



Standard Test Method for Rubber Property—Extrudability of Unvulcanized Compounds¹

This standard is issued under the fixed designation D 2230; 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 the extrudability of unvulcanized SBR and NBR rubber compounds through a screw-type extruder equipped with ASTM Extrusion Die, Garvey type. This test method is designed to allow the observation of the appearance and contours of the extrusion. Rating systems are provided along with recipes for compounds of known extrusion characteristics. The utility of the test method for evaluating rubbers or compounding materials other than those listed has not been established. Since extrusion machines differ among laboratories, the procedure includes techniques that minimize differences between machines.

1.2 The values stated in SI units are to be regarded as the standard. The values given in parentheses are 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.*

2. Referenced Documents

2.1 ASTM Standards:

D 3182 Practice for Rubber—Materials, Equipment, and Procedures for Mixing Standard Compounds and Preparing Standard Vulcanized Sheets²

D 3185 Test Methods for Rubber—Evaluation of SBR (Styrene-Butadiene Rubber) Including Mixtures With Oil²

D 3187 Test Methods for Rubber—Evaluation of NBR (Acrylonitrile-Butadiene Rubber)²

D 3674 Test Method for Carbon Black—Relative Extrusion Mass³

3. Summary of Test Method

3.1 A standard compound is prepared and extruded through a specially shaped die that produces an extrusion having a

combination of relatively flat surfaces, sharp corners, and thin sections. The operating conditions are varied until a satisfactory extrusion of the standard compound is obtained. The test compound is then extruded, using the conditions just established, and the nature of the extrusion is rated visually for smoothness, sharp corners, and integrity of thin sections.

4. Significance and Use

4.1 One objective in the extrusion of rubber compounds is to obtain a smooth extrusion that closely reproduces the contours of the extrusion die. This test method provides for a subjective determination of this under controlled conditions. As the rating is subjective, it does not lend itself readily to incorporation as a specification requirement. It does not measure other aspects of extrudability such as rate of extrusion or die swell in a quantitative manner.

5. Apparatus

5.1 *Mill*, 150 by 300 mm (6 by 12 in.), as described in Practice D 3182.

5.2 *Die*—ASTM Extrusion Die, Garvey type, conforming to the dimensions and shape shown in Fig. 1 shall be used.

NOTE 1—Good precision in the manufacture of the opening in the die can be attained by ultrasonic machining. The die should be replaced when a dimension has changed by 0.02 mm (0.001 in.) from its original value or if the die is damaged.

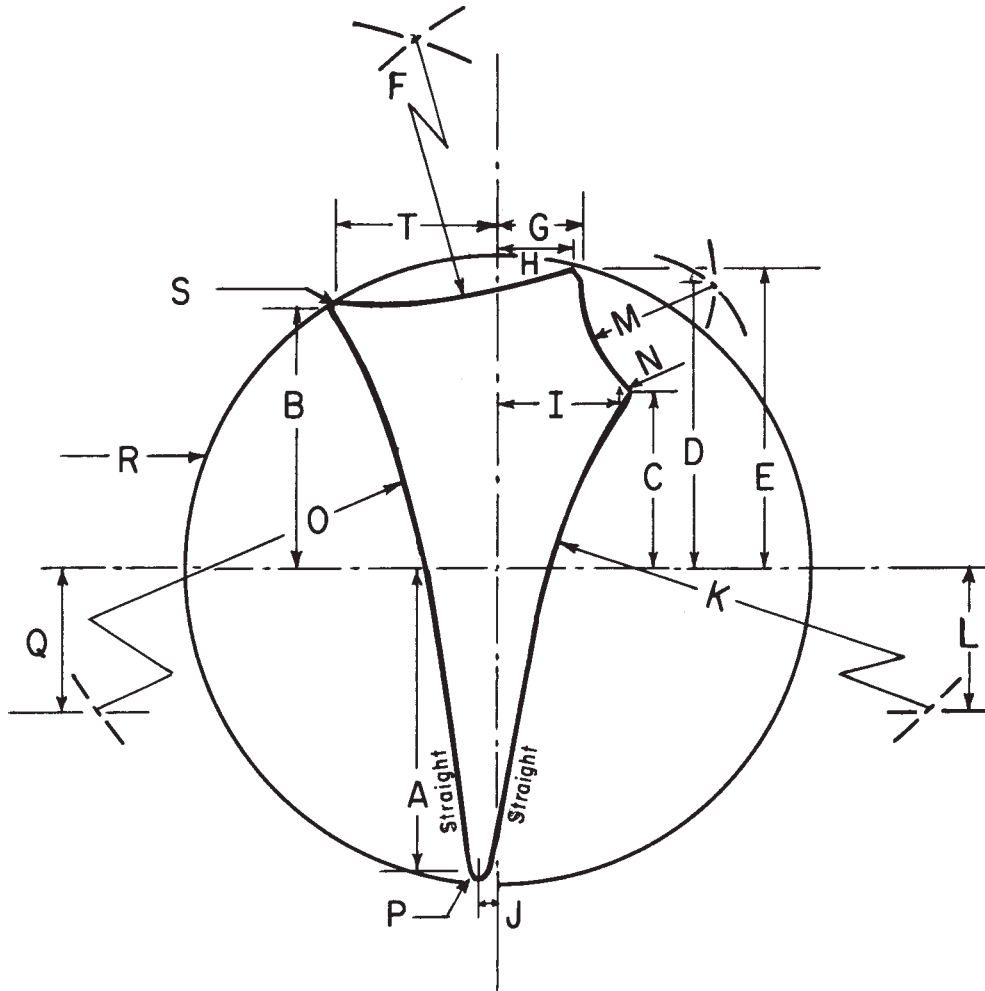
5.3 *Adapter*—A hollow, cone-shaped ring insert tapered with an angle of $30 \pm 15^\circ$ (shown in Fig. 2) shall be used with the die to contour the interior of the extruder head. This will reduce turbulent flow of the rubber.

