



Standard Test Methods for Rubber Hose¹

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This standard has been approved for use by agencies of the Department of Defense. These methods have been approved for use by agencies of the Department of Defense to replace Methods 7431, 7421, 10011, 10021, 10211, 10221, 10311, 10341, 10351, and 10361 of Federal Test Method Standard No. 601 and for listing in the DoD Index of Specifications and Standards.

1. Scope

1.1 These test methods describe procedures for inspection and test of all types and constructions of rubber hose.²

1.2 In case of conflict between provisions of these test methods and those of detailed specifications or test methods for a particular hose, the latter shall take precedence.

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

2. Referenced Documents

2.1 ASTM Standards:

D 412 Test Methods for Vulcanized Rubber and Thermoplastic Elastomers—Tension³

D 413 Test Methods for Rubber Property—Adhesion to Flexible Substrate³

D 471 Test Method for Rubber Property—Effect of Liquids³

D 572 Test Method for Rubber—Deterioration by Heat and Oxygen³

D 573 Test Method for Rubber—Deterioration in an Air Oven³

D 865 Test Method for Rubber—Deterioration by Heating in Air (Test Tube Enclosure)³

D 1149 Test Method for Rubber Deterioration—Surface Ozone Cracking in a Chamber³

D 1349 Practice for Rubber—Standard Temperatures for Testing³

D 1415 Test Method for Rubber Property—International Hardness³

D 2240 Test Method for Rubber Property—Durometer Hardness³

D 3183 Practice for Rubber—Preparation of Pieces for Test Purposes from Products³

D 3767 Practice for Rubber—Measurement of Dimensions³

D 4483 Practice for Determining Precision for Test Method Standards in the Rubber and Carbon Black Industries³

E 4 Practices for Force Verification of Testing Machines⁴

3. General Test Methods

3.1 Except as otherwise specified in these test methods for rubber hose, the following test methods, applicable in general to vulcanized rubber, shall be complied with as required and are hereby made a part of these test methods:

3.1.1 *General Physical Test Requirements*—Practice D 3183.

3.1.2 *Tension Test*—Test Method D 412.

3.1.3 *Aging Test*—Test Method D 572, Test Method D 573, and Test Method D 865.

3.1.4 *Adhesion Test*—Test Methods D 413.

3.1.5 *Immersion Test*—Test Method D 471.

3.1.6 *Hardness Test*—Test Method D 2240.

3.1.7 *Hardness Test*—Test Method D 1415.

4. Significance and Use

4.1 These test methods provide uniform methods for inspection and test of rubber hoses that can be referenced in hose specifications for various applications.

4.2 Uniform test methods make quality comparisons of hose easier and more meaningful, and are more economical particularly when the same rubber vulcanizates are used in different types, constructions, or sizes of hose.

¹ These test methods are under the jurisdiction of ASTM Committee D11 on Rubber and are the direct responsibility of Subcommittee D11.31 on Rubber Hose and Belting.

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² For specifications covering hose used in automotive, construction, and industrial equipment applications, reference should be made to SAE Standards for Coolant System Hoses (SAE J20e), Fuel and Oil Hoses (SAE J30b), Power Steering Pressure Hose—High Volumetric Expansion (SAE J188), Power Steering Return Hose (SAE 189), Power Steering Pressure Hose—Low Volumetric Expansion (SAE J191), Power Steering Pressure Hose—Wire Braid (SAE J190), Windshield Wiper Hose (SAE J50a), Emission Control Hose (SAE J1010), Windshield Washer Tubing (SAE J1037), Tests and Procedures for SAE 100R Series Hydraulic Hose and Hose Assemblies (SAE J343c), and for Tests and Procedures for High-Temperature Transmission Oil Hose, Lubricating Oil Hose, and Hose Assemblies (SAE J1019).

³ *Annual Book of ASTM Standards*, Vol 09.01.

⁴ *Annual Book of ASTM Standards*, Vol 03.01.

