



Designation: D2412 – 21

Standard Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading¹

This standard is issued under the fixed designation D2412; 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 U.S. Department of Defense.

1. Scope*

1.1 This test method covers the determination of load-deflection characteristics of plastic pipe under parallel-plate loading.

1.2 This test method covers thermoplastic resin pipe, reinforced thermosetting resin pipe (RTRP), and reinforced polymer mortar pipe (RPMP).

1.3 The characteristics determined by this test method are pipe stiffness, stiffness factor, and load at specific deflections.

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

NOTE 1—While this test method can be used in measuring the pipe stiffness of corrugated plastic pipe or tubing, other profile wall designs, and products produced from polyethylene, PVC or polypropylene, special conditions and procedures are used. These details are included in the product standards, for example, Specifications F667/F667M, F949, F2764/F2764M, and others.

1.5 The text of this test method references notes and footnotes that provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the test method.

1.6 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *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.*

¹ This test method is under the jurisdiction of ASTM Committee F17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.40 on Test Methods.

Current edition approved Feb. 1, 2021. Published February 2021. Originally approved in 1965. Last previous edition approved in 2018 as D2412 – 11(2018). DOI: 10.1520/D2412-21.

2. Referenced Documents

2.1 *ASTM Standards:*²

D695 Test Method for Compressive Properties of Rigid Plastics

D1600 Terminology for Abbreviated Terms Relating to Plastics

D2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings

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

F412 Terminology Relating to Plastic Piping Systems

F667/F667M Specification for 3 through 24 in. Corrugated Polyethylene Pipe and Fittings

F949 Specification for Poly(Vinyl Chloride) (PVC) Corrugated Sewer Pipe With a Smooth Interior and Fittings

F2764/F2764M Specification for 6 to 60 in. [150 to 1500 mm] Polypropylene (PP) Corrugated Double and Triple Wall Pipe and Fittings for Non-Pressure Sanitary Sewer Applications

3. Terminology

3.1 *Definitions*—Definitions are in accordance with Terminology F412, and abbreviations are in accordance with Terminology D1600, unless otherwise specified.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 Δy —measured change of the inside diameter in the direction of load application expressed in inches (millimetres).

3.2.2 *initial inside diameter* (d)—the average of the inside diameters as determined for the several test specimens and expressed in inches (millimetres).

3.2.3 *load* (F)—the load applied to the pipe to produce a given percentage deflection. Expressed as newtons per metre or pounds-force per linear inch.

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

3.2.4 *mean radius (r)*—the mid-wall radius determined by subtracting the average wall thickness from the average outside diameter and dividing the difference by two. Expressed as inches (millimetres).

3.2.5 *pipe deflection (P)*—the ratio of the reduction in pipe inside diameter to the initial inside diameter expressed as the percentage of the initial inside diameter.

3.2.6 *pipe significant events:*

3.2.6.1 *liner cracking or crazing*—the occurrence of a break or network of fine breaks in the liner visible to the unaided eye.

3.2.6.2 *rupture*—a crack or break extending entirely or partly through the pipe wall.

NOTE 2—The significant events listed may or may not occur in a specific pipe material.

3.2.6.3 *wall cracking*—the occurrence of a break in the pipe wall visible to the unaided eye.

3.2.6.4 *wall delamination*—the occurrence of any separation in the components of the pipe wall visible to the unaided eye.

3.2.7 *pipe stiffness (PS)*—the value obtained by dividing the force per unit length of specimen by the resulting deflection in the same units at the prescribed percentage deflection.

3.2.8 *stiffness factor (SF)*—the product of pipe stiffness and the quantity $0.149 r^3$.

3.2.9 *Discussion*—The “pipe stiffness” and “stiffness factor” are related as follows:

$$PS = F/\Delta y \quad (1)$$

$$SF = EI = 0.149 Fr^3/\Delta y = 0.149 r^3(PS) \quad (2)$$

NOTE 3—See [Appendix X2](#) for information relating PS, E, and Δy .

4. Summary of Test Method

4.1 A short length of pipe is loaded between two rigid parallel flat plates at a controlled rate of approach to one another. Load-deflection (of the pipe diameter) data are obtained. If cracking, crazing, delamination, or rupture occurs, the corresponding load and deflection are recorded.

