Designation: F735 – 17

Standard Test Method for Abrasion Resistance of Transparent Plastics and Coatings Using the Oscillating Sand Method[1]

This standard is issued under the fixed designation F735; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method determines the resistance of transparent plastics and transparent coatings utilized in windows or viewing ports, to surface abrasion using oscillating sand.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.2.1 *Exception*—The inch-pound units in parentheses are provided for information only.

1.3 *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.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C136 Test Method for Sieve Analysis of Fine and Coarse Aggregates

D618 Practice for Conditioning Plastics for Testing

D1003 Test Method for Haze and Luminous Transmittance of Transparent Plastics

E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

3. Summary of Test Method

3.1 The test method consists of measuring and recording the haze and light transmission of a test specimen, mounting the specimen so that it forms part of the bottom tray (sand cradle), covering the specimen with abrading media, and subjecting the cradle to a specific number of oscillations. After exposure to the abrasion, the haze and light transmission are remeasured to determine any change in these values.

3.2 At the stroke velocity specified in this test method, the entire mass of sand shifts significantly within the sand cradle because of its inertia; therefore the relative motion between sand and specimen at the interface is large.

3.3 The thickness or height of the sand resting on top of the test specimen remains relatively constant during the motion of the cradle. Therefore, the average pressure of the sand also remains constant, giving highly reproducible results over the entire surface of the test specimen.

3.4 The degree of abrasion is measured by the amount of change in luminous transmission and haze after exposure to the test.

4. Significance and Use

4.1 Plastic materials, when used as transparencies, covers, or enclosures, are subject to wiping, cleaning, or other types of rubbing actions that cause abrasion. It is the intent of this test method to provide a means of estimating the resistance of such materials to this type and degree of abrasion.

5. Apparatus

5.1 *Abrader*—The abrader consists of a specimen holder, sand cradle, drive mechanism, and counter. One such example is shown in Fig. 1.

5.1.1 The specimen holder shall have a cutout approximately 100 by 100 mm (4 by 4 in.) to receive the specimen. Alternative specimen holders can be used to test other specimen sizes as long as they can be used within the testing limitations defined in this test method.

5.1.2 The specimen holder forms the bottom of the sand cradle.

[1] This test method is under the jurisdiction of ASTM Committee F07 on Aerospace and Aircraft and is the direct responsibility of Subcommittee F07.08 on Transparent Enclosures and Materials.

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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.

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

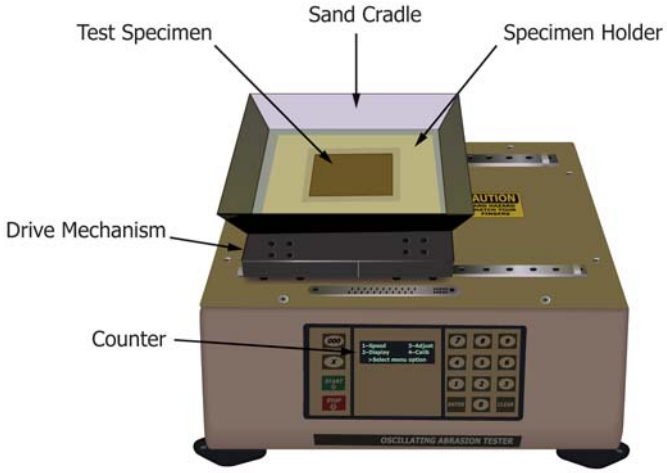

FIG. 1 Oscillating Sand Abrader

5.1.3 The sand cradle shall be approximately 250 × 250 × 50 mm (10 × 10 × 2 in.), with the sides set at an angle of 60°.

5.1.4 A drive mechanism shall provide 300 strokes per minute of reciprocating motion of approximately 100-mm (4-in.) travel. Motion in one direction is defined as one stroke. One forward stroke and one reverse stroke are defined as one oscillation or cycle.

5.1.5 A counter shall record the number of strokes (or cycles) during a test.

5.2 *Photometer*—An integrating sphere photoelectric photometer, described in Test Method D1003, shall be used to measure light transmission (LT) and haze.

6. Reagents and Materials

6.1 *Abrading Medium—Quartz Sand*[3]—The sand shall be quartz silica, graded 6/9, and shall meet the following requirements:

6.1.1 *Properties (typical)*—See Table 1 for sieve analysis percent retained.

