INTERNATIONAL

Designation: D 2105 – ~~97~~01

An American National Standard

Standard Test Method for Longitudinal Tensile Properties of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Tube[1]

This standard is issued under the fixed designation D 2105; 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 test method covers the determination of the comparative longitudinal tensile properties of fiberglass pipe when tested under defined conditions of pretreatment, temperature, and testing machine speed. Both glass-fiber-reinforced thermosetting-resin pipe (RTRP) and glass-fiber-reinforced ~~plastic~~ polymer mortar pipe (RPMP) are fiberglass pipes.

NOTE 1—For the purposes of this standard, polymer does not include natural polymer.

1.2 This test method is generally limited to pipe diameter of 6 in. (150 mm) or smaller. Larger sizes may be tested if required apparatus is available.

1.3 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are provided for information purposes only.

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~~2—There is no similar or equivalent ISO standard.

2. Referenced Documents

2.1 *ASTM Standards:*

C 33 Specification for Concrete Aggregates[2]

[1] This test method is under the jurisdiction of ASTM Committee D-20 on Plastics and is the direct responsibility of Subcommittee D20.23 on Reinforced Plastic Piping Systems.

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

D 618 Practice for Conditioning Plastics and Electrical Insulating Materials for Testing[3]
D 638 Test Method for Tensile Properties of Plastics[3]
D 638M Test Method for Tensile Properties of Plastics (Metric)[3]
D 883 Terminology Relating to Plastics[4]
D 1600 Terminology for Abbreviated Terms Relating to Plastics[4]
D 3567 Practice for Determining Dimensions of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Fittings[5]
E 4 Practices for Load Force Verification of Testing Machines[6]
E 83 Practice for Verification and Classification of Extensometers[6]
F 412 Terminology Relating to Plastic Piping Systems[5]

3. Terminology

3.1 *General*—Definitions are in accordance with Terminology D 883 and F 412 and abbreviations are in accordance with Terminology D 1600, unless otherwise indicated.

3.2 Other definitions of terms and symbols relating to tension testing of plastics appear in the Annex to Test Methods D 638 and D 638M.

3.3 *Definitions of Terms Specific to This Standard:*

3.3.1 *aggregate*—a siliceous sand conforming to the requirements of Specification C 33, except that the requirements for gradation shall not apply.

3.3.2 *exterior surface resin layer*—a resin layer, with or without filler or reinforcement, or both, applied to the exterior surface of the pipe structural wall.

3.3.3 *fiberglass pipe*—a tubular product containing glass fiber reinforcement embedded in or surrounded by cured thermosetting resin; the composite structure may contain aggregate, granular or platelet fillers, thixotropic agents, pigments, or dyes; thermoplastic or thermosetting liners may be included.

3.3.4 *liner*—the inner portion of the wall at least 0.005 in. (0.13 mm) in thickness, as determined in 9.1.2, which does not contribute to the strength in the determination of the hydrostatic design basis.

3.3.5 *reinforced plastic polymer mortar pipe (RPMP)*—a fiberglass pipe with aggregate.

3.3.6 *reinforced thermosetting resin pipe (RTRP)*—a fiberglass pipe without aggregate.

3.3.7 *reinforced wall thickness*—the total wall thickness minus the liner or exterior coating thickness, or both.

4. Significance and Use

4.1 Tensile properties include modulus of elasticity, yield stress, elongation beyond yield point, tensile strength, elongation at break, and energy absorption. Materials possessing a low order of ductility may not exhibit a yield point. Stress-strain data at several levels of temperature, humidity, time, or other variables may be needed to furnish reasonably accurate indications of the behavior of the material.

NOTE 23—It is realized that the method of preparation of a material is one of the many variables that affect the results obtained in testing a material. Hence, when comparative tests of materials per se are desired, the greatest care must be exercised to ensure that all samples are prepared in exactly the same way; similarly, for referee or comparative tests of any given series of specimens, care must be taken to secure the maximum degree of uniformity in details of preparation, treatment, and handling.

4.2 Tension tests may provide data for research and development, engineering design, quality control, acceptance or rejection under specifications, and for special purposes. The tests cannot be considered significant for applications differing widely from the load-time scale of the standard test (Note 2). 3). Such applications require more suitable tests, such as impact, creep, and fatigue.

