Designation: F3131 – 14

Standard Specification for Epoxy / Cotton Raw Materials for the Use in Bearing Cages[1]

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1. Scope

1.1 This specification covers basic characteristics required for porous laminated Epoxy materials intended for use as instrument and thin-section ball-bearing retainers (cages) and the methods of determining these characteristics.

1.2 *Forms*—Sheets and Rolled Tubes are recommended forms of laminated material covered by this specification.

1.3 *Intended Use*—Materials produced to this specification are intended for use as ball bearing retainers (cages). Temperature range is limited to 284°F (140°C) and below

1.4 *Units*—The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D618 Practice for Conditioning Plastics for Testing

D229 Test Methods for Rigid Sheet and Plate Materials Used for Electrical Insulation

D570 Test Method for Water Absorption of Plastics

D695 Test Method for Compressive Properties of Rigid Plastics

D790 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials

D792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement

D2257 Test Method for Extractable Matter in Textiles

E1640 Test Method for Assignment of the Glass Transition Temperature By Dynamic Mechanical Analysis

2.2 *ANSI/ASQC Standards:*[3]

ANSI/ASQC Z1.4 Sampling Procedures and Tables for Inspection by Attributes

2.3 *Federal Standard:*[4]

MIL-STD-129 Military Making for Shipment and Storage

3. Material and Test Conditioning

3.1 *Material Conditioning Prior to Tests:* (designation as follows)

3.1.1 A number indicating in degrees Celsius the conditioning temperature, or

3.1.2 A number indicating relative humidity, whenever humidity is controlled, or a word to indicate immersion in liquid.

3.2 The numbers shall be separated from each other by a slant marks. A sequence of conditions shall be denoted by use of a plus (+) sign between successive conditions. “Des” shall be used to indicate desiccation over anhydrous calcium chloride. A capital letter “T” (test condition) following the prior material conditioning designation shall be separated by a colon, with the testing condition noted in the same format as the material conditioning. Temperature and relative humidity tolerances shall be in accordance with Practice D618 Section 7, unless otherwise specified.

3.2.1 *EXAMPLES:*

3.2.1.1 *C-96/35/90*—— Humidity conditioning – 96 h at 95°F, (35°C) and 90% relative humidity.

3.2.1.2 *E-48/50*—Temperature conditioning - 48 h at 122°F, (50°C).

3.2.1.3 *D1-24/23*—Immersion conditioning - 24 h in distilled water at 73.4°F, (23°C), followed by E-1/105 - temperature conditioning - 1 h at 221°F, (105°C).

3.3 *Standard Procedures:*

3.3.1 *Procedure A:*

3.3.1.1 *Condition A*—40/23/50 for thickness equal or less than 0.250 in., (7mm) or Condition A-88/23/50 for thickness

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[2] 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.

[3] Available from American Society for Quality (ASQ), 600 N. Plankinton Ave., Milwaukee, WI 53203, http://www.asq.org.

[4] DLA Document Services Building 4/D 700 Robbins Avenue Philadelphia, PA 19111-5094 http://quicksearch.dla.mil/

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greater than 0.250 in., (7mm) Standard Laboratory atmosphere for a minimum of either 40 h or 88 h, dependent on thickness, at 73.4°F (23°C) and 50% relative humidity.

3.3.2 *Procedure D:*

3.3.2.1 *Condition D_1*—24/23 See example above.

3.3.2.2 *Condition D*—24/23 – Immersion conditioning - 24 h at 73.4°F, (23°C).

3.3.2.3 *Condition D*—48/50 – Immersion conditioning - 48 h at 122°F, (50°C).

3.3.3 *Procedure E:*

3.3.3.1 Condition E-1/150: T-150 – Temperature conditioning - 1 h at 302°F, (150°C) - immediately followed with Test at 302°F, (150°C).

3.3.3.2 *Condition E*—48/50 See example above.

3.3.3.3 *Condition E*—168/185 – Temperature conditioning – 168 h at 365°F, (185°C).