5. Sampling

5.1 A sample of sufficient length for proper performance of the required tests shall be cut from the hose when possible without impairing its use and the pieces of hose from which samples have thus been cut shall be accepted by the purchaser as full length, provided the hose meets the specified requirements. The length of samples required depends on the tests which are required. The following will show the minimum length required for the various tests:

5.1.1 *Thickness of Tube, Cover, and Rubber Elements; Tensile Strength and Elongation (Original); Adhesion:*

Nominal Bore Diameter, mm (in.)	Sample Length, mm (in.)
below 19 (0.75)	900 (36)
19 to 31.5 (0.75 to 1.25)	750 (30)
over 31.5 (1.25)	600 (24)

5.1.2 *Volumetric Expansion*—For all sizes 450 mm (18 in.)

5.1.3 *Straight Burst*—For hose nominal 76 mm (3 in.) and smaller, 450 mm (18 in.); for hose over 76 mm in inside diameter 600 mm (24 in.) but not exceeding 900 mm (36 in.). Use 900 mm for all sizes of jacketed rubberlined fire hose.

NOTE 1—Volumetric samples can be used for burst tests when hose is nominal 76 mm (3 in.) inside diameter and smaller.

5.1.4 *Curved Burst*—For all bore diameters of hose, 900 mm (36 in.).

5.1.5 *Hold Test*—For hose 76 mm (3 in.) and smaller, 450 mm (18 in.); for hose over 76 mm in inside diameter, 600 mm (24 in.) but not exceeding 900 mm.

5.1.6 *Immersion Test—Volume Change and Strength Deterioration:*

Nominal Bore Diameter, mm (in.)	Sample Length, mm (in.)
below 19 (0.75)	450 (18)
19 to 31.5 (0.75 to 1.25)	300 (12)
over 31.5 (1.25)	150 (6)

5.1.7 *Low-Temperature Test:*

Nominal Bore Diameter, mm (in.)	Sample Length, mm (in.)
below 31.5 (1.25)	500 (20)
31.5 to 50 (1.25 to 2)	700 (28)
over 50 (2)	1 000 (40)

5.2 Where the construction of the hose does not permit the cutting of samples as described in 5.1 without impairment of use, as in wire inserted hose, dredging sleeves, etc., a separate length having the same specifications shall be provided, either as an additional length or as a prolongation built onto the hose. Wire shall be omitted from the prolongation or sample length unless the detailed physical tests include requirements that measure the effect of the wire or metal elements in the construction. Additional length taken for purpose of tests shall be paid for by the purchaser, provided they conform to the specified requirements.

5.3 The sampling of woven-jacketed rubber-lined hose shall be in accordance with detailed specifications for this material.

6. Measurement of Hose

6.1 *Length*—Determine the length by means of a steel tape or calibrated measuring device. It shall not include the length of fittings except when specifically so requested and recorded. In the case of woven-jacketed rubber-lined hose, or hose with

a helical wire reinforcement, determine the length under a 70-kPa (10-psi) internal pressure.

6.2 *Outside Diameter and Reinforcement Diameter*—Measure the circumference with a flexible tape and determine the diameter by calculation. Use of a pi (π) tape graduated to read the diameter directly is acceptable. On diameters of 25 mm (1 in.) or less, caliper measurements are acceptable when at least two measurements are made approximately 90° apart and the measurements averaged. The measuring device shall be capable of measuring in increments of 0.25 mm (0.01 in.) or less. All diameter measurements shall be made at least 25 mm (1 in.) distance back from the ends of the hose.

6.3 *Inside Diameter*—On hose up to and including nominal inside diameter of 75 mm (3 in.) suitable expanding ball gages, telescoping gages, or cylindrical-plug gages shall be used.

6.3.1 The measuring devices shall have the following minimum precision:

Nominal Bore Diameter, mm (in.)	Plug Gages, mm (in.)	Calipers, mm (in.)	Scales, mm (in.)
25 (1) or less	0.25 (0.01)		
over 25 to 50 (1 to 2)	0.50 (0.02)		
over 50 to 75 (2 to 3)	0.75 (0.03)		
over 75 (3)		0.25 (0.01)	
150 (6) or more		0.50 (0.02)	0.50 (0.02)

6.3.1.1 Plug gages shall have the maximum increments in diameter as given above and a minimum step length of 9.5 mm (0.37 in.).