NOTE 34—It is recognized that the constant rate-of-crosshead-movement type of test leaves much to be desired from a theoretical standpoint, that wide differences may exist between gage marks on the specimen, and that the testing speeds specified disguise important effects characteristic of materials in the plastic state. Further, it is realized that variations in the thicknesses of test specimens, which are permitted by these procedures, produce variations in the surface-volume ratios of such specimens, and that these variations may influence the test results. Hence, where directly comparable results are desired, all samples should be of equal thickness and outside diameter. Appropriate modifications of the test procedure should be used when more precise physical data are needed.

NOTE 45—Reinforcements of plastics with glass fiber offer wide opportunities for designing and producing products with markedly different responses to loading even when the basic geometry of the product is similar. For example, a tubular product may be designed to give maximum resistance to torsion loading, but such a product might develop a twist or bow if tested in tension or under internal pressure loading. In the case of pipe for general field use, internal pressure, as well as loads in tension, compression, torsion, and flexure must be resisted to some degree. Different pipe producers have chosen, by design, to offer products having different balances of resistance to such stressing conditions. As a result, it is important that the purchaser and the seller both have a clear understanding and agreement on the significance of this test method relative to the intended use.

[2] *Annual Book of ASTM Standards*, Vol 04.02.
[3] *Annual Book of ASTM Standards*, Vol 08.01.
[4] *Annual Book of ASTM Standards*, Vols 08.01 and 08.04.
[5] *Annual Book of ASTM Standards*, Vol 08.04.
[6] *Annual Book of ASTM Standards*, Vol 03.01.

5. Apparatus

5.1 *Testing Machine*—A testing machine of the constant-rate-of-crosshead-movement type (Note 2) 3) and comprising essentially the following:

5.1.1 *Fixed Member*—A fixed or essentially stationary member carrying one grip.

5.1.2 *Movable Member*—A movable member carrying a second grip.

5.1.3 *Grips*—Grips for holding the test specimen between the fixed member and the movable member. The grips shall be self-aligning; that is, they shall be attached to the fixed and movable member, respectively, in such a manner that they will move freely into alignment as soon as any load is applied. With this arrangement, the long axis of the test specimen will coincide with the direction of the applied pull through the center line of the grip assembly. The test specimen shall be held in such a way that slippage relative to the grips is prevented insofar as possible. The grips shall be designed so that no crushing load shall be applied to the pipe ends. A suggested set of grips and mandrels is shown in Fig. 1 and Fig. 2.

5.1.4 *Drive Mechanism*—A drive mechanism for imparting to the movable member a uniform, controlled velocity with respect to the stationary member, this velocity to be regulated as specified in 9.3.

5.1.5 *Load Indicator*—A suitable load-indicating mechanism capable of showing the total tensile load carried by the test specimen when held by the grips. This mechanism shall be essentially free from inertia lag at the specified rate of testing and shall indicate the load with an accuracy of ±1 % of the indicated value, or better. The accuracy of the testing machine shall be verified in accordance with Practice E 4.

NOTE 56—Experience has shown that many testing machines now in use are incapable of maintaining accuracy for as long as the periods between inspection recommended in Practice E 4. Hence, it is recommended that each machine be studied individually and verified as often as necessary. It will frequently be necessary to perform this function daily.