NOTE 1—The use of quartz silica sand 6/12 or 4/10 specified in previous versions of this test method can still be used if available. See Appendix X1 for additional details

[3] The sole source of supply of the sand known to the committee at this time is Premier Silica LLC, Brady, TX 76825. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

TABLE 1 Properties

E11 Sieve Designation		Individual % Weight Retained
U.S. No.	mm	
5	4.00	0 – 7
6	3.36	2 – 11
7	2.83	15 – 25
8	2.38	30 – 50
10	2.00	20 – 40
12	1.68	1 – 7
Pan	...	< 1 – 5

Physical Analysis: Roundness 0.6+; Sphericity 0.6+; Hardness 7.0; S.G. 2.65, Loss on Ignition 0.1; MP 2800°/3100°; Color Tan/White; pH Neutral 7.0.
Chemical Content (%); SiO_2 99.48; Fe_2O_3 0.06; Al_2O_3 0.21; MgO < 0.01; CaO < 0.01; and TiO_2 < 0.01.

7. Test Specimens

7.1 The specimens shall be clean, transparent plates, 100-mm (4-in.) square, having both sides substantially plane and parallel, unless otherwise specified and defined in 5.1.1. Three specimens shall be tested. Any specimen thickness can be utilized provided the specimen is flush with the specimen holder when mounted (see 9.2).

NOTE 2—A protective backing material may be applied to the unabraded side of the specimen to prevent scratching during testing and handling. Prior to measuring light transmission and haze, remove the backing material and clean the specimen thoroughly according to 9.4.1.

8. Conditioning

8.1 Where conditioning of the test specimen is required, utilize Procedure A of Practice D618.

8.2 Tests shall be conducted in the Standard Laboratory Atmosphere of 23 ± 2°C and 50 ± 5 % relative humidity, unless otherwise specified.

9. Procedure

9.1 Prior to testing, clean the specimen using the procedure described in 9.4.1. Measure the specimen's initial average transmission and haze in accordance with 9.5.

9.2 Mount the specimen in the specimen holder using a protective means (such as masking tape) to secure in place and prevent sand from damaging the specimen's bottom surface. The specimen shall be mounted flush to within ±1 mm (0.04 in.) of the specimen holder.

9.3 Fill the sand cradle and cover specimen with sand to a uniform depth of 13 mm (0.50 in.).

NOTE 3—For a sand cradle 10 in. × 10 in., 800 mL of sand has been found to be sufficient to obtain a uniform depth of 13 mm (0.50 in.).

9.3.1 A given batch of sand may be used for a maximum of 600 strokes (300 cycles). New sand shall be used for each specimen tested.

9.4 Subject the specimen to 100, 200, 300, and 600 strokes (50, 100, 150, and 300 cycles).

9.4.1 After each increment (as listed in section 9.4) of strokes, remove the specimen from the holder. Handle specimen by edges only. Wash both sides of the specimen with 50:50 IPA / distilled water and a clean rymple cloth. Soak the cloth first, and then use a linear motion to wipe the test specimen; first wipe the specimen vertically, then wipe the specimen horizontally, and as a final step wipe the edges. Dry by blowing lightly with filtered air or nitrogen. Alternative acceptable cleaning methods can be used if agreed between the interested parties.

9.4.2 2 Measure the transmission and haze in accordance with section 9.5.

9.5 Using a photoelectric, integrating sphere photometer and Test Method D1003, measure the percentage of transmitted light and percent of haze in three different locations on the specimen. The abraded side of the specimen shall be placed against the entrance port of the integrating sphere of the hazemeter (facing away from the light source). Report as the average.

9.6 Subtract the initial light transmittance (haze) percentage of the unabraded specimen determined by 9.1 from the light transmittance (haze) percentage of the unabraded specimen as measured by 9.4.2. The difference represents the light scatter resulting from abrading the specimen.

10. Report

10.1 The report shall include the following:

10.1.1 Type of material being tested,

10.1.2 The percentage of the transmitted light and percent haze for each specimen tested, both before and after exposure to abrasion of 100, 200, 300, and 600 strokes, (50, 100, 150, and 300 cycles), along with the change in transmitted light and haze,

10.1.3 Test results shall be reported as the average of the three specimens tested, and

10.1.4 Abrading medium, if different than specified in 6.1.

11. Precision and Bias

11.1 *Precision*—The precision of this test method is based on an interlaboratory study of F735, Standard Test Method for Abrasion Resistance of Transparent Plastics and Coatings Using the Oscillating Sand Method, conducted in 2016. Four laboratories participated in this study. Each of the four labs reported four replicate test results for three different transparent plastics, each determined after four different cycle counts. Every "test result" reported represents an individual determination. Except for the use of only four laboratories, Practice E691 was followed for the design and analysis of the data; the details are given in ASTM Research Report No. F07-1010.[4]

11.1.1 Repeatability (*r*)—The difference between repetitive results obtained by the same operator in a given laboratory applying the same test method with the same apparatus under constant operating conditions on identical test material within short intervals of time would in the long run, in the normal and correct operation of the test method, exceed the following values only in one case in 20.