5.4 *Extruder*—A screw-type laboratory extruder having a screw diameter of 50 mm or less and which will accommodate the specified die may be used. The distance between the end of the screw and the die shall be from 1 to 2 times the diameter of the screw, the ratio of the length to diameter of the screw shall be 5:1 or greater, and the compression ratio shall be 1:1. The use of breaker plates, screens, or spiders in the extruder is not recommended. Solid or hollow screws are acceptable; however, fluid temperature shall be controlled in hollow screws.

¹ This test method is under the jurisdiction of ASTM Committee D11 on Rubber and is the direct responsibility of Subcommittee D11.12 on Processability Tests. Current edition approved Dec. 10, 2002. Published February 2003. Originally approved in 1963. Last previous edition approved in 1996 as D 2230 – 96⁴.

² *Annual Book of ASTM Standards*, Vol 09.01.

³ Discontinued, see 1999 *Annual Book of ASTM Standards*, Vol 09.01.



| Dimension | mm | in. | Dimension | mm | in. |
|-----------|---------|---------|-----------|-----------|-----------|
| A | 7.62 | 0.300 | K | 13.33 R | 0.525 R |
| B | 6.60 | 0.260 | L | 3.56 | 0.140 |
| C | 4.44 | 0.175 | M | 3.301 R | 0.130 R |
| D | 7.24 | 0.285 | N | 0.32 R | 0.013 R |
| E | 7.62 | 0.300 | O | 20.32 R | 0.800 R |
| F | 13.97 R | 0.550 R | P | 0.25 R | 0.010 R |
| G | 2.16 | 0.085 | Q | 3.56 | 0.140 R |
| H | 1.90 | 0.075 | R | 15.87 Dia | 0.625 Dia |
| I | 3.05 | 0.120 | S | 0.13 | 0.005 |
| J | 0.51 | 0.020 | T | 4.06 | 0.160 |

Tolerance, ± 0.025 mm (± 0.001 in.)

Area, 50 mm² (0.0776 in²)

Thickness of die, 5 ± 2.0 mm (0.197 ± 0.79 in.)

FIG. 1 ASTM Extrusion Die, Garvey Type

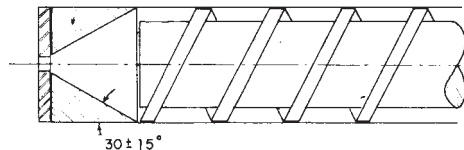


FIG. 2 Diagram Showing Stock Flow from End of Screw to ASTM Extrusion Die

5.4.1 The extruder shall be equipped with devices capable of monitoring the temperature of the barrel, the head, the discharged heating fluid from the screw, and the surface of the die. These monitoring devices shall have a sensitivity of $\pm 0.5^\circ\text{C}$ (1°F).

5.5 *Take-away Conveyor*—A motor-driven belt conveyor at least 150 mm (6 in.) wide, at least 1.5 m (5 ft) long and variable in speed up to at least 75 mm/s (15 ft/min).

5.6 *Pyrometer or Equivalent Instruments*, with a sensitivity of $\pm 0.5^\circ\text{C}$ (1°F) for measuring mill rolls and die surface.

6. Materials: Standard Recipes

6.1 The appropriate formulas and mixing procedures described in Methods D 3187 for NBR and Test Methods D 3185 for SBR shall be used for preparing the standard compound and test compound. The standard compound is used to determine the proper combination of test conditions for evaluating the test compounds.