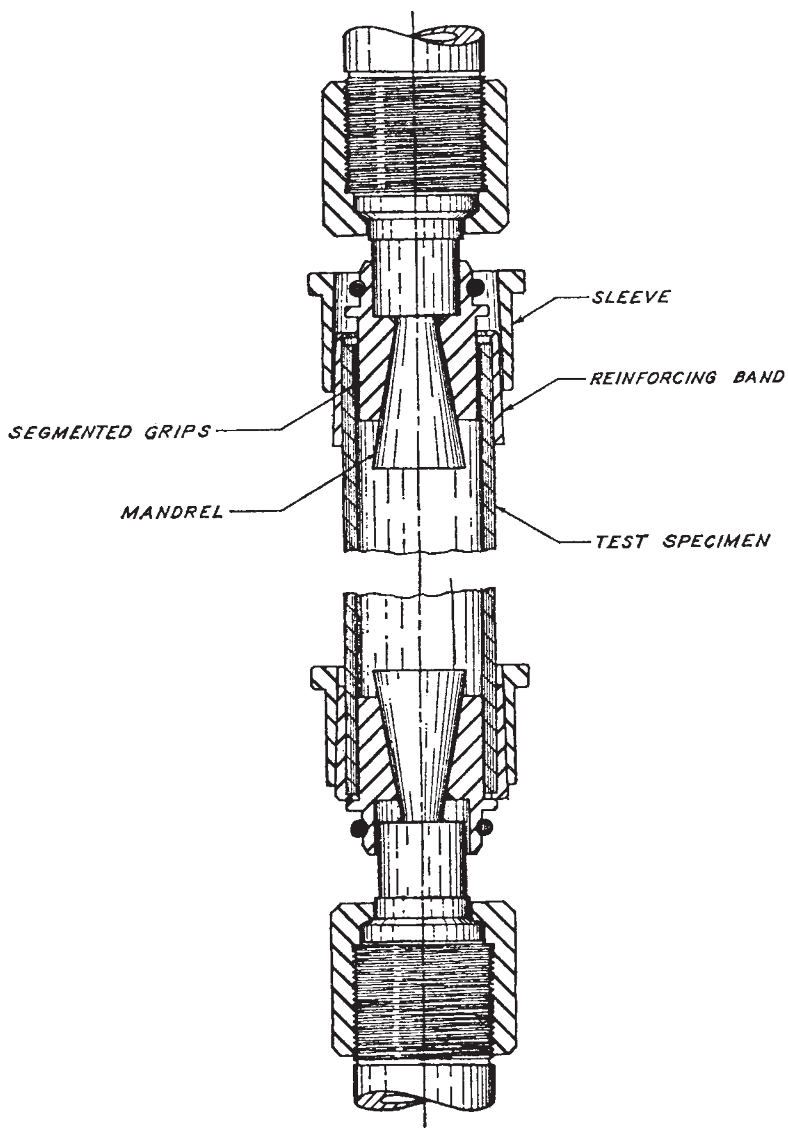
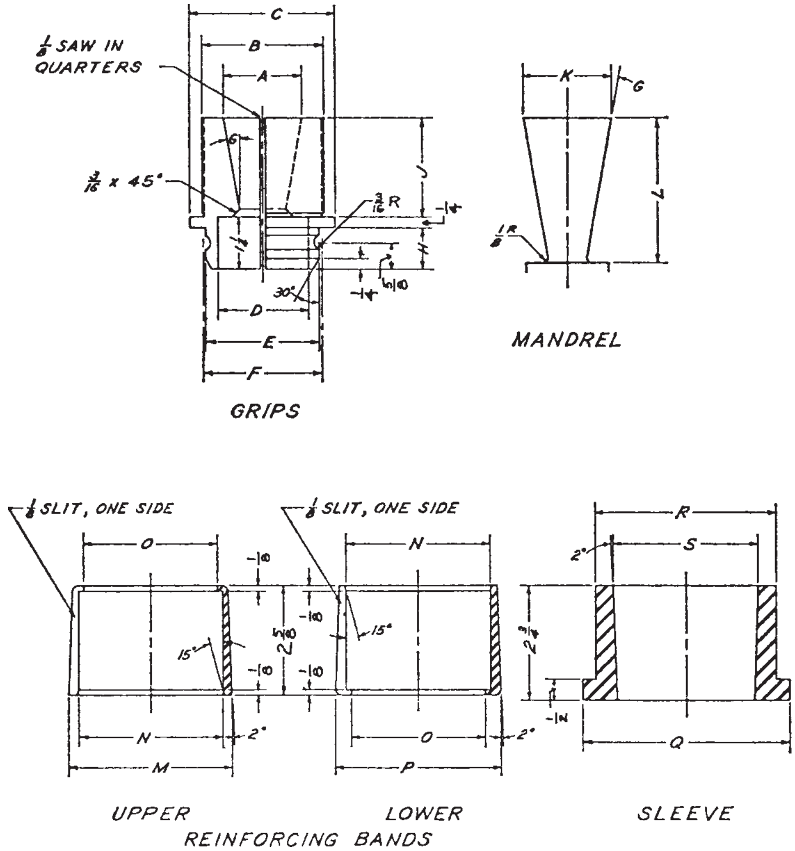


