Designation: D 3763 – 06

Standard Test Method for High Speed Puncture Properties of Plastics Using Load and Displacement Sensors[1]

This standard is issued under the fixed designation D 3763; 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 covers the determination of puncture properties of plastics, including films, over a range of test velocities.

1.2 Test data obtained by this test method is relevant and appropriate for use in engineering design.

1.3 The values stated in SI units are to be regarded as standard.

1.4 *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—This specification does not closely conform to ISO 6603.2. The only similarity between the two tests is that they are both instrumented impact tests. The differences in striker, fixture, and specimen geometries and in test velocity can produce significantly different test results.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

D 618 Practice for Conditioning Plastics for Testing

D 883 Terminology Relating to Plastics

D 1600 Terminology for Abbreviated Terms Relating to Plastics

D 4000 Classification System for Specifying Plastic Materials

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

2.2 *ISO Standard:*[3]

ISO 6603.2 Plastics—Determination of Multiaxial Impact Behavior of Rigid Plastics Part 2: Instrumented Puncture Test

3. Terminology

3.1 *Definitions*—For definitions see Terminology D 883 and for abbreviations see Terminology D 1600.

4. Significance and Use

4.1 This test method is designed to provide load versus deformation response of plastics under essentially multiaxial deformation conditions at impact velocities. This test method further provides a measure of the rate sensitivity of the material to impact.

4.2 Multiaxial impact response, while partly dependent on thickness, does not necessarily have a linear correlation with specimen thickness. Therefore, results should be compared only for specimens of essentially the same thickness, unless specific responses versus thickness formulae have been established for the material.

4.3 For many materials, there may be a specification that requires the use of this test method, but with some procedural modifications that take precedence when adhering to the specification. Therefore, it is advisable to refer to that material specification before using this test method. Table 1 of Classification System D 4000 lists the ASTM materials standards that currently exist.

5. Interferences

5.1 *Inertial Effects*— A loading function encountered when performing an instrumented impact test that may, in some cases, confuse the interpretation of the test data. For further definition and examples of inertial effects, refer to Appendix X1.

6. Apparatus

6.1 The testing machine shall consist of two assemblies, one fixed and the other driven by a suitable method to achieve the required impact velocity (that is, hydraulic, pneumatic, mechanical, or gravity):

6.1.1 *Clamp Assembly,* consisting of two parallel rigid plates with a 76.0 ± 3.0 mm diameter hole in the center of each. The hole edges shall be rounded to a radius of 0.8 ± 0.4

[1] This test method is under the jurisdiction of ASTM Committee D20 on Plastics and is the direct responsibility of Subcommittee D20.10 on Mechanical Properties.

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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 National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

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

mm. Sufficient force must be applied (mechanically, pneumatically, or hydraulically) to prevent slippage of the specimen in the clamp during impact. If films are tested, some type of gasket may also be required to prevent slippage.

6.1.2 *Plunger Assembly,* consisting of a 12.70 ± 0.13 mm diameter steel rod with a hemispherical end of the same diameter positioned perpendicular to, and centered on, the clamp hole.

6.1.3 *Other Geometries*— The dimensions given in 6.1.1 and 6.1.2 shall be the standard geometry. If other plunger or hole sizes are used they shall be highlighted in the report. Correlations between various geometries have not been established.

6.1.4 *Load Sensing System*—A load cell of sufficiently high natural resonance frequency, as described in A1.1, used together with a calibrating network for adjusting load sensitivity.

6.1.5 *Plunger Displacement Measurement System*—A means of monitoring the displacement of the moving assembly during the loading and complete penetration of the specimen. This can be accomplished through the use of a suitable transducer or potentiometer attached directly to the system. Photographic or optical systems can also be utilized for measuring displacement.

6.1.5.1 Alternatively, displacement may be calculated as a function of velocity and total available energy at initial impact, along with increments of load versus time, using a microprocessor.

6.1.5.2 Some machines use an accelerometer, whose output is used to calculate both load and displacement.

6.1.6 *Display and Recording Instrumentation*—Use any suitable means to display and record the data developed from the load and displacement-sensing systems, provided its response characteristics are capable of presenting the data sensed, with minimal distortion. The recording apparatus shall record load and displacement simultaneously. For further information, see A1.2.

6.1.6.1 The most rudimentary apparatus is a cathode-ray oscilloscope with a camera. This approach also requires a planimeter or other suitable device, capable of measuring the area under the recorded load-versus-displacement trace of the event with an accuracy of ±5 %.

6.1.6.2 More sophisticated systems are commercially available. Most of them include computerized data reduction and automatic printouts of results.