5. Significance and Use

5.1 The external loading properties of plastic pipe obtained by this test method are used for the following:

5.1.1 To determine the stiffness of the pipe. This is a function of the pipe dimensions and the physical properties of the material of which the pipe is made.

5.1.2 To determine the load-deflection characteristics and pipe stiffness which are used for engineering design (see [Appendix X1](#)).

5.1.3 To compare the characteristics of various plastics in pipe form.

5.1.4 To study the interrelations of dimensions and deflection properties of plastic pipe and conduit.

5.1.5 To measure the deflection and load-resistance at any of several significant events if they occur during the test.

6. Apparatus

6.1 *Testing Machine*—A properly calibrated compression testing machine of the constant-rate-of-crosshead movement type meeting the requirements of Test Method [D695](#) shall be

used to make the tests. The rate of head approach shall be 0.50 ± 0.02 in. (12.5 ± 0.5 mm)/min.

NOTE 4—Hydraulic testing machines that may vary slightly from these rate limits are commonly used and are satisfactory for testing RTRP and RPMP pipe 24-in. (610-mm) size and larger.

6.2 *Loading Plates*—The load shall be applied to the specimen through two parallel steel bearing plates. The plates shall be flat, smooth, and clean. The thickness of the plates shall be sufficient so that no bending or deformation occurs during the test, but it shall not be less than 0.25 in. (6.0 mm). The plate length shall equal or exceed the specimen length and the plate width shall not be less than the pipe contact width at maximum pipe deflection plus 6.0 in. (150 mm).

NOTE 5—For some types of testing machines a greater plate thickness may be required to limit plate bending.

6.3 *Deformation (Deflection) Indicator*—The change in inside diameter, or deformation parallel to the direction of loading, shall be measured with a suitable instrument meeting the requirements of Test Method [D695](#), except that the instrument shall be accurate to the nearest 0.010 in. (0.25 mm). The instrument shall not support the pipe test specimen or the plate or affect in any way the load deflection measurements. Changes in diameter are measured during loading by continuously recording plate travel or by periodically computing it.

7. Test Specimens

7.1 For thermoplastic pipe, the test specimen shall be a piece of pipe $6 \pm \frac{1}{8}$ in. (150 ± 3 mm) long.

7.2 For reinforced thermosetting resin pipe, the minimum test specimen length shall be three times the nominal pipe diameter or 12.0 in. (300 mm), whichever is smaller. For pipe larger than 60 in. (1524 mm) in diameter, the minimum specimen length shall be 20 % of the nominal diameter adjusted to the nearest 1 in. (25.4 mm).

7.3 The ends of specimens shall be cut square and shall be free of burrs and jagged edges.

7.4 No less than three specimens shall be tested for each sample of pipe.

NOTE 6—For quality control testing a single specimen may be used with the thinnest wall at the top.

7.5 Certain RTRP pipes exhibit surface irregularity because the production process is inside diameter controlled. To assure accurate test results by parallel-plate loading, the test specimen must be uniformly loaded along its entire bearing surface. If surface irregularities (resin-rich areas) along the outside diameter prevent the bearing load from being uniformly distributed along the length of the specimen, the outside surface along the loading line shall be sanded smooth by hand. This sanding shall only be done if the reinforcement is not damaged. Note that sanding shall be done only along the plate contact lines.

8. Conditioning

8.1 Condition pipe for at least 4 h in air, at a temperature of 73.4 ± 3.6 °F (23 ± 2 °C), and conduct the test in a room maintained at the same temperature.

8.2 When a referee test is required, condition specimens for at least 40 h at 73.4 ± 3.6 °F (23 ± 2 °C) and 50 ± 5 % relative humidity and conduct the test under the same conditions.

9. Procedure

9.1 Make the following measurements on each specimen:

9.1.1 Determine the length of each specimen to the nearest 1/32 in. (1 mm) or better, by making and averaging at least four equally spaced measurements around the perimeter.

9.1.2 Measure the wall thickness of each specimen in accordance with Test Method D2122. Make at least eight measurements equally spaced around one end and calculate the average wall thickness.

9.1.3 Determine whether a line of minimum wall thickness exists along the length of the specimen and if so mark it for use in 9.2.1.

NOTE 7—On RTRP and RPMP pipe measurements may be made at both ends.

