	0.025	(0.63)
Length Tolerances			
Length of Bearing, L		Plus or Minus Tolerance	
in.	(mm)	in.	(mm)
0 to 2.50	(0 to 65)	0.02	(0.5)

X3. IRON-BASE PM BEARINGS—ENGINEERING INFORMATION

X3.1 *Introduction*:

X3.1.1 This section contains some basic engineering information concerning the design, installation, and operation of iron-base PM bearings that is important to their successful use. It does not purport to be all-inclusive and is only included as a helpful guide.

X3.2 *Compressive Yield Strength*:

X3.2.1 The load carrying capacity of a bearing is directly related to the compressive yield strength of the bearing material. The yield strength is determined by testing cylindrical specimens 0.375 ± 0.003 in. (9.53 ± 0.08 mm) diameter by 1.005 ± 0.003 in. (25.53 ± 0.08 mm) in length, in accordance with the procedure in Test Method E9. (Section on cemented carbide test specimen).

X3.3 *Bearing Loading and Speeds*:

X3.3.1 *Operating Factors*—There are two main factors that must be considered when engineering a bearing application. Both strongly influence the selection of the bearing material and in many cases the load can control the length of the bearing. Design is often based upon experience.

X3.3.1.1 *Shaft Speed*—The shaft velocity is one important factor. It is expressed as V, the circumferential surface speed (rpm × πD) of the shaft in ft./min. (m/min.)

X3.3.1.2 *Operating Speeds*—Iron-base bearings are generally used at slower speeds than bronze-base bearings. Industrial experience with commercial applications has shown that iron-base bearings operate most successfully at shaft speeds between 50 and 200 ft/min (15 to 60 m/min.), but can be used at shaft speeds as high as 2000 ft/min (600 m/min) if very lightly loaded.

X3.3.1.3 *Bearing Loading*—The load on the bearing is also a major factor and is expressed as P, the pressure in psi. (N/mm^2 or MPa). It is calculated by dividing the load in lbf (N) by the projected bearing area (d × L).

X3.3.2 *Static Loads*—The maximum static load-carrying capacity is primarily a function of the strength of the material. It is recommended that the static pressure on the bearing not exceed 75 % of the compressive yield strength of the PM bearing material. The compressive yield strength (0.1 % permanent offset) of iron-base bearing materials range from 15 000 to 40 000 psi (100 to 270 MPa) depending upon composition while heat-treated materials may have 50 000 to 75 000 psi (340 to 520 MPa) yield strength.

X3.3.3 *Operating Speeds*—Iron-base bearings are generally used at slower speeds than bronze-base bearings. Industrial experience with commercial applications has shown that iron-base bearings operate most successfully at shaft speeds between 50 and 200 ft/min (15 to 60 m/min.), but can be used at shaft speeds as high as 2000 ft/min (600 m/min) if very lightly loaded.

X3.3.4 *Operating Loads*—Iron-base bearings can carry higher operating loads than bronze-base bearings. Pressures up to 400 psi (3 MPa) have been found to be most successful, but greater loads up to 1000 psi (7 MPa) can be accommodated at slower shaft speeds. The maximum permissible operating load is directly related to the strength of the iron-base bearing material.

X3.4 *Pressure/Velocity (PV) Factor*:

X3.4.1 The design of any type of bearing and the selection of a bearing material may also be based on a term called the PV Factor. This engineering guideline defines the load carrying capacity of a bearing as measured by a friction and wear criteria that is an index of the heat generated in the bearing. The PV Factor is the product of P, the bearing load divided by the projected bearing area (d × L) expressed in psi and V, the circumferential surface velocity of the shaft in ft/min (in SI units, P is measured in N/mm^2 (MPa) and V is in m/min).

X3.4.2 Most bearing handbooks list an upper limit for PV, a value based on the type of bearing and the bearing material, which, under ideal conditions, should not be exceeded for satisfactory performance. For oil-impregnated iron-base sleeve bearings, this published value is from 35 000 to 50 000 psi × ft/min (75 to 105 MPa × m/min). However, the working PV Limit is a function of the bearing material, the operating conditions and the external environment and many factors can cause a reduction in the usable PV value.

X3.4.3 Detailed information on PV calculations and influences is available from PM bearing manufacturers. This may be a complicated calculation and the bearing purchaser is cautioned to consult with their technical service engineers with regard to the use of this procedure in the design of a PM bearing for a specific application. MPIF Standard 35 (Bearings) also contains information on external factors that influence the working PV Limit.