FIG. 1 Suggested Holding Device for Tension Test Specimen



Pipe Size	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*J*
~~2~~	~~1 1732 17/32~~	~~1 78 7/8~~	~~2 38 3/8~~	~~1 34 3/4~~	~~2 38 3/8~~	~~2 12 1/2~~	~~8°~~	~~1 14 1/4~~	~~2 18 1/8~~
2	1 17/32	1 7/8	2 3/8	1 3/4	2 3/8	2 1/2	8°	1 1/4	2 1/8
~~2 12 1/2~~	~~1 1516 15/16~~	~~2 38 3/8~~	~~2 78 7/8~~	~~2 316 3/16~~	~~2 34 3/4~~	~~2 78 7/8~~	~~10°~~	~~1 14 1/4~~	~~2 14 1/4~~
2 1/2	1 15/16	2 3/8	2 7/8	2 3/16	2 3/4	2 7/8	10°	1 1/4	2 1/4
~~3~~	~~1 2932 29/32~~	~~2 1516 15/16~~	~~3 12 1/2~~	~~2 316 3/16~~	~~2 34 3/4~~	~~2 78 7/8~~	~~10°~~	~~1~~	~~2 38 3/8~~
3	1 29/32	2 15/16	3 1/2	2 3/16	2 3/4	2 7/8	10°	1	2 3/8
~~4~~	~~2 132 1/32~~	~~3 1316 13/16~~	~~4 12 1/2~~	~~2 316 3/16~~	~~2 34 3/4~~	~~2 78 7/8~~	~~10°~~	~~1~~	~~2 34 3/4~~
4	2 1/32	3 13/16	4 1/2	2 3/16	2 3/4	2 7/8	10°	1	2 3/4

Pipe Size	*K*	*L*	*M*	*N*	*O*	*P*	*Q*	*R*	*S*
~~2~~	~~1 1932 19/32~~	~~3 116 1/16~~	~~2 5364 53/64~~	~~2 2564 25/64~~	~~2 18 1/8~~	~~2 78 7/8~~	~~3 78 7/8~~	~~3 14 1/4~~	~~2 2732 27/32~~
2	1 19/32	3 1/16	2 53/64	2 25/64	2 1/8	2 7/8	3 7/8	3 1/4	2 27/32
~~2 12 1/2~~	~~2 18 1/8~~	~~3 12 1/2~~	~~3 2164 21/64~~	~~2 5764 57/64~~	~~2 58 5/8~~	~~3 38 3/8~~	~~4 38 3/8~~	~~3 34 3/4~~	~~3 1132 11/32~~
2 1/2	2 1/8	3 1/2	3 21/64	2 57/64	2 5/8	3 3/8	4 3/8	3 3/4	3 11/32
~~3~~	~~2 18 1/8~~	~~3 12 1/2~~	~~3 6164 61/64~~	~~3 3364 33/64~~	~~3 14 1/4~~	~~4~~	~~5~~	~~4 38 3/8~~	~~3 3132 31/32~~
3	2 1/8	3 1/2	3 61/64	3 33/64	3 1/4	4	5	4 3/8	3 31/32
~~4~~	~~2 18 1/8~~	~~3 12 1/2~~	~~4 6164 61/64~~	~~4 3364 33/64~~	~~4 14 1/4~~	~~5~~	~~6~~	~~5 38 3/8~~	~~4 3132 31/32~~
4	2 1/8	3 1/2	4 61/64	4 33/64	4 1/4	5	6	5 3/8	4 31/32

NOTE 1—Other sizes of pipe may be tested using this test method by varying the dimensions of the holding fixture given in Fig. 2 to fit the specimen and testing machine.

FIG. 2 Suggested Holding Device, Details

5.1.6 The fixed member, movable member, drive mechanism, and grips shall be constructed of such materials and in such proportions that the total elastic longitudinal strain of the system constituted by these parts does not exceed 1 % of the total longitudinal strain between the two gage marks on the test specimen at any time during the test and at any load up to the rated capacity of the machine.

