Designation: D 3368 – 99

Standard Specification for FEP-Fluorocarbon Sheet and Film[1]

This standard is issued under the fixed designation D 3368; 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 unfilled, unpigmented FEP-fluorocarbon resin sheet and film less than 3.175 mm (0.125 in.) thick. Recycled materials are allowed in accordance with 6.2.

1.2 The values stated in SI units as detailed in IEEE/ASTM SI 10 are to be regarded as the standard and the practices of IEEE/ASTM SI 10 incorporated herein.

1.3 The following safety hazards caveat pertains only to the test methods portion, Section 14, of 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.*

NOTE 1—There is no similar or equivalent ISO standard.

2. Referenced Documents

2.1 *ASTM Standards:*

D 149 Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies[2]

D 374 Test Methods for Thickness of Solid Electrical Insulation[3]

D 618 Practice for Conditioning Plastics and Electrical Insulating Materials for Testing[4]

D 638 Test Method for Tensile Properties of Plastics[4]

D 882 Test Methods for Tensile Properties of Thin Plastic Sheeting[4]

D 883 Terminology Relating to Plastics[4]

D 1505 Test Method for Density of Plastics by the Density-Gradient Technique[4]

D 2116 Specification for FEP Fluorocarbon Molding and Extrusion Materials[4]

D 3892 Practice for Packaging/Packing of Plastics[5]

D 5740 Guide for Writing Material Standards in the D 4000 Format[6]

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method[7]

IEEE/ASTM SI 10 Standard for Use of the International System of Units (SI)[8]

2.2 *Other Standard:*

TAPPI 411 Standard Thickness (Caliper) of Paper and Paper Products[9]

3. Terminology

3.1 *Definitions*—For definitions of terms used in this specification, see Terminology D 883.

3.1.1 *lot, n*—one production run or a uniform blend of two or more production runs.

4. Classification

4.1 This specification covers four types of FEP-fluorocarbon sheet and film:

4.1.1 *Type I*—General purpose.

4.1.2 *Type II*—Cementable film. Type II materials can be subdivided into two grades:

4.1.2.1 *Grade 1*—One side cementable, and

4.1.2.2 *Grade 2*—Two sides cementable.

4.1.3 *Type III*—Special film for applications requiring unusual flexural endurance or extreme thermal and chemical service.

4.1.4 *Type IV*—Film for mold release applications.

4.2 A one-line system may be used to specify materials covered by this specification. The system uses predefined cells to refer to specific aspects of this specification, which are illustrated as follows:

[1] This specification is under the jurisdiction of ASTM Committee D-20 on Plastics and is the direct responsibility of Subcommittee D20.15 on Thermoplastic Materials, Section D-20.15.12 on Fluoropolymers.

Current edition approved Dec. 10, 1999. Published March 2000. Originally published as D 3368 – 75. Last previous edition D 3368 – 94.

[2] *Annual Book of ASTM Standards*, Vol 10.02.

[3] *Annual Book of ASTM Standards*, Vol 10.01.

[4] *Annual Book of ASTM Standards*, Vol 08.01.

[5] *Annual Book of ASTM Standards*, Vol 08.02.

[6] *Annual Book of ASTM Standards*, Vol 08.03.

[7] *Annual Book of ASTM Standards*, Vol 14.02.

[8] *Annual Book of ASTM Standards*, Vol 14.04.

[9] Available from the Technical Association of the Pulp and Paper Industry (TAPPI), P.O. Box 105113, Atlanta, GA 30348-5113. Phone: 1-800-332-8686.

Specification				
Standard Number Block	Type	Grade	Class	Special Notes
Example: Specification D 3368 – 9_,	II	1		, 0.051 mm thick

For this example, the line callout would be Specification D 3368 – 9_, II 1, 0.051 mm thick. This callout would specify a film of FEP that is cementable on one side and that has all of the properties listed for that type and grade in the appropriate specified properties or tables, or both, in this specification. Inclusion of a class is provided for in the system, but is not used in this particular specification. A comma is used as the separator between the standard number and the type. Separators are not needed between the type, grade, and class.[10] Provision for special notes is included in the system so that other information can be provided when required, in this case, the thickness of the film. When special notes are used, they should be preceded by a comma.

5. Ordering Information

5.1 The sheet and film shall be furnished in the form of sheets or rolls in accordance with good commercial practice. Rolls shall be wound evenly and tightly on substantial cores suitably restrained to prevent unwinding.