X3.5 *Installation*:

X3.5.1 Plain cylindrical PM journal bearings are commonly installed by press fitting the bearing into the journal housing with the use of an insertion arbor. The outside diameter of the insertion arbor must be the correct size to maintain the inside diameter and the tolerances and concentricity of the bearing after installation. For housings rigid enough to withstand the press fit without appreciable distortion and for bearings with a wall thickness approximately one eighth of the bearing outside

TABLE X3.1 Recommended Press Fits

Outside Diameter, D, of Bearing		Recommended Interference	
in.	(mm)	in.	(mm)
up to 0.760	(up to 19.31)	0.001 to 0.003	(0.025 to 0.08)
0.761 to 1.510	(19.32 to 38.36)	0.0015 to 0.004	(0.04 to 0.10)
1.511 to 2.510	(38.37 to 63.76)	0.002 to 0.005	(0.05 to 0.13)
2.511 to 3.010	(63.77 to 76.45)	0.002 to 0.006	(0.05 to 0.15)
over 3.010	(over 76.45)	0.002 to 0.007	(0.05 to 0.18)

TABLE X3.2 Minimum Running Clearance for Iron-Base Bearings

Shaft Diameter		Minimum Running Clearance	
in.	(mm)	in.	(mm)
up to 0.250	(up to 6)	0.0006	(0.015)
0.251 to 0.760	(6.01 to 19)	0.0008	(0.020)
0.761 to 1.510	(19.01 to 38)	0.0013	(0.033)
1.511 to 2.510	(38.01 to 63)	0.0018	(0.045)
over 2.510	(over 63)	0.0023	(0.058)

diameter, the diametrical interference values shown in Table X3.1 are recommended.

X3.6 *Running Clearance*:

X3.6.1 Proper running clearance for sintered iron-base bearings depends to a great extent on the particular application. Therefore, only minimum recommended clearances are listed in Table X3.2.

X3.6.2 With good design practice, the maximum running clearances will automatically be held for normal operating conditions. It is assumed that hardened and ground steel shafts having a recommended surface finish of 4 to 16 µin. (0.1 to 0.4 µm) shall be used and that all bearings will be oil-impregnated.

X3.7 *Bearing Life*:

X3.7.1 Oil-impregnated PM bearing are maintenance free and designed to last the life of the unit. Tests have shown that fractional horse power motor bearings in vacuum cleaners, small electric tools and household appliances will still perform satisfactorily after 10 000 h of normal operation. Elevated bearing temperatures due to operating conditions or the external environment is the major cause of reduced bearing life.[6]

X3.8 *Technical Support*:

X3.8.1 For detailed information concerning the strength of specific compositions, safe operating speeds and loads or for assistance on bearing design and material selection for new or unusual applications, the purchaser is strongly urged to contact the engineering department of the PM bearing manufacturer

[6] Kindler, A. E., and Stein, H., "Determination of the Life of Sintered Bearings," *Metal Powder Report*, 1985, pp. 347-356.

X4. PM BEARINGS—ADDITIONAL INFORMATION

X4.1 *MPIF Standard*:

X4.1.1 For more complete engineering information and detailed specifications regarding additional grades of iron-base and bronze-base oil-impregnated powder metallurgy (PM) bearing materials, refer to MPIF Standard 35 (Bearings).

X4.2 *Metric Bearings*:

X4.2.1 For design information on self-lubricating bearings in standard metric sizes, refer to ISO 2795. Any of the standardized PM materials covered by this ASTM specification may be used in the manufacture of metric bearings.

SUMMARY OF CHANGES

Subcommittee B09.04 has identified the location of these selected changes, made to this standard since issue B439 – 08, that may impact the use of this standard.

(1) The new Iron-Base bearing grades that were taken from MPIF 35 are listed in Section 2 and the specifications are shown in Table 1 and 2.
(2) All references to obsolete standards B612 and B782 have been removed.
(3) The reference to SI 10 has been removed.
(4) Section 4 has been rewritten to present more general descriptions of the grades, leaving the specifics to Tables 1 and 2.
(5) Wet density has been changed to impregnated density throughout.
(6) A new paragraph on the applications of Diffusion-Alloyed Iron-Bronze has been added as X1.7.