6.3.1.2 Ball gages and telescoping gages shall be capable of measuring increments of 0.50 mm (0.02 in.) or less.

6.3.2 On hose 150 mm (6 in.) or larger in nominal inside diameter, in addition to inside calipers, a graduated steel scale can be used. On hose 150 mm (6 in.) or larger the measuring device shall be capable of measuring 0.50 mm (0.02 in.) or less. With the exception of cylindrical plug gages, at least two measurements shall be made approximately 90° apart and these measurements averaged. For hose that has a visual inside diameter variation at the end of the hose, for example, the flared or necked down end on wire braid reinforced hose, measurements shall be made at least 25 mm (1 in.) distance back from the end of the hose.

6.4 *Wall Thickness*—Determine the wall thickness at least 12 mm from the end of the hose to avoid flare. Use a micrometer with a rounded anvil in contact with the inside of the hose. Contact surface of the anvil should be about 8 mm long. Support for the anvil should be smaller in diameter than the anvil to avoid inward flare. Care is needed to be sure that the anvil and the foot are square to the surface of the hose. Sufficient force shall be applied to obtain firm contact with, but not indent, hose surface.

6.4.1 The minimum wall thickness shall be the minimum measurement obtained from a series of measurements taken around the circumference of the hose but concentrated in the area visually suspected of being thin.

6.4.2 The maximum wall thickness shall be the maximum measurement obtained from a series of measurements taken around the circumference of the hose but concentrated in the area visually suspected of being thick.

6.4.3 The average wall thickness shall be the average of at

least four measurements taken equidistant around the circumference of the hose.

6.5 Wall Concentricity—The difference between the minimum and maximum wall thickness determined in 6.4.1 and 6.4.2.

7. Thickness of Tube, Cover or Other Rubber Elements

7.1 Determine the thickness of a rubber element from any type of hose in accordance with Method A of Practice D 3767.

7.2 Take the thickness of a rubber element adjoining a braid- or helical-wound reinforcing member of any material as the average between two measurements of thickness, one of which shall be obtained using the unbuffed specimen and the other using a specimen that is buffed just sufficiently to remove the braid or helical corrugations.

7.3 Take the thickness of a rubber element adjoining a seamless woven jacket of any material on a specimen that is buffed just sufficiently to remove the corrugations caused by the woven jacket. Where backing is used on a rubber element, remove the backing before measuring thickness.

7.4 Determine the thickness of a rubber element adjoining flexible metal convoluted lining at the valleys formed by the tops of the metal convolutions. Prepare the opposite side of the rubber element, adjacent to other reinforcing members, for thickness measurement as specified in the other paragraphs of this section, depending on the type of reinforcing member.

7.5 Determine the thickness of a rubber element adjoining reinforcing fabric woven prior to assembly in the hose on a specimen that is unbuffed.

8. Test Conditions

8.1 The temperature of the testing room shall be between 21 and 32°C (70 and 90°F). The samples to be tested shall be kept in this room for at least 30 min previous to the time of testing. In case of arbitration a test atmosphere of 50 ± 5 percent relative humidity at a temperature of $23 \pm 2^\circ\text{C}$ ($73.4 \pm 3.6^\circ\text{F}$) shall be used.

NOTE 2—These special test conditions shall be confined to tension and immersion testing only.

9. Number of Tests

9.1 When test value limits are established, test one specimen for each physical characteristic required in the detailed specifications for a particular hose, except in the immersion tests given in Sections 19-23 inclusive. If the results do not meet the specified requirements, prepare two additional specimens from the original sample and test. Should the results of either of these tests be below the specified requirements, consider the sample to have failed to meet the specifications.