4. Classification

4.1 The material shall be furnished in the following types and forms as specified:

Type	Description
FB	Rolled tube made from cotton fabric weighing 4 oz/yd^2 (0.14 kg/m^2) or less, with a nominal thread count of 80 by 80 threads per in. (31.5 by 31.5 cm). Thread tolerance of ± 5%.
FBFW	Rolled tube made from cotton fabric weighing 4 oz/yd^2 (0.14 kg/m^2) or less, with a nominal thread count of 100 by 100 threads per in. (39.4 by 39.4 cm). Thread tolerance of ± 5%.
FBEFW	Rolled tube made from cotton fabric weighing 3 oz/yd^2(0.1 kg/m^2) or less, with a nominal thread count of 130 by 130 threads per in. (51.2 cm). Thread tolerance of ± 5%.

5. Ordering Information

5.1 Procurement documents should specify the following:

5.1.1 Title, designation, and date of this specification;

5.1.2 Type required (see Section 4);

5.1.3 Dimensions required; and

5.1.4 Special marking required (see 10.2).

5.2 Required test data shall be requested at the time the purchase order is submitted and listed on the purchase order.

6. Order of Precedence

6.1 In the event of a conflict between the text of this specification and references cited herein, the text of this specification takes precedence. Nothing in this specification, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

7. Performance Requirement

7.1 *Tube*—Performance requirements for tube laminated materials specified in Table 1.

7.2 *Sheet*—Performance requirements for sheet laminated materials, specified in Table 2.

7.3 *Construction*—Tubes and Sheets shall consist of cotton base material (reinforcement) as described in 4.1, impregnated and bonded with a non-plasticized Epoxy resin. Tubes will be made by passing the impregnated material over heated rolls and winding the heated material onto a mandrel while applying pressure to the material/mandrel. The overwrapped mandrel is then placed in an oven to cure the tube. Sheets will be made by stacking pre-cut impregnated material between steel plates and loaded into a press applying heat and pressure to cure the sheet.

7.4 *Base Materials:*

7.4.1 *Cotton Fabric Construction*—Material shall consist of a woven cotton fabric substrate impregnated and bonded with an Epoxy resin matrix and processed to meet the requirements of this specification, (see 4.1). Finished fabric shall be de-sized, washed, and bleached, with remaining impurities per Test Method D2257 Extractable Matter, not greater than 1.5 % after finishing.

7.5 *Property Values*—Tubes shall conform to the property values shown in Table 1, when tested in accordance with Section 8. The property value requirements for special sizes of tubes shall be as specified in the purchase order (see Section 5). Sheets shall conform to the property values shown in Table 2, when tested in accordance with Section 8. The property value requirements for special sizes of sheets shall be as specified in the purchase order (see Section 5).

7.6 *Dimensional:*

7.6.1 *Diameter of Tubes Rolled Round (TRR)*—Range of sizes for tubes rolled round shall be as specified in Table 3. The inside diameter and outside diameter shall be included in the part number. An example of a part number for a rolled tube with an inside diameter of 0.188 in., (0.478 cm) and an outside diameter of 0.250 in., (0.635 cm) is TRR-00.188/00.250. The wall thickness tolerances for finished outside diameter shall be as specified in Table 4.

TABLE 1 Performance Requirements for Tubes

	Condition	ASTM Test Method	Unit	FB	FBFW		FBEFW
Compressive Strength Axial[A]	A	D695	Min. psi	27 000	27 000		27 000
Compressive Strength Axial[A] Modulus	A	D695	Min. kpsi	255	255		285
Density[A] (Range)	A	D792	gm/cc	1.24 – 1.34	1.28 – 1.38		1.30 – 1.38
Tg by DMA	A	E1640	Min. °C	150	150		150
Water Absorption (ID range of 0.25 in. (0.635 cm.) – 8.0 in. (20.3 cm.))	D_1 – 24/23	D570	Max. %	Wall < 0.062 in. (0.16 cm.) 1.5	Wall < 0.125 in. (0.32 cm.) 1.0	Wall <0.250 in. (0.63 cm.) 0.75	Wall <0.5 in. (1.27 cm.) 0.5

[A]Pounds per square inches (psi). 1 psi = 6.8948 kPa. Test is limited to tubes 0.250 in. (0.635 cm) and greater ID. One specimen to be taken from center of sample tube. The other two specimens to be taken 1 in. (2.54 cm) from each end of the sample tube.