6.2 The standard compound shall be mixed using the current Industry Reference Carbon Black (IRB) and either SBR 1500 or NBR standard polymers as required. If a different composition is to be evaluated, the reference and test compounds shall be prepared by the same recipe.

NOTE 2—If two batches must be blended to obtain sufficient material for a test, it is imperative that all mixes within a set receive equal treatment, as extrusion characteristics change with milling or other working.

7. Temperatures

7.1 *Mill Roll Temperature*, $50 \pm 5^{\circ}\text{C}$ ($122 \pm 9^{\circ}\text{F}$) shall be used for warm-up.

7.2 *Screw Fluid Temperature* (if equipped for control), $40 \pm 5^{\circ}\text{C}$ ($104 \pm 9^{\circ}\text{F}$).

7.3 *Barrel Temperature*, $70 \pm 10^{\circ}\text{C}$ ($158 \pm 18^{\circ}\text{F}$).

7.4 *Head Temperature*, $110 \pm 15^{\circ}\text{C}$ ($230 \pm 27^{\circ}\text{F}$).

7.5 *Die Temperature*, $110 \pm 15^{\circ}\text{C}$ ($230 \pm 27^{\circ}\text{F}$). The die temperature may be allowed to reach equilibrium by conduction or through application of external heat.

7.6 The temperature ranges given in 7.2-7.5 are the ranges within which screw, barrel, head, and die temperatures may be varied. The constancy of temperature, once set, should be $\pm 2^{\circ}\text{C}$.

NOTE 3—Certain rubbers may require temperatures for processing that do not fall within these limits. Individual adjustment must be made in these cases.

8. Procedure

8.1 Weigh approximately 1 kg of standard compound and warm up on the mill. The amount of stock required depends on the size of the extruder. Set the mill rolls to form a rolling bank. Warm up the stock by banding it on the mill, and then cut the batch from side to side at 30-s intervals for 4 min. Record the stock temperature at the end of the warm-up operation.

8.2 Set the rotational speed of the screw to 4.7 rad/s (45 r/min). If the extrusion is not smooth, higher screw speeds may be tried until a smooth delivery is obtained. Once the screw speed is established, it will remain unchanged during the evaluation of the samples being tested.

8.3 Position the take-away conveyor so that the vertical distance of the belt below the die opening does not exceed 25 mm (1 in.) and the belt is centered below the extruder die opening.

8.4 Remove the die and remove all stock from the die and extruder head. Replace the die and immediately proceed with the following steps.

8.5 Remove the stock from the mill in a continuous strip 3 to 5 mm (0.12 to 0.20 in.) thick, adjusting the width to fit the flight width of the feed section of the screw. Feed the strip into the extruder hopper until the barrel is full and the rubber begins to extrude through the die. While continuing to feed the extruder, take the extrusion from the die by the take-away conveyor. Avoid stretching the extrusion.

8.6 By observation, determine when the extrusion has reached a stable condition. Measure the die temperature to ensure that it has again stabilized at the set point. Select a specimen approximately 250 mm (10 in.) in length that is representative of the stable extrusion.

8.7 Rate the extrusion by System A or B, described in 9.1 and 9.2, respectively.

8.8 If the rating for the standard compound is not acceptable, adjust the extrusion temperatures within the prescribed limitations in Section 7 and repeat the test on new batches of the standard compound until a rating of 4,4,4,4 by System A, or 10A by System B, is achieved. Once these conditions are established, do not change them during the evaluation of the test compounds. If temperature changes are not successful, then try higher screw speeds as described in 8.2.

8.9 Warm up the sample mix as described in 8.1 and repeat 8.4-8.7 for the test or experimental rubber compounds, using the extrusion conditions established in 8.8.

8.10 If specimens are to be saved for reference purposes, rest them for 1 h with ends secured and then cure in open steam with ends secured.

9. Rating Systems

9.1 *System A*—This system is based on four separate gradings, each grading represented by a digit. The first digit in the rating refers to swelling or porosity, the second digit refers to sharpness and continuity of the 30° edge, the third digit refers to smoothness of the surface, and the fourth digit refers to sharpness and continuity of corners. The ratings range from 1 (poor) to 4 (excellent) (see Fig. 3).⁴

9.2 *System B*—In this system, a combination of a digit and a letter of the alphabet is used to grade extrusions. The number, ranging from 1 (poor) to 10 (excellent), rates the sharpness and continuity of the 30° edge; the letter, ranging from A (excellent) to E (poor), rates the smoothness of the surface (see Fig. 4).⁴

10. Report

10.1 Report the following information:

10.1.1 Stock identification.

10.1.2 Extrusion conditions as follows:

10.1.2.1 Stock temperature at end of warm-up,

10.1.2.2 Screw temperature,

10.1.2.3 Barrel temperature,

10.1.2.4 Head temperature,

10.1.2.5 Die temperature, and

10.1.2.6 Screw rotational speed, (or angular speed), rad/s (r/min).

10.1.3 Rating of the extrusion by either System A or System B, or both.

11. Precision and Bias

11.1 A precision statement is not directly applicable since both Systems A and B yield only qualitative comparison data for a candidate test compound versus a standard compound.