7. Test Specimen

7.1 Specimens must be large enough to be adequately gripped in the clamp. In general, the minimum lateral dimension should be at least 13 mm greater than the diameter of the hole in the clamp (see 6.1.1 and 10.9).

7.2 Specimens may be cut from injection-molded, extruded, or compression molded sheet; or they may be cast or molded to size.

8. Conditioning

8.1 *Conditioning*— Condition the test specimens in a room or enclosed space maintained 23 ± 2°C, and 50 % relative humidity, in accordance with Procedure A in Practice D 618 unless otherwise specified.

8.2 *Test Conditions*— Conduct tests in the standard laboratory atmosphere of 23 ± 2°C, and 50 ± 5 % relative humidity, unless otherwise specified. In cases of disagreement, the tolerances shall be ±1°C, and ±2 % relative humidity.

8.2.1 By changing the conditioning and test temperature in a controlled manner for a given test velocity, the temperature at which transition from ductile to brittle failure occurs can be determined for most plastics.

NOTE 2—To facilitate high throughput during automated testing at temperatures other than ambient, it is often necessary to stack the specimens in a column with no airflow in between. To assure compliance with Section 10 of Practice D 618, the time to equilibrium must be determined for a given material. A thermocouple may be placed at the center of a specimen stack in which its height is equal to its minimum width. Determine the time to reach equilibrium at the desired test temperature. Experiments with materials having low thermal conductivity values have shown that more than 7.5 h of soak time was required before the stack center temperature fell within the tolerances specified in D 618 at a setpoint of -40°C. Two and a half additional hours were needed to reach equilibrium. The opposite extreme was seen in a material of higher thermal conductivity that only required 2 h to reach equilibrium at -40°C.

9. Speed of Testing

9.1 For recommended testing speeds see 10.4.

10. Procedure

10.1 Test a minimum of five specimens at each specified speed.

10.2 Measure and record the thickness of each specimen to the nearest 0.025 mm at the center of the specimen.

10.3 Clamp the specimen between the plates of the specimen holder, taking care to center the specimen for uniform gripping. Tighten the clamping plate in such a way as to provide uniform clamping pressure to prevent slippage during testing.

10.4 Set the test speed to the desired value. The testing speed (movable-member velocity at the instant before contact with the specimen) shall be as follows:

10.4.1 For single-speed tests, use a velocity of 200 m/min.

10.4.1.1 Other speeds may be used, provided they are clearly stated in the report.

10.4.2 To measure the dependence of puncture properties on impact velocity, use a broad range of test speeds. Some suggested speeds are 2.5, 25, 125, 200, and 250 m/min.

10.5 Set the available energy so that the velocity slowdown is no more than 20 % from the beginning of the test to the point of peak load. If the velocity should decrease by more than 20 %, discard the results and make additional tests on new specimens with more available energy.

NOTE 3—It is observed that when the available energy is at least three times the absorbed energy at the peak load velocity slow-down is less than 20 %.

10.6 Place a safety shield around the specimen holder.

10.7 Make the necessary adjustments to data collection apparatus as required by the manufacturer's instructions or consult literature such as STP 936[4] for further information regarding setting up data acquisition systems.

[4] *Instrumented Impact Testing of Plastics and Composite Materials, ASTM STP 936,* ASTM, 1986.

10.8 Conduct the test, following the manufacturer's instructions for the specific equipment used.

10.9 Remove the specimen and inspect the gripped portion for striations or other evidence of slippage. If there is evidence of slippage, modify the clamping conditions or increase the specimen size and repeat test procedures.

11. Calculation

11.1 Using the load-versus-displacement trace and appropriate scaling factors, calculate the following:

11.1.1 Peak load, in newtons.

11.1.2 Deflection, in millimetres, to the point where peak load first occurred.

11.1.3 From the area within the trace, calculate:

11.1.3.1 Energy, in joules, to the point where load first occurred.

11.1.3.2 Total energy absorbed. The point for determining this has not been standardized. Therefore, the point used for each test must be stated in the report.

11.1.4 Load, deflection, energy, or combination thereof, at any other specific point of interest (see Appendix X1).

11.2 For each series of tests, calculate the arithmetic mean for each of the above, to three significant figures.

11.3 Calculate the estimated standard deviations as follows:

$$S = \left(\frac{\Sigma X^2 - n\overline{X}^2}{n-1} \right)^{1/2} \quad (1)$$

where:

S = estimated standard deviation,
X = value of a single determination,
n = number of determinations, and
$\overline{X}$ = arithmetic mean of the set of determinations.