9.1.4 Determine the average outside diameter to the nearest 0.01 in. (0.2 mm) using a circumferential wrap tape or by averaging the maximum and minimum outside diameters as measured with a micrometer or caliper.

9.1.5 For OD-controlled pipe calculate the average pipe inside diameter (ID) by subtracting two times the average of all wall thicknesses (9.1.2) from the average of all outside diameters (9.1.4). For ID-controlled pipe determine the average ID by measuring the maximum and minimum inside diameters. Use this average ID as the basis for computing the percentage of deflection for all specimens in that lot of pipe.

9.2 Locate the pipe section with its longitudinal axis parallel to the bearing plates and center it laterally in the testing machine.

9.2.1 If an orientation of minimum wall thickness has been found, place the first specimen so the thinnest wall is at the top and rotate successive specimens 35 and 70°. If no minimum wall thickness was identified, use any base line.

9.3 With the deflection indicator in place, bring the upper plate into contact with the specimen with no more load than is necessary to hold it in place. This establishes the beginning point for subsequent deflection measurements.

9.4 Compress the specimen at a constant rate of 0.50 ± 0.02 in. (12.5 ± 0.5 mm)/min.

NOTE 8—For larger sizes of pipe made from relatively low-modulus materials, creep may affect the results of this test because of the loading rate specified.

9.5 Record load-deflection measurements continuously or intermittently with reference to the relative movement of the bearing plates. If measurements are made intermittently, make and record such measurements at increments of not more than 5 % of the average inside diameter of the specimen. Refer to Annex A1.

9.6 Observe and note the load and deflection at the first evidence of each of the following significant events when and if they occur:

- 9.6.1 Liner cracking or crazing.
- 9.6.2 Wall cracking.
- 9.6.3 Wall delamination.
- 9.6.4 Rupture.

9.7 Record type and position of each event with respect to the corresponding load and deflection. Discontinue the test when either of the following occur:

- 9.7.1 The load on the specimen fails to increase with increasing deflection (maximum point on load-deflection plot has been reached).
- 9.7.2 The specimen deflection reaches 30 % of the average inside diameter or the required maximum deflection.

10. Calculation

10.1 Calculate the pipe stiffness, PS, for any given deflection as follows:

$$PS = F/\Delta y \quad \text{lbf/in./in. (kPa)} \quad (3)$$

NOTE 9—Refer to Appendix X3 for additional information on units.

10.2 When required, calculate the stiffness factor, SF, for any given deflection as follows:

$$SF = 0.149 r^3 \cdot PS \quad \text{in.}^3 \cdot \text{lbf/in.}^2 \text{ (Pa} \cdot \text{m}^3) \quad (4)$$

10.3 When required, calculate the percentage pipe deflection, P, as follows:

$$P = \Delta y/d \times 100 \quad (5)$$

11. Report

TABLE 1 Pipe Stiffness—Precision Statistics^A

Material	Deflection Level, %	Average	S _{mean}	S _r ^B	S _R ^B	r	R	Standard Deviation of Cell Averages ^C	Repeatability Standard Deviation ^C	Reproduce-ability Standard Deviation ^C	Repeatability Limit (95 %) ^C	Reproduce-ability Limit (95 %) ^C
A	2.5	772.3	54.95	84.69	101.0	237.1	282.7	7.11	11.0	13.1	30.7	36.6
B	2.5	380.2	20.52	18.12	27.37	50.72	76.64	5.40	4.77	7.20	13.3	20.2
C	2.5	463.9	79.07	57.82	97.96	161.9	274.3	17.0	12.5	21.1	34.9	59.1
A	5.0	755.7	33.30	80.30	86.93	224.8	243.4	4.41	10.6	11.5	29.7	32.2
B	5.0	356.1	19.13	15.32	24.51	42.89	68.62	5.37	4.30	6.88	12.0	19.3
C	5.0	419.4	37.80	27.74	46.89	77.68	131.3	9.01	6.61	11.2	18.5	31.3
A	7.5	724.8	27.85	76.14	81.07	213.2	227.0	3.84	10.5	11.2	29.4	31.3
B	7.5	332.6	16.87	13.94	21.88	39.02	61.27	5.07	4.19	6.58	11.7	18.4
C	7.5	371.7	26.70	18.82	32.66	52.69	91.45	7.18	5.06	8.79	14.2	24.6

^A Terms are used as specified in Practice E177.