9.2 If test value limits are not established, test at least three specimens and take the median.

10. Separation of Rubber Parts

10.1 Cut a sufficient length from the hose sample to provide longitudinal tension test specimens from hose 76 mm (3 in.) and under in nominal diameter and transverse test specimens on larger sizes. Separate the rubber parts to be tested from the balance of the hose. Perform the separation without the use of a solvent, if practicable, and without excessive stretching of the

rubber. Make the separation a little at a time while the rubber is gripped near the point of separation. If it is necessary to use a solvent in the separating operation use commercial *isooctane*. If *isooctane* is used, place the rubber so as to permit free evaporation of the solvent from all parts of its surface, and allow it to rest at least 1 h before being tested.

TENSILE STRENGTH AND ELONGATION OF RUBBER

11. Procedure

11.1 Test in accordance with Test Method D 412. When specimen thickness is less than 1.5 mm (0.06 in.) after preparation a greater variation in test values can be anticipated. At times acceptable test specimens cannot be obtained or true values do not result from dumbbells prepared from the hose. In such cases substitution of sheet material in accordance with the section on Pieces of Practice D 3183 is recommended.

ADHESION TESTS

12. Test Specimens

12.1 From woven-jacketed rubber-lined hose, cut adhesion test specimens all transversely from the samples in rings 50 mm (2 in.) in width. Then open these rings and lay them out flat so as to give rectangular specimens of length equal to the full circumference of the hose. Accurately cut on each specimen a central strip of lining 38 mm (1.5 in.) in width, the cut extending through the lining but not entirely through the woven jacket. Separate these strips from the jacket at one end for a distance of about 38 mm.

12.2 From other types of hose, cut the adhesion test specimens transversely from the samples in rings 25 mm (1 in.) in width using a sharp tool that will leave clean edges. On hose 6.5 to 100 mm (0.25 to 4 in.), inclusive, in inside diameter test the specimens in ring form and refer to them as “ring specimens.” For hose over 100 mm in inside diameter cut the rings through at the point where the outside ply of fabric ends, and open them to form strips that shall be referred to as “strip specimens.”

12.3 Cut adhesion specimens from hose less than 6.5 mm in inside diameter longitudinally from the hose (Note 3). Since the width of these specimens will be less than 25 mm (1 in.), determine the adhesion on the contact width of the test specimen.

NOTE 3—Adhesion tests on hose smaller than 6.5 mm (0.25 in.) are not recommended, due to the size of the specimen available.

12.4 In hose constructions having braided wire reinforcing members, it is impractical to prepare adhesion test specimens.

12.5 On hose 19 mm (0.75 in.) to 100 mm (4 in.), inclusive, in inside diameter, having a woven wire filler reinforcement, prepare specimens for the adhesion test as follows: Cut the hose to form a longitudinal specimen 150 mm (6 in.) long and 50 mm (2 in.) wide. Flatten the specimen thus prepared and draw two parallel lines 25 mm (1 in.) apart along the tube and cover and cut through to the woven carcass. Separate from the jacket for a short distance the ends of the central portion between these two cuts. Determine adhesion in accordance with 13.2 for strip specimens.

13. Procedure

13.1 *Ring Specimens*—Test in accordance with the Static-Mass Method or Machine Method of Test Method D 413.

13.2 *Strip Specimens*—Test in accordance with the Static-Mass Method or Machine Method of Test Method D 413.

13.3 For hose with woven wire reinforcement having an inside diameter under 19 mm (0.75 in.), the hose may be tested for value of tube adhesion by use of the ball-vacuum method as follows: Lay sections of hose in a straight line on an inclined table. Pass a steel ball, 3.18 mm (0.125 in.) less in diameter than the nominal inside diameter of the hose, through the hose while the internal pressure is 60 ± 10 kPa (18 ± 3 in. Hg) below the external pressure.

13.4 Report:

13.4.1 The report shall include the following:

13.4.1.1 Value of the adhesions obtained by the Static-Mass Method in accordance with 13.1 and 13.2 as average millimetres per second (or inches per minute) of separation under a stated mass required to separate specimens at an average rate of 0.42 mm/s (or 1 in./min),

13.4.1.2 Value of the adhesions obtained by the Machine Method (see the Calculation section of Test Method D 413) in accordance with 13.1 and 13.2, and

13.4.1.3 Value of adhesion obtained in accordance with 13.3, as ball passing or not passing.

13.5 *Precision and Bias*—The precision and bias of the Static-Mass and Machine Methods are given in Test Method D 413. No statement is made about either the precision or bias of the ball method for measuring adhesion of hose lining since the results merely indicate whether there is conformance to the criteria specified in the procedure.