5.2 Dimensions of sheet and film with respect to length, width, and core diameter shall be upon agreement between the purchaser and the manufacturer. The agreement shall apply also to the maximum number of splices per roll and tolerances for length and core.

[10] See the ASTM *Form and Style Manual*. Available from ASTM Headquarters.

5.3 Requests for certification or test results should be made at the time of order placement.

6. Materials and Manufacture

6.1 The sheet and film shall be made from FEP-fluorocarbon resin as specified in Specification D 2116 without filler or plasticizer.

6.2 This specification allows for the use of recycled, reprocessed, and reworked FEP materials provided the following:

6.2.1 The final physical, mechanical, and performance requirements as stated in this specification are met.

6.2.2 The toxicological characteristics are essentially unaltered from that of virgin material.

7. Other Requirements

7.1 The sheet and film shall conform to the physical, mechanical, and performance property requirements specified in Table 1. The nominal thickness of sheet or film and thickness tolerances shall be in accordance with Table 2.

7.2 The film and sheet shall be uniform in appearance and shall be sufficiently free of contamination, wrinkles, holes, scratches, and other imperfections so as to be functionally acceptable. The color shall be uniform and be characteristic of unpigmented sheet or film that ranges from clear to translucent and is dependent upon the thickness.

7.3 Tolerances for width of rolls shall be ±1.6 mm (±0.0625 in.) for film or sheet thickness less than 0.508 mm (0.020 in.) and ±3.2 mm (±0.125 in.) for sheet thickness equal to or greater than 0.508 mm.

TABLE 1 Detail Requirements for Property Values

	Type I	Type II	Type III	Type IV
Tensile Strength, min, MPa (psi), at nominal thickness, mm (in.):				
0.0127 (0.0005)	13.8 (2000)	13.8 (2000)	...	11.0 (1600)
0.025 to 3.175 (0.001 to 0.125)	17.25 (2500)	17.25 (2500)	17.25 (2500)	14.5 (2100)
Elongation at Break, min, %, at nominal thickness, mm (in.):				
0.0127 to 0.025 (0.0005 to 0.001)	175	175	...	150
0.051 to 3.175 (0.002 to 0.125)	250	250	250	250
Dimensional Change on Heating, max, %, at nominal thickness, mm (in.):				
0.0127 to 0.025 (0.0005 to 0.001)	±5	±5	...	±5
0.051 (0.002)	±3	±3	±4	±3
0.076 to 0.508 (0.003 to 0.020)	±2	±2	±3	...
0.762 to 1.524 (0.030 to 0.060)	...	...	±4	...
2.285 to 3.175 (0.090 to 0.125)	...	...	±5	...
Cementability, min, peel strength, kg/m (g/in.), at nominal thickness, mm (in.):				
0.0127 (0.0005)	...	6.69 (170)	...	...
0.025 (0.001)	...	11.8 (300)	...	...
0.051 (0.002)	...	29.5 (750)	...	...
0.076 (0.003)	...	31.5 (800)	...	...
0.102 (0.004)	...	47.2 (1200)	...	...
0.127 (0.005)	...	78.7 (2000)	...	...
0.254 (0.010)	...	94.5 (2400)	...	...
0.508 (0.020)	...	94.5 (2400)	...	...
Dielectric Strength, min, kV/mm (V/mil), at nominal thickness, mm (in.):				
0.127 to 0.025 (0.0005 to 0.001)	160 (4000)	160 (4000)	...	...
0.051 (0.002)	140 (3500)	140 (3500)	...	...
0.076 (0.003)	120 (3000)	120 (3000)	...	...
0.102 (0.004)	110 (2750)	110 (2750)	...	...
0.127 (0.005)	100 (2500)	100 (2500)	...	...
0.254 (0.010)	72 (1800)	72 (1800)	...	...
0.356 (0.014)	64 (1600)	64 (1600)	...	...
0.508 (0.020)	56 (1400)	56 (1400)	...	...
Density at 23°C, g/cm^3	2.13 to 2.17	2.13 to 2.17	2.13 to 2.17	2.13 to 2.17