TABLE 2 Performance Requirements for FB Sheets

	Condition	ASTM Test Method	Unit	Thickness (in.)[A]									
				0.031	0.062	0.094	0.125	0.188	0.250	0.500	0.750	1.000	1.001 – Max.
Flexural strength													
Lengthwise:	A	D790	Min. psi	19 000	19 000	19 000	19 000	19 000	19 000	19 000	18 000	16 500	16 000
Crosswise:			Min. psi	16 000	16 000	16 000	16 000	16 000	16 000	16 000	15 000	12 500	12 500
Flexural strength													
Lengthwise:	A	D790	Min. kpsi	...	900	900	900	900	900	900	900	900	900
Modulus													
Crosswise: modulus	...	...	Min. kpsi	...	750	750	750	750	750	750	750	750	750
Tg by DMA	A	E1640	Min. °C	150	150	150	150	150	150	150	150	150	150
Bonding strength	A D-48/50	D229	Min. lbs.	...	...	...	...	...	...	1 800 1 700	1 800 1 700	2 200 2 200	2 200 2 200
Water absorption	D_1 – 24/23 D570	D570	Max. %	1.50	1.25	1.00	1.00	0.75	0.75	0.50	0.50	0.25	0.25
Silicone content	E-168/185	Customer Specific	Max. ppm	50	50	50	50	50	50	50	50	50	50

[A] 1 in. = 2.54 cm. 1 lb = 0.45 kg. 1 psi = 6.8948 kPa
[B] Maximum thickness tested shall be 2.000 in. (5.08 cm).

TABLE 3 Tolerances on Diameters of Rolled Tubes

Nominal Diameters in.[A,B]	Tolerances (±)	
	Inside Diameters (in.)[B] (ID)	Ground Outside Diameters (in.)[B] (OD)
0.090 up to 0.750	0.003	0.005
0.750 up to 2.000	0.004	0.005
2.000 – 4.000, inclusive[C]	0.008	0.008
4.001 – 12.000, inclusive[C]	0.010	Ground, Turned or (As Wound) 0.025 (+ only 0.050 min.)
12.001 - 18.000, inclusive[C]	0.030	Turned only or (As Wound) 0.030 (+ only 0.060 min.)
18.001 up to 24.000, inclusive[C]	0.040	0.035 (+ only 0.070 min.)
24.000 to 48.000, inclusive[C]	0.060	0.040 (+ only 0.080 min.)

[A] The term "up to" means "up to but not including."
[B] 1 in. = 2.54 cm
[C] Rolled tube only

7.6.2 *Thickness of Sheets*—Thickness of laminated sheets, permissible variations, and the applicable part number shall be as specified in Table 5.

7.6.3 *Warpage*—Warpage of material furnished in the tube or sheet form, as delivered, shall not be greater than the following when measured per method in 8.4: Tubes Outside Diameter (OD) and Sheet Thickness, Permissible Warp, Table 6.

NOTE 1—Percentage of warp is specified in terms of 36-in. (91-cm) material lengths.

7.6.4 *Lengths*—Unless otherwise specified (see Section 5), tubes shall be furnished in Manufacturer's standards lengths.

7.6.5 *Tolerances*—Tube diameters ID, OD and Wall thickness shall be specified by only two dimensions ID by OD or ID by Wall, (see Section 5). For tube ID and OD tolerances (see Table 3). For tube Wall thickness tolerance (see Table 5). Unless otherwise specified, tubes shall conform to the specified dimensions from nominal ID and OD, but variations in wall thickness shall not be greater than the tolerances shown in Table 5. As an option a buyer may request an unfinished OD or trimmed length, or both. For sheet thickness tolerance (see Table 5).

7.7 *Resin*—Shall be used and stored within the manufacturer's requirements.

7.8 *Pre Preg*—Prepreg shall be used within six months when stored at 68 ± 5.4°F (20 ± 3°C) and 30 % maximum relative humidity. Some resin systems may require Prepreg to be frozen.