5.2 *Extension Indicator*—A suitable instrument for determining the distance between two fixed points located within the gage length of the test specimen at any time during the test. It is desirable, but not essential, that this instrument automatically record this distance (or any change in it) as a function of the load on the test specimen or of the elapsed time from the start of the test, or both. If only the latter is obtained, load-time data must also be taken. This instrument shall be free of inertia lag at the specified speed of testing and shall be accurate to ± 1 % of strain or better.

NOTE 67—Reference is made to Practice E 83.

5.3 *Micrometers*—Suitable micrometers, reading to at least 0.001 in. (0.025 mm), for measuring the diameter and thickness of the test specimens.

6. Test Specimen

6.1 The test specimens shall be sections of fiberglass pipe or tubing with a minimum length of 18 in. (45.7 cm) between grips.

6.2 All surfaces of each specimen shall be free from visible flaws, scratches, or imperfections.

6.3 The minimum gage length shall be 2.0 in. (5.1 cm) for mechanical extension measuring devices. A gage length of less than 2.0 in. (5.1 cm) is acceptable for electrical extension measuring devices, such as strain gages.

6.4 Gage marks may be placed on the specimen using ink, crayon, scratches, punches, etc., provided they do not damage the reinforcement.

6.5 Pipe with high tensile properties may require additional reinforcement at the grip areas to prevent pipe failure from the crush load of the grips.

6.6 For determination of joint strength, specimens shall include a joint centered between the grips.

7. Number of Test Specimens

7.1 At least five specimens shall be tested for each sample.

7.2 Results from tested specimens that break at some obvious flaw or within one pipe diameter of the grips may be discarded.

8. Conditioning

8.1 *Conditioning*—Condition the test specimens at 73 ± 4°F (22.7 ± 2.2°C) and 50 ± 5 % relative humidity for not less than 40 h prior to test in accordance with Procedure A of Methods D 618, for those tests where conditioning is required. In cases of disagreement, the tolerances shall be± 2°F (±1.1°C) and ±2 % relative humidity.

8.2 *Test Conditions*—Conduct tests in the Standard Laboratory Atmosphere of 73 ± 4°F (22.7 ± 2.2°C) and 50 ± 5 % relative humidity, unless otherwise specified in the test methods or in this specification. In cases of disagreements, the tolerances shall be ±2°F (1.1°C) and ±2 % relative humidity.

9. Procedure

9.1 *Dimensions and Tolerances*:

9.1.1 *Wall Thickness and Diameter*—Determine in accordance with Practice D 3567.

9.1.2 *Liner Thickness*—If the test specimens contain a liner, determine the average liner thickness in accordance with Practice D 3567.

9.2 Place the specimen in the grips of the testing machine, taking care to align the long axis of the specimen and the grips with an imaginary line joining the points of attachment of the grips to the machine. Tighten the grips evenly and firmly to the degree necessary to prevent slippage of the specimen during the test but not to the point where the specimen would be crushed.

9.3 Speed of testing is the velocity of separation of the crossheads (or grips) of the testing machine when operating under no load. The speed of testing shall be either:

9.3.1 0.20 to 0.25 in./min (0.508 to 0.635 cm/min) or

9.3.2 0.40 to 0.50 in./min (1.02 to 1.27 cm/min).

9.4 Attach the extension indicator. Set the speed of testing, and start the machine. Specimens shall be carried to failure. Record loads and corresponding deformations at appropriate even intervals of strain. Record the load carried by the specimen when the strain reaches 0.02 and the elapsed time from the start of the test until this point is reached. If rupture occurs before the strain reaches 0.02, record the elapsed time from the start of the test until the specimen breaks.

10. Calculation

10.1 *Tensile Strength*—Calculate the tensile strength by dividing the maximum (or breaking) load by the original minimum reinforced cross-sectional area of the specimen. Report the result to three significant figures.

10.2 *Percentage Elongation*—Calculate the percentage elongation by dividing the extension at the moment of rupture of the specimen by the original distance between gage marks and multiplying by 100. Report the percentage elongation to two significant figures.