TABLE 2 Thickness and Tolerance Requirements

Nominal Thickness, mm (in.)	Applicable Types	Thickness, mm (in.)			
		min		max	
0.0127 (0.0005)	I, II, IV	0.0089	(0.00035)	0.0165	(0.00065)
0.025 (0.001)	I, II, IV	0.0177	(0.0007)	0.033	(0.0013
0.051 (0.002)	I, II, III	0.038	(0.0015)	0.0635	(0.0025)
0.076 (0.003)	I, II, III	0.05715	(0.00225)	0.094	(0.00375)
0.102 (0.004)	I, II, III	0.080	(0.00315)	0.123	(0.00485)
0.127 (0.005)	I, II, III	0.102	(0.004)	0.152	(0.006)
0.254 (0.010)	I, II, III	0.216	(0.0085)	0.292	(0.0015)
0.356 (0.014)	I	0.320	(0.0126)	0.391	(0.0154)
0.508 (0.020)	I, II, III	0.432	(0.017)	0.584	(0.023)
0.762 (0.030)	I, III	0.648	(0.0255)	0.876	(0.0345)
1.016 (0.040)	III	0.889	(0.0350)	1.143	(0.0450)
1.524 (0.060)	III	1.372	(0.054)	1.676	(0.0666)
2.413 (0.095)	III	2.172	(0.0855)	2.654	(0.1045)
3.175 (0.125)	III	2.921	(0.113)	3.429	(0.137)

8. Sampling

8.1 Sampling shall be statistically adequate to satisfy the requirements of 16.4.

9. Number of Tests

9.1 One set of test specimens as prescribed in Section 10 shall be considered sufficient for testing each batch. The average result of the specimens tested shall conform to the requirements of this specification.

10. Specimen Preparation

10.1 Take test specimens across the width of film excluding areas of wrinkles, folds, gel, and other obvious, visually determined, imperfections.

11. Conditioning

11.1 For those tests where conditioning is required and unless otherwise specified in the test method, condition the test specimens in accordance with Procedure A of Practice D 618 for a period of at least 4 h prior to test.

12. Apparatus

12.1 *Heat Sealer,*[11] single heated jaw with silicone rubber pad, temperature range from 150 to 275°C (300 to 525°F), pressure 138 kPa (20 psi), and dwell time 10 s.

12.2 *Rod,*[12] or other means for coating aluminum evenly with adhesive.

13. Reagents and Materials

13.1 *Methyl Ethyl Ketone*.

13.2 *Acrylic Adhesive.*[13]

13.3 *Anodized Aluminum,*[14] 0.5 mm (0.019 in.) thick. Other sheet aluminum, either plain or anodized, should be satisfactory if it can be shown that the peel failure of the seal is between the treated film surface and the adhesive, and not between the adhesive and the aluminum.

14. Test Methods

14.1 *Test Conditions*—Unless otherwise specified, conduct tests at the standard laboratory temperature of 23 ± 2°C (70 to 77°F). Since this film and sheeting does not absorb water, the importance of constant humidity during testing is not important.

14.2 *Specific Gravity*—Use Test Method D 1505, with a tube having a linear gradient over the range from 1.90 to 2.19.

14.3 *Tensile Properties*:

14.3.1 Film 0.254 mm (0.010 in.) or less in nominal thickness.

14.3.1.1 Determine the tensile strength and elongation in accordance with Method A of Test Methods D 882.

14.3.2 Sheet greater than 0.254 mm (0.010 in.) in nominal thickness.

14.3.2.1 Cut five bars with the microtensile die shown in Fig. 1. The die may be of the steel rule type and shall have a curvature of 4 ± 0.8 mm (5⁄32 ± 1⁄32 in.). The tabs at each end of the die may be longer than specified in Fig. 1.

14.3.2.2 Determine the tensile properties in accordance with the procedures described in Test Method D 638, except that the specimens shall be as detailed in 14.3.1-14.3.2.1, the initial jaw separation shall be 22.2 ± 0.13 mm (0.875 ± 0.005 in.), and the speed of testing shall be 51 mm/min (2 in./min). Clamp the specimen with essentially equal lengths of the tabs in each jaw. If an extensiometer is not available, the elongation at break may be determined from the chart record, expressing the value as a percentage of the initial jaw separation. Average the test results. In making the test for tensile properties, a full-scale load of 22.5 kg (50 lb) has been found suitable. If the specimens break quickly, it may be necessary to increase the chart speed so that the chart record for each specimen covers at least 51 mm (2 in.) on the time axis of the chart.