12. Report

12.1 Report the following information:

12.1.1 Complete identification of the material tested, including type, source, manufacturer's code number, form and previous history,

12.1.2 Specimen size and thickness,

12.1.3 Method of preparing test specimens (compression molding, casting, etc.),

12.1.4 Geometry of clamp and plunger, if different from 6.1.1 and 6.1.2,

12.1.5 Source and types of equipment,

12.1.6 Speed of testing (see 10.4),

12.1.7 The point on the curve at which total energy was calculated (see 11.1.3.2),

12.1.8 Average value and standard deviation for each of the properties listed in 11.1,

12.1.9 Whether or not any slippage of the specimens was detected, and

12.1.10 If the effect of testing speeds was studied (see 10.4.2).

13. Precision and Bias

13.1 Tables 1-3 are based on a round robin conducted in 1996 in accordance with Practice E 691, involving 7 materials tested by 11 laboratories. For each material, all of the specimens were prepared at the laboratory of the company volunteering that material for the round robin. Ten specimens from each material were sent to each participating laboratory. Each test result was the average of 5 individual determinations. Each laboratory obtained 2 test results for each material. (**Warning—**The explanations of r and R (13.2-13.2.3) are only intended to present a meaningful way of considering the approximate precision of this test method. The data in Tables 1-3 should not be applied to acceptance or rejection of materials, as these data only apply to the materials tested in the round robin and are unlikely to be rigorously representative of other lots, conditions, materials, or laboratories. Users of this test method should apply the principles outlined in Practice E 691 to generate data specific to their materials and laboratory (or between specific laboratories). The principles of 13.2-13.2.3 would then be valid for such data.)

TABLE 1 Maximum Load

NOTE 1—MU = microcellular urethane, CP = cellulose propionate.
NOTE 2—Thicknesses were: aluminum, 0.031 in.; all others, 0.12 in.
NOTE 3—1982 round robin data, including precision and bias statements, may be found in Appendix X4.

Material	Mean, N	S_r[A] N	S_R[B] N	r[C] N	R[D] N
(A) Aluminum	4094	75.38	349.0	211	977
(B) ABS	3783	200.22	295.2	561	827
(C) MU	1704	110.53	149.6	309	419
(D) PC	6368	380.58	455.1	1066	1274
(E) Polyester	4244	154.57	278.7	433	780
(F) CP	4889	377.24	424.6	1056	1189
(G) PP	2703	164.89	246.5	462	690

[A] S_r = within-laboratory standard deviation for the indicated material. It is obtained by pooling the within-laboratory standard deviations from the test results from all of the participating laboratories as follows:

$$S_r = [[(S_1)^2 + (S_2)^2 \ldots + (S_n)^2]/n]^{1/2}$$

[B] S_R = between-laboratories reproducibility, expressed as standard deviation, as follows:

$$S_R = [S_r^2 + S_L^2]^{1/2}$$

where S_L = standard deviation of laboratory means.
[C] r = within-laboratory critical interval between two test results = 2.8 × S_r.
[D] R = between-laboratories critical interval between two test results = 2.8 × S_R.

TABLE 2 Deflection to Maximum Load Point

NOTE 1—MU = microcellular urethane, CP = cellulose propionate.
NOTE 2—Thicknesses were: aluminum, 0.031 in.; all others, 0.12 in.
NOTE 3—1982 round robin data, including precision and bias statements may be found in Appendix X4.

Material	Mean, mm	S_r[A] mm	S_R[B] mm	r[C] mm	R[D] mm
(A) Aluminum	8.74	0.2227	0.619	0.62	1.73
(B) ABS	15.75	0.7009	0.811	1.96	2.27
(C) MU	19.33	0.9923	1.238	2.78	3.47
(D) PC	22.21	0.8567	0.897	2.40	2.51
(E) Polyester	19.03	0.9144	0.940	2.56	2.63
(F) CP	16.21	1.0858	1.122	3.04	3.14
(G) PP	15.81	0.7763	0.920	2.17	2.58

[A] S_r = within-laboratory standard deviation for the indicated material. It is obtained by pooling the within-laboratory standard deviations from the test results from all of the participating laboratories as follows:

$$S_r = [[(S_1)^2 + (S_2)^2 \ldots + (S_n)^2]/n]^{1/2}$$

[B] S_R = between-laboratories reproducibility, expressed as standard deviation, as follows:

$$S_R = [S_{r2} + S_L^2]^{1/2}$$

where S_L = standard deviation of laboratory means.
[C] r = within-laboratory critical interval between two test results = 2.8 × S_r.
[D] R = between-laboratories critical interval between two test results = 2.8 × S_R.

TABLE 3 Energy to Maximum Load Point

NOTE 1—MU = microcellular urethane, CP = cellulose propionate.
NOTE 2—Thicknesses were: aluminum, 0.031 in.; all others, 0.12 in.
NOTE 3—1982 round robin data, including precision and bias statements, may be found in Appendix X4.