^B S_r = standard deviation of repeatability (variation of replicate samples by same laboratory).

S_R = standard deviation of reproducibility (variability between laboratory).

^C Precision statistics as percent of average.

11.1 Report the following information:

11.1.1 Complete identification of the material tested, including type, source, manufacturer’s code, previous history (if any), and product identification by standard number.

11.1.2 Dimensions of each specimen, including average outside diameter, average wall thickness, average inside diameter, liner thickness and reinforcement thickness where applicable, and average length.

11.1.3 Whether or not the outside diameter of the specimen was sanded.

11.1.4 Conditioning temperature, time, and environment.

11.1.5 The load and deflection at which any of the following events occurred:

11.1.5.1 Liner cracking or crazing,

11.1.5.2 Wall cracking,

11.1.5.3 Wall delamination, and

11.1.5.4 Rupture.

11.1.6 The reason for terminating the test.

11.1.7 If required, a plot on cartesian coordinates of the load in pounds-force per inch (or newtons per metre) versus deflection in inches (or millimetres) for each specimen tested. Each of the following occurrences shall be noted on the plots where applicable:

11.1.7.1 Liner cracking or crazing,

11.1.7.2 Wall cracking, and

11.1.7.3 Wall delamination.

11.1.8 Pipe stiffness, $F/\Delta y$, at 5 and 10 % deflection, for each specimen. If any cracking, crazing, or delamination occurred below 5 % deflection, calculate pipe stiffness at that percent deflection where cracking or delamination occurred and note this in the report.

11.1.9 When specifically requested determine the stiffness factor, SF, at 5 and 10 % deflection, for each specimen. If any cracking, crazing, or delamination occurred below 5 % deflection, calculate apparent stiffness factor at the percent deflection where cracking or delamination occurred and note this in the report.

11.1.10 Date of test.

12. Precision and Bias

12.1 *Precision*³:

12.1.1 *Thermoplastic Pipes*—An interlaboratory study of pipe stiffness was conducted in accordance with Practice E691 with seven laboratories participating, each obtaining nine results at three deflection levels on three pipe samples. The pipe samples were C = 4 in. corrugated PE pipe, A = 6 in. SDR 26 ABS dwv pipe, and B = 12 in. SDR 35 PVC sewer pipe. Information regarding the precision is found in Table 1.

12.1.2 *Thermoset Resin Pipes*—The precision of this test method is based on an interlaboratory study of pipe stiffness conducted in 2010. Each of eight laboratories tested three different thermoset resin pipe products at two deflections (2.5 % and 5 %). Every “test result” represents an individual determination, and all participants were asked to report fifteen test results for each pipe/deflection combination. Pipe samples were D = 24 in. filament wound fiberglass pipe, E = 36 in. continuous advancing mandrel fiberglass pipe and F = 33 in. cast fiberglass pipe. Practice E691 was followed for the design and analysis of the data; the details are given in ASTM Research Report No. RR:F17-1051.⁴

12.1.2.1 *Repeatability limit (r)*—Two test results obtained within one laboratory shall be judged not equivalent if they differ by more than the “r” value for the 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.

(1) Repeatability limits are listed in Table 2 and Table 3 below.

12.1.2.2 *Reproducibility limit (R)*—Two test results shall be judged not equivalent if they differ by more than the “R” value for the 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.

(1) Reproducibility limits are listed in Table 2 and Table 3 below.

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

12.1.2.4 Any judgement in accordance with statements 12.1.2.1 and 12.1.2.2 would have an approximate 95% probability of being correct.

12.1.3 To judge the equivalency of two test results, it is recommended to choose the material closest in characteristics to the test material.

12.2 *Bias*—Data obtained using this test method are believed to be reliable since accepted techniques of analysis are used. However, because no reference method is available, no bias statement is made.

³ Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:F17-1040.

⁴ Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:F17-1051.

TABLE 2 Stiffness at 2.5% Deflection (psi)

Material	Average ^A	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
	\bar{x}	S_r	S_R	r	R
Sample D	68.79	1.89	2.18	5.29	6.11
Sample E	126.6	5.48	5.81	15.3	16.3
Sample F	49.51	1.11	1.93	3.11	5.41

^AThe average of laboratories’ calculated averages.