7.9 *Surface Defects*—Finished, tube OD diameters and sheet surfaces shall be free from blisters, loose layers, resin pockets, voids and wrinkles. Finished walls and sheet thickness shall show no checks or cracks between the laminations on machined or sawed edges.

7.10 *Color*—The natural color of the laminate may vary and is not a cause for rejection.

7.11 *Surface Finish*—Laminate shall be finished to meet the customer requirements.

7.12 *Degree of Cure*—Degree of cure measuring Tg. (Glass Transition) by Test Method E1640, shall be measured by DMA method (or other similar test method), with a minimum value of 302°F, (150 °C).

8. Verification

8.1 *Responsibility for Inspection*—Unless otherwise specified in the contract or purchase order, the contractor is responsible for the performance of all inspection requirements (examinations and tests) as specified herein. Except as otherwise specified in the contract or purchase order, the contractor may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the customer. The customer reserves the right to perform any of the inspections set forth in this specification where such inspections are deemed necessary to ensure supplies and services conform to prescribed requirements.

8.2 *Conformance Inspection:*

8.2.1 *Sampling for Conformance Inspection*—Sampling for conformance inspection shall be performed in accordance with ASQC-Z1.4 unless otherwise specified. For purpose of sampling, an inspection lot for examination and tests shall consist of all materials of the same type dimensions, resin, and base material from one impregnation run.

8.2.2 *Examination of Material*—Examination of material shall be made in accordance with 7.4. The lot size for determining the sample size in accordance with ASQC-Z1.4. MIL-STD-129 Military Making for Shipment and Storage shall be expressed in units of tubes or sheets.

8.3 *Appearance and Workmanship*—The sample unit for the following examination shall be tubes or sheets of the specified lot. The inspection level shall be per ASQC-Z1.4 ASQC-Z1.4. MIL-STD-129 Military Making for Shipment and Storage, Level II with acceptance quality levels (AQLs) as follows: 1.5 for major defects and for minor defects. Classifications of defects are listed in Table 7.

8.4 *Testing*—Tubes or sheets shall be tested for applicable characteristics as indicated in Table 1 on each lot presented for inspection. The inspection level for determining the sample size shall be S-1 per ASQC-Z1.4 except that not less than two sample units shall be randomly selected from a lot. The lot size shall be expressed in units of tubes or sheets. The AQL shall be 6.5. Describe all failures and report all values on which test results are based.

9. Test Methods

9.1 *Measurements*—Tube or sheet shall be examined and dimensions other than length recorded to the nearest 0.001 in. (0.00254 cm.). Cut tube lengths shall be measured to the nearest; 0.0625 in. (0.1588 cm.) for less than 1 in. OD diameter, 0.125 in. (.3175 cm.) for less than 2 in. OD diameter, 0.250 in. (0.635 cm) for less than 4 in. OD diameter, and 1.0 in. (2.54 cm) for OD diameters greater than or equal to 4 in. Standard Manufacturer length shall be ± 1.0 in. (± 2.54 cm.) for tube, for sheet length and width.

9.2 *Axial Compressive Strength (Tube form only):*

TABLE 4 Tolerances on Wall Thickness of Rolled Tubes

Wall Thickness[A]	Thickness Tolerances (±) from Average Wall Thickness of Individual Tube (in.) Type FB, FBFW, FBEFW Inside Diameter (in.)		
	0.188 – 0.250	0.251 – 0.500	0.501 – Max.
0.031 up to 0.062	0.010	0.010	0.008
0.062 up to 0.126	0.011	0.011	0.009
0.126 up to 0.251	0.013	0.013	0.011
0.251 to 0.500, inclusive	0.015	0.015	0.013

[A] The term "up to" means "up to but not including."