NOTE 2—In determining elongation from the chart record, draw a perpendicular from the break point to the time axis. Measure the distance along the time axis from the intersection of this perpendicular with the axis to the intersection of an extension of the linear part of the load-time curve and the time axis. Then, calculate percent elongation as follows:

[11] Sentinel Model 12AS or 12-12AS, available from Packaging Industries Group, Inc., 130 North St., Hyannis, MA 02601, or equivalent, has been found satisfactory for this purpose.

[12] No. 24 "Draw Down" rod, available from R. D. Specialities, Inc., P.O. Box 206, Webster, NY 14580, has been found satisfactory for this purpose.

[13] No. 68040 acrylic adhesive available from E. I. DuPont de Nemours & Co., Inc., Polymers, Wilmington, DE 19898, has been found satisfactory for this purpose.

[14] "Aldine" No. 1200, available from Alsco, Inc., 225 S. Forge St., Akron, OH 44308, or equivalent, has been found satisfactory for this purpose.

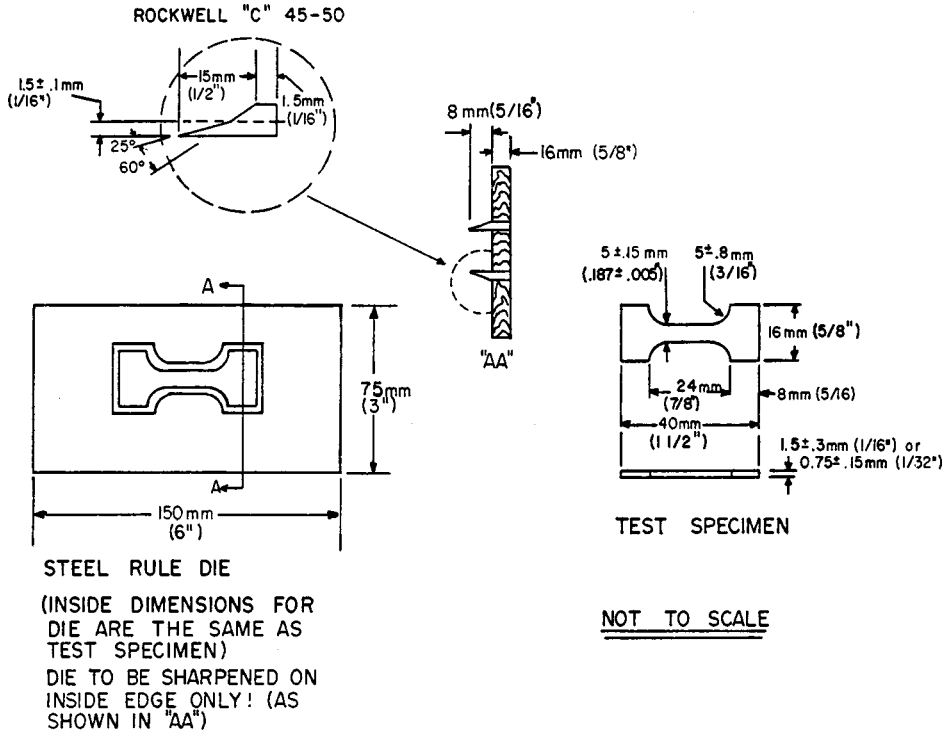

FIG. 1 Test Specimen and Die

$$\text{Elongation} = 100d/(22.2 \text{ or } 0.875)m \quad (1)$$

where:

d	=	distance on chart, mm (in.),
m	=	hart speed magnification,
	=	chart speed/crosshead speed (both in same units), and
22.2	=	factor when d is in millimetres, or
0.875	=	factor when d is in inches.

14.4 *Dielectric Strength*—Determine the dielectric strength in accordance with Test Methods D 149, using the short-time test and a 6.35-mm (¼-in.) brass electrode with a 0.79-mm (1/32-in.) radius.

14.5 *Dimensional Change on Heating*—Determine lengthwise change in dimensions by averaging five measurements on specimens immediately before and after oven heating. Each specimen shall be 101.6 ± 1.6 by 101.6 ± 1.6 mm (4 ± 1/16 by 4 ± 1/16 in.) and be freely suspended in an oven controlled at 200 ± 3°C (392 ± 5.4°F) for a minimum of 30 min. After the heating period, cool the specimens to 23 ± 2°C (73.4 ± 3.6°F), and remeasure them.

14.6 *Cementability*—Seal the treated surface of the material by the application of controlled heat, pressure, and time of dwell to an adhesive-coated strip of aluminum sheet. Measure the peel strength at a peel angle of 180°, and a speed of 30.5 cm/min (12 in./min).