Material	Mean, J	S_r,[A] J	S_R,[B] J	r,[C] J	R,[D] J
(A) Aluminum	14.78	0.506	2.03	1.42	5.67
(B) ABS	30.05	2.083	2.93	5.83	8.21
(C) MU	14.69	1.212	1.71	3.39	4.78
(D) PC	71.23	2.324	3.77	6.51	10.56
(E) Polyester	43.16	1.642	3.12	4.60	8.75
(F) CP	35.31	3.359	3.75	9.41	10.49
(G) PP	21.21	1.357	2.86	3.80	8.01

[A] S_r = within-laboratory standard deviation for the indicated material. It is obtained by pooling the within-laboratory standard deviations from the test results from all of the participating laboratories as follows:

$$S_r = [[(S_1)^2 + (S_2)^2 \ldots + (S_n)^2]/n]^{1/2}$$

[B] S_R = between-laboratories reproducibility, expressed as standard deviation, as follows:

$$S_R = [S_r^2 + S_L^2]^{1/2}$$

where S_L = standard deviation of laboratory means.
[C] r = within-laboratory critical interval between two test results = 2.8 × S_r.
[D] R = between-laboratories critical interval between two test results = 2.8 × S_R.

13.2 *Concept of r and R in* Tables 1-3—If S_r and S_R have been calculated from a large enough body of data, and for test results that were averages from testing 5 specimens for each test result, then the following applies:

13.2.1 *Repeatability*— Two test results obtained within one laboratory shall be judged not equivalent if they differ by more than the r value for that material. r is the interval representing the critical difference between two test results for the same material, obtained by the same operator using the same equipment on the same day in the same laboratory.

13.2.2 *Reproducibility*— Two test results obtained by different laboratories shall be judged not equivalent if they differ more than the R value for that material. R is the interval representing the critical difference between two test results for the same material, obtained by different operators using different equipment in different laboratories.

13.2.3 Any judgment in accordance with 13.2.1 and 13.2.2 would have an approximate 95 % (0.95) probability of being correct.

13.3 *Bias*—There are no recognized standards by which to estimate bias of this test method.

14. Keywords

14.1 falling weight; impact testing; plastics; puncture properties

ANNEX

(Mandatory Information)

A1. MINIMUM INSTRUMENTATION REQUIREMENTS

A1.1 *Force Measurement*—Any transducer that meets the performance requirements for dynamic force measurement may be used. This includes, but is not limited to, strain gage force transducers, piezo-electric force transducers and accelerometers.

A1.1.1 *Performance Requirements*—The natural frequency (f_{dev}) of the transducer plus striker shall be sufficient to avoid distortion of the force-time or acceleration-time data. The time failure (t_f), in seconds, of a given test specimen regulates the minimum natural frequency for a transducer/striker assembly by the following relationship:

$$t_f = 3/f_{dev} \quad \text{(A1.1)}$$

Since time to failure is generally greater than 0.5 msec for plastics, a transducer assembly with a natural frequency greater than 6 kHz is recommended (0.0005 >= 3/6000). In addition, the transducer must have the durability to survive repeated impact tests without change in output from its initial calibrated state.

NOTE A1.1—Failure has been shown to be difficult to universally define. One application might define failure as the point on a load versus time curve where the load returns to zero. Another might define failure as a sharp drop in load, followed by a change in load slope, indicating formation of a crack.

A1.1.2 *Natural Frequency*—The mass of the striker assembly between transducer and specimen is directly related to the natural frequency (f_{dev}) of that transducer and can influence the force or acceleration data. Appendix X1, (X1.9.3) describes a method for approximating f_{dev} for any given transducer assembly.

A1.1.3 *Transducer Location*—The transducer should be located as close as possible to the impact point of the transducer/striker assembly to minimize the mass effect as described in A1.1.2. For testing involving extremely tough materials, it may be necessary to locate the transducer further from the impact point to prevent damage. Generally, this class of materials will produce a high loading impact event with a long t_f. Under these conditions, a transducer/striker assembly with a f_{dev} lower than 6 kHz will not adversely affect the test data. This is due to the damping effect of the test specimen itself as well as the large magnitude of the loading event in comparison to the initial oscillation produced by the transducer assembly.

A1.2 *Recording Apparatus*—Any recording device that meets the performance requirements of dynamic data acquisition may be used. This includes, but is not limited to, oscilloscopes, data loggers, and computer based data acquisition systems.

A1.2.1 *Performance Requirements*—The recording device used to capture a dynamic signal must have the capability to accurately represent that signal with minimal alteration. The following are system recommendations:

A1.2.1.1 8-bit or larger analog to digital converter,