TABLE 5 Thickness of Laminated Sheets[A]

Nominal Thickness (in.)	Permissible Variations (± in.)
0.015	0.0035
0.020	0.004
0.025	0.0045
0.031	0.005
0.047	0.0055
0.062	0.006
0.094	0.007
0.125	0.008
0.156	0.009
0.188	0.010
0.219	0.011
0.250	0.012
0.312	0.0145
0.375	0.017
0.438	0.019
0.500	0.021
0.625	0.024
0.750	0.027
0.875	0.030
1.000	0.033
1.125	0.035
1.250	0.037
1.375	0.039
1.500	0.041
1.625	0.043
1.750	0.045
1.875	0.047
2.000	0.049

[A] On sheets of nominal thickness not listed in this table, the permissible variations shall be the same as for the next greater thickness. 1 in. = 2.54 cm.

TABLE 6 Maximum Percent

Inch	Sheets	Tubes
0.031 up to 0.063	5.0	(---)
0.063 up to 0.126	2.5	(---)
0.126 up to 0.251	1.0	2.0
0.251 up to 0.750	0.5	1.0
0.750 to Max	0.25	0.5

9.2.1 The Axial Compressive Strength shall be determined by Table 1 and Test Method D695, except that the specimen length shall be 1 in. (2.54 cm.) for tubes to 2 in. (5 cm) OD or less, with wall thickness of 0.0625 in. (0.1588 cm) or greater.

9.2.2 The Axial Compressive Strength requirement and test method for tubes over 2 in. (5 cm.) in OD or with walls less than 0.0625 in. (0.1588 cm) will be as specified in the purchase order.

9.3 *Density (Tube form only)*——the density shall be as determined by Test Method D790.

9.4 *Water Absorption*—Water Absorption shall be as determined by Test Method D570.

9.5 *Flexural Strength (Sheet form only)*—Flexural Strength and Modulus shall be determined by Test Method D790.

9.6 *Bond Strength*—Bond Strength shall be determined by Test Method D229.

9.7 *Warpage (Tube and Sheet forms)*—The warpage of material furnished in tube and sheet forms, as delivered, shall not exceed permissible allowance, Table 6 (See 7.6.3).

9.7.1 *Apparatus–For Tube*—A horizontal flat surface and rigid bar with a vertical plane surface firmly fixed at right angles to the flat surface shall be greater than the specimen to be tested. The height of the bar shall exceed by one half the outside diameter of the tube. Feeler gauges shall also be required.

9.7.2 *Procedure*—For tube specimen shall be placed on the vertical plane and rotated against the vertical plane surface of the rigid bar. The bar shall be firmly fastened to the horizontal flat surface. The maximum separation between the tube and the vertical plane surface shall be measured to the nearest 0.001 in. (0.0025 cm). For sheet specimen, hold a straightedge along the side the dimension to be measured. Place the concave side of the sheet adjacent to the straightedge. Measure the greatest deviation of the concave surface from the straightedge.

9.7.3 *Report and Calculation*—Warp or lack of bearing straightness shall be reported as the maximum separation or any part of the tube or sheet from a straight edge which contacts the ends of the specimen. The permissible allowance is based on a 36 in. (91.4 cm.) length. The warpage shall then be calculated as follows:

$$W = [(36\ D)/L^2] \times 100 \quad (1)$$

where:

W = Percentage of warp, calculated to a 36 in. (91.4 cm) length;
D = Maximum deviation of tube from straight edge in inches (centimeters); and
L = Length of tube in inches (centimeters).

10. Packaging and Package Marking

10.1 *Packaging*—Material to be packaged per Vendor's accepted standard practice unless detailed requirements are specified in the contract.

10.2 *Marking*—Shipping containers shall be marked in accordance with Federal Standards, MIL-STD-129.

10.3 Laminate lot traceability.

11. Keywords

11.1 ball bearing separator; ball bearing cage; epoxy; fabricated; laminated; plastic

TABLE 7 Classification of Defects

Examination	Defect	Classification	
		Major	Minor
Appearance and Workmanship	Not uniform in texture and finish		X
	Presence of foreign matter, grit, or abrasives	X	
	Any crack, break, bulge, blisters, wrinkles, scratches, dents, voids or resin pockets detrimental to finished part	X	
	Any separation of laminations	X	
	Laminations not as specified Ragged or rough edges or sides	X	
	Fabric not continuous	X	

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