14.6.1 *Procedure for Preparation of Adhesive-Coated Aluminum*:

14.6.2 Coat sheets of aluminum 254 by 254 mm (10 by 10 in.) evenly with No. 68040 adhesive using a No. 24 "Draw Down" rod and allow to dry in air for 8 h. The thickness of coating is not critical but it is important that the coating be smooth and bubble-free. Methyl ethyl ketone may be used for thinning the adhesive if necessary, and for cleaning the equipment.

14.6.3 Cut the coated sheets into strips 38.1 by 127 mm (1.5 by 5 in.) and store in a desiccator. It is not advisable to prepare more than a 2 or 3-month supply of coated aluminum at one time, as the adhesive slowly crosslinks in time and seal strength values are lowered.

14.6.4 Cut five 25.4 by 127-mm (1 by 5-in.) sample strips evenly spaced across the width of the film sample. The film must be free of fingerprints and contamination.

14.6.5 Place each film specimen on a strip of the coated aluminum with the treated surface facing the adhesive. Seal the strips in the heat sealer with the aluminum strip facing the heated jaw and the film facing the silicone rubber pad. Set the sealer at 10-s dwell time and 138-kPa (20-psi) jaw pressure. Set the temperature in accordance with Table 3.

14.6.6 Make the seal, and after the specimen has cooled to room temperature, determine the peel strength in a tension tester, at a peel angle of 180°.

TABLE 3 Temperature Setting

Film Thickness, mm (in.)	Temperature, °C (°F)
0.0127 (0.0005)	149 (300)
0.025 (0.001)	163 (325)
0.051 (0.002)	191 (375)
0.076 (0.003)	191 (375)
0.102 (0.004)	220 (428)
0.127 (0.005)	274 (525)
0.254 (0.010)	274 (525)
0.508 (0.020)	274 (525)

14.6.7 Calculate the average seal strength in grams per inch from the five determinations.

14.6.8 *Precision*—In a laboratory test, a sample tested by this test method had an average of 1316 g/in. with a 1 Σ value of 170 covering 52 determinations by 8 operators.

14.7 *Thickness*—Measure the thickness in accordance with Method C or Method D of Test Methods D 374, except for modification as follows: For Method C, the deadweight dial micrometer shall exert a pressure of 34.5 ± 0.7 kPa (5 ± 0.1 psi) and measurements shall be 2± 0.1 s after the pressure foot contacts the film. For Method D, the deadweight shall have a head diameter of 15.8 mm (⅝ in.) and exert a pressure of 48.3 ± 0.7 kPa (7.0 ± 0.1 psi). Measurement shall be made 2 ± 0.1 s after the pressure foot contacts the film.[15] The mean of 10 random measurements shall fall within the specified limits and the area over which such measurements are made shall be at least 77 cm (12 in.).

15. Rejection and Rehearing

15.1 If any failure occurs, the materials may be retested to establish conformity in accordance with agreement between the purchaser and the manufacturer.

16. Inspection and Certification

16.1 Inspection and certification of the material supplied with reference to this specification shall be for conformance to the requirements specified herein.

16.2 Lot-acceptance inspection shall be the basis on which acceptance or rejection of the lot is made. The lot-acceptance inspection shall consist of all the requirements.

16.3 Periodic check inspection with reference to this specification shall consist of the tests for all requirements of the material under this specification. Inspection frequency shall be adequate to ensure the material is certifiable in accordance with 16.4.

16.4 Certification shall be that the material was manufactured by a process in statistical control, sampled, tested, and inspected in accordance with this specification, and that the average values for the lot meet the requirements of this specification (line callout).

16.5 A report of test results shall be furnished when requested. The report shall consist of results of the lot-acceptance inspection for the shipment and the results of the most recent periodic-check inspection.

17. Packaging and Package Marking

17.1 All packing, packaging, and marking provisions of Practice D 3892 shall apply to this specification.

18. Precision and Bias [16]

18.1 Table 4 is based on a round robin conducted in 1985–1986 in accordance with Practice E 691, involving seven materials tested by six laboratories. For each material, the sheeting from which the test specimens were to be cut was obtained from one source. Using a steel rule die, one set of test specimens for each laboratory was cut by one of the laboratories. Sheeting and a duplicate die were furnished to each participating laboratory and used to cut a second set of test specimens. Each test result was the average of five individual determinations. Each laboratory obtained four test results on each material, two test results each on the specimens furnished and two on the specimens cut by the laboratory doing the testing.