11.1.1.1 Repeatability can be interpreted as the maximum difference between two results, obtained under repeatability conditions, that is accepted as plausible due to random causes under normal and correct operation of the test method.

11.1.1.2 Repeatability limits are listed in Tables 2-9.

11.1.2 Reproducibility (*R*)—The difference between two single and independent results obtained by different operators applying the same test method in different laboratories using different apparatus on identical test material would, in the long run, in the normal and correct operation of the test method, exceed the following values only in one case in 20.

11.1.2.1 Reproducibility can be interpreted as the maximum difference between two results, obtained under reproducibility conditions, that is accepted as plausible due to random causes under normal and correct operation of the test method.

11.1.2.2 Reproducibility limits are listed in Tables 2-9.

11.1.3 The above terms (repeatability limit and reproducibility limit) are used as specified in Practice E177.

11.1.4 Any judgment in accordance with statements 11.1.1 and 11.1.2 would normally have an approximate 95% probability of being correct, however the precision statistics obtained in this ILS must not be treated as exact mathematical quantities which are applicable to all circumstances and uses. The limited number of materials tested and laboratories reporting results guarantees that there will be times when differences greater than predicted by the ILS results will arise, sometimes with considerably greater or smaller frequency than the 95% probability limit would imply. The repeatability limit and the reproducibility limit should be considered as general guides, and the associated probability of 95% as only a rough indicator of what can be expected.

11.2 *Bias*—At the time of the study, there was no accepted reference material suitable for determining the bias for this test method, therefore no statement on bias is being made.

11.3 The precision statement was determined through statistical examination of 384 test results, from four laboratories,

[4] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:F07-1010. Contact ASTM Customer Service at service@astm.org.

TABLE 2 Δ Light Transmission at 100 Cycles

Material	Average[A]	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
	x	s_r	s_R	r	R
Polycarbonate	-0.3650	0.3268	1.4348	0.9151	4.0175
Stretched Acrylic	-2.4725	0.6824	1.1344	1.9108	3.1762
Coated Acrylic	-0.3213	0.2149	0.2663	0.6016	0.7457

[A] The average of the laboratories' calculated averages.

TABLE 3 Δ Light Transmission at 200 Cycles

Material	Average[A]	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
	x	s_r	s_R	r	R
Polycarbonate	-.06513	0.5043	2.1669	1.4121	6.0673
Stretched Acrylic	-2.7669	0.3446	1.0913	0.9648	3.0555
Coated Acrylic	-0.4125	0.1626	0.3370	0.4553	0.9437

[A]The average of the laboratories' calculated averages.

TABLE 4 Δ Light Transmission at 300 Cycles

Material	Average[A]	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
	x	s_r	s_R	r	R
Polycarbonate	-1.0613	0.4982	1.9853	1.3949	5.5588
Stretched Acrylic	-3.2431	0.4893	1.7896	1.3702	5.0109
Coated Acrylic	-0.5288	0.1960	0.4420	0.5487	1.2376

[A]The average of the laboratories' calculated averages.

TABLE 5 Δ Light Transmission at 600 Cycles

Material	Average[A]	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
	x	s_r	s_R	r	R
Polycarbonate	-1.8894	0.1803	2.2206	0.5048	6.2178
Stretched Acrylic	-4.2250	0.3113	2.9146	0.8717	8.1609
Coated Acrylic	-0.6838	0.3828	0.7953	1.0718	2.2267

[A]The average of the laboratories' calculated averages.

TABLE 6 Δ Haze at 100 Cycles

Material	Average[A]	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
	x	s_r	s_R	r	R
Polycarbonate	28.40	1.37	4.83	3.85	13.53
Stretched Acrylic	25.67	1.44	2.96	4.04	8.30
Coated Acrylic	4.02	0.93	1.51	2.60	4.22

[A]The average of the laboratories' calculated averages.

TABLE 7 Δ Haze at 200 Cycles

Material	Average[A]	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
	x	s_r	s_R	r	R
Polycarbonate	42.66	1.28	3.90	3.57	10.91
Stretched Acrylic	39.82	1.55	4.10	4.35	11.49
Coated Acrylic	6.97	1.34	1.99	3.76	5.57

[A]The average of the laboratories' calculated averages.

on the three materials described in the tables. To judge the equivalency of two test results, it is recommended to choose the plastic material closest in characteristics to the test material.