10.3 *Mean Rate of Stressing*—Calculate the mean rate of stressing by dividing the tensile load carried by the specimen when the strain reaches 0.02 or at the moment of rupture, whichever occurs first, by the original minimum reinforced cross-sectional area of the specimen, and then dividing this result by the time in seconds, measured from the beginning of the test, required to attain this tensile load and strain. Report the result to three significant figures.

NOTE 78—It is realized that "mean rate of stressing" as defined in this test method has only limited physical significance. It does, however, roughly describe the average rate at which most of the stress carried by the test specimen is applied and for that portion of the stress-strain curve in which principal stressing occurs. It is affected by the elasticity of the materials being tested but is fairly accurately determined by the method described. It can, if desired, be determined more precisely by calculation from load-time data, recorded especially for the purpose during a test.

10.4 *Mean Rate of Straining*—Calculate the mean rate of straining from a strain-time curve, plotted for the purpose, by selecting any convenient point on the curve and dividing the strain represented by the point by the corresponding time. Express the result as a dimensionless ratio per second (units per second) and report it to three significant figures.

10.5 *Elastic Modulus* shall be obtained by extending the initial linear portion of the load-extension curve and dividing the difference in stress corresponding to a certain section on this straight line by the corresponding difference in strain. Report the result to three significant figures.

NOTE 89—Since the existence of a true elastic limit in plastics, as in many other organic materials and in many metals is debatable, the propriety of applying the term "elastic modulus" in its referenced generally accepted definition to describing the "stiffness" or "rigidity" of a plastic has been seriously questioned. The exact stress-strain characteristics of plastic materials are highly dependent on such factors as rate of application of stress, temperature, previous history of specimen, etc. However, stress-strain curves for plastics determined as described in this test method almost always show a linear region at low stresses, and a straight line drawn tangent to this portion of the curve permits calculation of an elastic modulus of the usually defined type. Such a constant is useful if its arbitrary nature and dependence on time, temperature, and similar factors are realized.

10.6 For each series of tests, calculate the arithmetic mean of all values obtained to three significant figures and report it as the "average value" for the particular property in question.

10.7 Calculate the standard deviation (estimated) as follows and report it to two significant figures:

$$s = \sqrt{(\Sigma X^2 - n\bar{X}^2)/(n-1)} \quad (1)$$

where:

s = estimated standard deviation,
X = value of single observation,
n = number of observations, and
$\bar{X}$ = arithmetic mean of the set of observations.

11. Report

11.1 The report shall include the following:

11.1.1 Complete identification of the material tested, including type, source, manufacturer's code numbers, form, principal dimensions, previous history, etc.,

11.1.2 Type of test specimen, gage length, gross dimensions, and reinforced wall thickness,

11.1.3 Conditioning procedure used,

11.1.4 Atmospheric conditions in test room,

11.1.5 Number of specimens tested,

11.1.6 Speed of testing,

11.1.7 Mean rate of stressing as calculated in 10.3,

11.1.8 Mean rate of straining as calculated in 10.4,

11.1.9 Tensile strength, average value, and standard deviation,

11.1.10 Percentage elongation, average value, and standard deviation,

11.1.11 Elastic modulus, average value, and standard deviation,

11.1.12 Description of type of failure, and

11.1.13 Date of test.

12. Precision and Bias

12.1 *Precision*—Round-robin test programs are considered impractical for this procedure because grips used must be specially sized to fit the inside diameter of each pipe product as closely as possible for optimum results (see 5.1.3). Data obtained using this test method are nevertheless believed reliable.

12.2 *Bias*—Because of the lack of round-robin test programs, an undetermined bias may exist for various reasons as noted in Section 4. For referee tests, the resolution of discrepancies must be resolved between the purchaser and the seller.

13. Keywords

13.1 fiberglass pipe; fiberglass tube; longitudinal; reinforced plastic polymer mortar pipe (RPMP); reinforced thermosetting resin pipe (RTRP); tensile strength

SUMMARY OF CHANGES

Committee D-20 has identified the location of selected changes to this test method since the last issue , D 2105–97 that may impact the use of this test method:
(method.

(1) Added ISO equivalency statement.
(2) Added Keywords Section. Changed acronym, RPMP, definition from reinforced *plastic* mortar pipe to reinforced *polymer* plastic mortar pipe.