TABLE 4 Precision Summary, Tensile Strength and Elongation at Break

NOTE 1—$I_r = 2.8 \times CV_r$; $I_R = 2.8 \times CV_R$.

Material	Tensile Strength				
	Mean psi	CV_r%	CV_R %	I_r%	I_R %
Granular					
PTFE	4801	2.79	8.85	7.81	24.78
Coagulated Dispersion					
PTFE	4807	2.71	3.37	7.59	9.46
PFA	4164	3.11	9.03	8.71	25.28
FEP	4144	2.98	7.98	8.34	22.34
Material	Percentage Elongation at Break				
	Mean % E	CV_r%	CV_R %	I_r%	I_R %
Granular					
PTFE	337	2.83	16.43	7.92	46.00
Coagulated Dispersion					
PTFE	300	2.17	13.74	6.08	38.47
PFA	336	3.27	9.66	9.16	27.05
FEP	319	2.21	7.60	6.19	21.28

18.1.1 The properties used in the analysis are tensile strength and elongation at break. The stress-strain curves of the fluorocarbon polymers (but not the fluoropolymers: modified ETFE and poly(vinylidene fluoride), PVDF) are similar in shape. Data on ETFE and PVDF, therefore, were excluded from the analysis used for this precision and bias statement but are available for use in precision and bias statements and are to be included in the research report at ASTM. Based on advice from experts in statistical analysis of round-robin data, and since use of fillers is excluded in the applicable standards, information from the testing on glass-fiber-filled PTFE also is not included in Table 4. In addition, the experts advised that information from the samples cut in one laboratory and tested by all the laboratories should not be included in Table 4. The data are available in the report. (**Warning**—The explanations of I_r and I_R given in 18.3-18.3.3 are intended only to present a meaningful way of considering the approximate precision of this test method. The data in Table 4 should not be applied rigorously to acceptance or rejection of material, as those data are specific to the round robin and may not be representative of other lots, conditions, materials, or laboratories.)

18.2 Users of this test method should apply the principles outlined in Practice E 691 to generate data specific to their laboratory and materials, or between specific laboratories. The principles of 18.3-18.3.3 would then be valid for such data.

18.3 *Concept of I_r and I_R* —If *CV_r and CV_R have been calculated from a large enough body of data, and for test results that were averages from testing five specimens:*

[15] A Twing-Albert VIR Electronic Thickness Tester, 89-2B Model II, has been found satisfactory for this measurement. This instrument provides a digital readout, a printed record, and meets the TAPPI 411 Standard. It is available from the Twing-Albert Co., 10960 Dutton Road, Philadelphia, PA 19154. Other equivalent instruments are acceptable.

[16] Supporting data are available from ASTM Headquarters.

18.3.1 *Repeatability (I_r)*—Comparing two test results for the same material, obtained by the same operator using the same equipment on the same day the two test results should be judged not equivalent if they differ by more than the I_r value for that material.

18.3.2 *Reproducibility (I_R)*—Comparing two test results for the same material, obtained by different operators using different equipment on different days the two test results should be judged not equivalent if they differ by more than the I_R value for that material.

18.3.3 Any judgment in accordance with 18.3.1 and 18.3.2 would have an approximate 95 % (0.95) probability of being correct.

18.4 Bias is systematic error that contributes to the difference between a test result and a true (or reference) value. There are no recognized standards on which to base an estimate of bias for this test procedure.

19. Keywords

19.1 FEP-fluorocarbon resin; film; fluoropolymer; recycled material; sheet

SUMMARY OF CHANGES

This section identifies the location of selected changes to this specification. For the convenience of the user, Committee D-20 has highlighted those changes that may impact the use of this specification. This section may include descriptions of the changes or the reasons for the changes, or both.

D 3368–99:

(1) In 1.1, added recycled statement.
(2) In 1.2, replaced Practice E 380 with IEEE/ASTM 10.
(3) In 2.1, deleted Practice D 1898 and Practice E 380 and added IEEE/ASTM 10.
(4) In Section 3, deleted definition of film and added definition of lot.
(5) In 8.1, added proper sampling statement in accordance with Guide D 5740.
(6) In Section 16, added proper wording for inspection and certification in accordance with Guide D 5740.
(7) In Section 17, deleted excess wording.
(8) In 19.1, added recycled materials.
(9) Added Summary of Changes section.