12. Keywords

12.1 abrader; abrasion; haze; oscillating sand; plastic; strokes; transmission; transparent

TABLE 8 Δ Haze at 300 Cycles

Material	Average[A]	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
	x	s_r	s_R	r	R
Polycarbonate	54.35	3.61	12.78	10.12	35.79
Stretched Acrylic	47.94	2.19	4.96	6.13	13.89
Coated Acrylic	10.17	1.77	1.98	4.96	5.55

[A]The average of the laboratories' calculated averages.

TABLE 9 Δ Haze at 600 Cycles

Material	Average[A]	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
	x	s_r	s_R	r	R
Polycarbonate	63.17	1.49	4.66	4.16	13.05
Stretched Acrylic	57.28	2.27	2.68	6.35	7.51
Coated Acrylic	15.52	3.23	3.23	9.05	9.05

[A]The average of the laboratories' calculated averages.

APPENDIX

(Nonmandatory Information)

X1. QUANTIFYING A NEW SOURCE OF SAND

X1.1 Two different grades of sand that originated from the same quarry in Brady, TX have been specified in previous versions of this method. Both have been discontinued and are no longer commercially available. The properties for both sands are shown in Table X1.1 and Table X1.2:

X1.2 Previous versions of this test method also included information when qualifying a new source (supply) of sand. This is summarized below.

X1.2.1 *Test Methods:*

X1.2.1.1 Perform sieve analysis in accordance with Test Method C136.

X1.2.1.2 Plot the cumulative percent retained, on logarithmic probability paper.

X1.2.1.3 Read from the plot the sizes in millimetres at 40, 50, and 90 % retained.

TABLE X1.1 6/12 (Texan Filter Sand #7 Quartz Silica Sand)

E11 Sieve Designation U.S. No.	mm	Mean % on Sieve	Std Deviation, %	Cumulative % Retained, Mean
8	2.36	30.0	7.4	30.0
10	2.00	40.0	8.4	70.0
12	1.70	22.0	7.8	92.0
14	1.40	6.0	1.1	98.0
Pan	...	2.0	0.7	100.0

Effective size at 90% retained = 1.70 ± 0.10 mm
Uniformity Coefficient = 1.29 ± 0.05 mm
Shape Factor = 0.40 ± 0.07 mm.

TABLE X1.2 4/10 (Ogleby Norton Industrial Sand)

E11 Sieve Designation U.S. No.	mm	Mean % on Sieve	Std Deviation, %	Cumulative % Retained, Mean
4	4.75	0		0
6	3.35	7.6		7.6
7	2.80	22.3		29.9
8	2.36	45.1		75.0
10	2.00	21.9		96.9
12	1.70	2.6		99.5
Pan	...	0.5		100.0

Roundness 0.6+; Sphericity 0.6+; Hardness 7.0; S.G. 2.65, Loss on Ignition 0.1; MP 2800°/ 3100° ; Color Tan/White; pH 6.9-7.0
Typical Chemical Content (%): SiO_2 99.48; $Fe2O_3$ 0.06; $A_{l2}O_3$ 0.21; MgO < 0.01; CaO < 0.01; and TiO_2 < 0.01

X1.2.1.4 Calculate the uniformity coefficient as the ratio (mm at 40 % / mm at 90 %).

X1.2.1.5 Count out 100 grains, taking care to be nonselective, and weigh to ± 10 mg.

X1.2.1.6 Calculate the shape factor as:

$$\frac{\text{(weight of 100 particles)}}{265\ \text{(millimetres at 50 \% retained)}^3} \quad \text{(X1.1)}$$

NOTE X1.1—There are many conflicting definitions of shape factor.[5] The definition given in X1.2.1.6 is arbitrary and not comparable with any others, except that for a single quartz sphere it has the usual value of 0.524 (π/6).

[5] Orr, C., and J. M. Dallavalle, *Fine Particle Measurement*, The Macmillan Co., New York, NY1959, pp 35–36.

SUMMARY OF CHANGES

Committee F07 has identified the location of selected changes to this standard since the last issue (F735-11) that may impact the use of this standard.

(1) Replaced Fig. 1 with a photograph of a commercially available instrument.
(2) Updated the abrader description by eliminating the variable power supply and including details on the sand cradle.
(3) Updated the abrading medium from quartz silica, graded 4/10 to 6/9 (see ASTM Research Report No. F07-1010) along with the sieve analysis in Table 1.
(4) Moved the test referenced for qualifying a new source (supply) of sand to Appendix X1.
(5) Changed the cleaning procedure.
(6) Measured the percentage of transmitted light and haze on three locations and report the average.
(7) Determined the change in light transmittance and haze.
(8) Added Precision statement.