11.2 Since no accepted reference values can be determined or theoretically calculated, no estimation of bias can be made.

12. Keywords

12.1 appearance; extrudability; extrusion; processability

⁴ Glossy prints of Figs. 3 and 4 are available at a nominal cost from ASTM Headquarters, 100 Barr Harbor Drive, Conshohocken, PA 19428. Request ADJD2230.

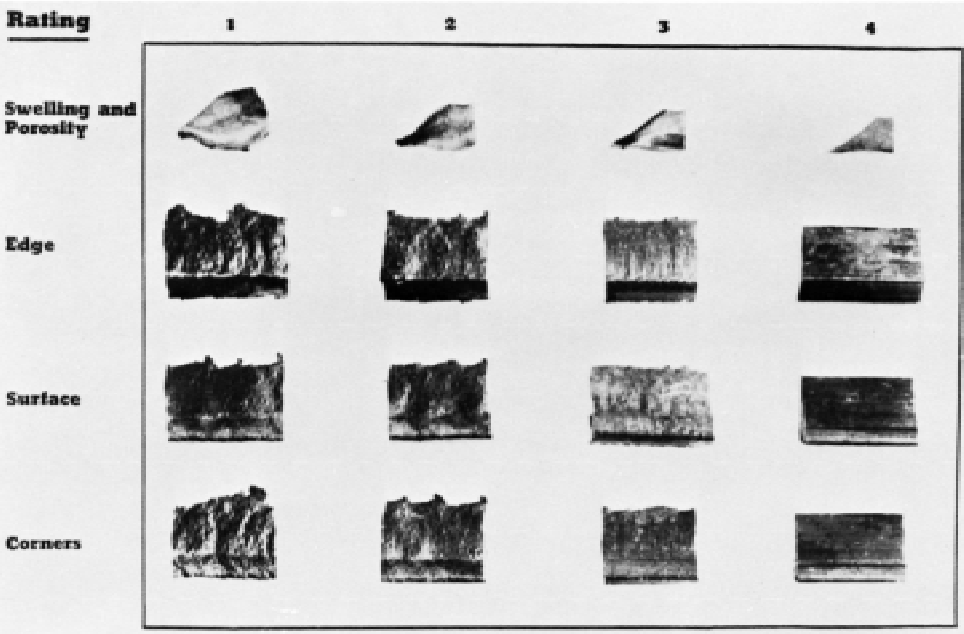


FIG. 3 Appearance Ratings by Rating System A

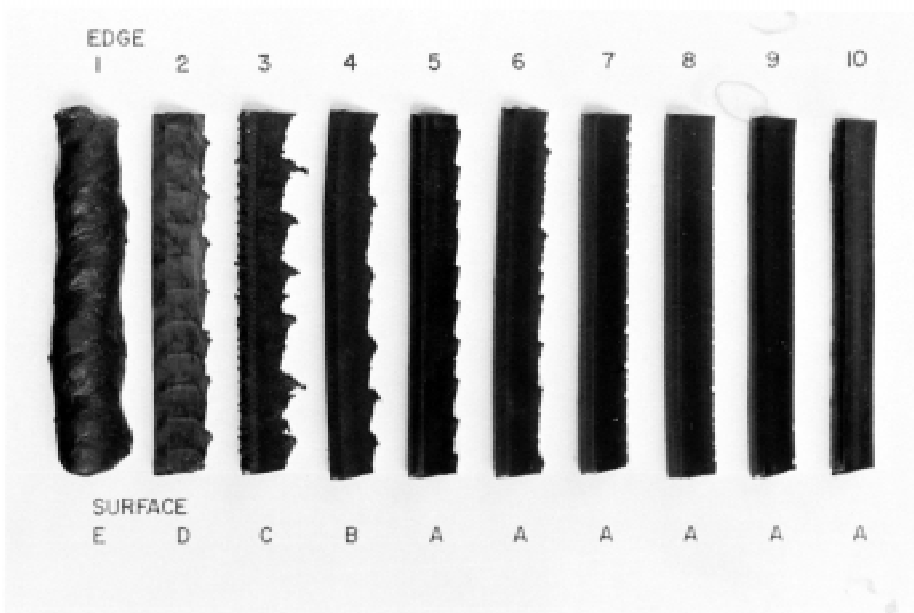


FIG. 4 Appearance Ratings by Rating System B

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