PRESSURE TESTS

14. Types of Tests

14.1 Hydrostatic tests of hose consist of subjecting the specimen to the action of internal water pressure under specified conditions to determine either the bursting strength of the hose or the effect of lower hydrostatic pressures in producing changes similar to those occurring in service. In the latter case, the test may be used as an inspection proof test with a minimum safe limit. Bursting strength is determined on short specimens cut from the full hose lengths, but in tests for service effects and for proof inspection, the full lengths are used as specimens. The specimens may be tested, as required, in straight, curved, or kinked positions, depending upon the stresses which are desired to be evaluated.

14.2 Aerostatic pressure tests of hose consist of subjecting the specimen to the action of internal air or nitrogen gas pressure under specified conditions to determine the integrity and leak resistance of the hose or hose assembly. Normally the hose or hose assembly is submerged under water and a constant stream of bubbles is an indication of leakage.

15. Application of Pressure

15.1 Apply hydrostatic pressure by means of a hand- or power-driven hydraulic pump or an accumulator system. Connect the hose to the waterline or pump and fill with water prior to application of pressure, allowing all air in the hose to escape

through a petcock provided for the purpose. This is important as a safety measure because expansion of air compressed in the hose, when suddenly released by bursting or other failure, might result in serious accident. Then close the petcock and apply the pressure at a uniform rate of increase of approximately 7 MPa (1000 psi)/min except for hose with bursting strength specified above 14 MPa (2000 psi), in which case the pressure shall be applied at a rate of 70 MPa (10 000 psi)/min or as rapidly as pump capacity will permit. Measure the pressure with a calibrated gage.

NOTE 4—The specified rate of 7 MPa (1000 psi)/min requires too much time for small-diameter high-strength hose, such as hydraulic brake hose, wire-reinforced grease gun hose, etc. With 3.2-mm (0.125-in.) hydraulic brake hose, pressure increases at rates as high as 280 MPa (40 000 psi)/min are satisfactory.

15.2 Apply aerostatic pressure by connecting the hose or hose assembly to a source of air or nitrogen gas pressure. Submerge the hose and couplings entirely in water such that visual observations of the hose assembly is permitted. Apply the specified internal pressure, measured with a calibrated gage, and maintain for the specified period of time. Any evidence of leakage from the hose or couplings shall be reported. Initial appearance of bubbles may be an indication of air entrapped in the hose wall. Agitate the hose after 2 min to break the air bubbles from the hose surface. Following this a steady stream of bubbles from any location shall be considered failure to meet the test.

16. Bursting Tests

16.1 *Straight Bursting Test*—The specimen for the hydrostatic test for bursting strength shall be at least 450 mm (18 in.) in length for hose 76 mm (3 in.) and smaller in inside diameter, and at least 600 mm (24 in.) in length for larger hose. Shorter or longer lengths may be burst tested when circumstances dictate, for example, when a burst on a manufactured part is specified. The pressure shall be raised as specified in Section 15, until failure, and the pressure at which failure occurs shall be considered the bursting strength of the hose.

16.2 *Curved Bursting Test*—The curved bursting strength test for woven rubber-lined fire hose shall be made in accordance with 16.1, except that the hose shall be firmly secured at both ends to a suitable test frame which is curved to a radius of 690 mm (27 in.).

16.3 Precision and Bias:

16.3.1 This precision and bias section has been prepared in accordance with Practice D 4483. Refer to Practice D 4483 for terminology and other statistical calculation details.

16.3.2 The precision results in this precision and bias section give an estimate of the precision of this test method with the rubber materials used in the particular inter-laboratory program is described below. The precision parameters should not be used for acceptance/rejection testing of any group of materials without documentation that they are applicable to those particular materials and the specific testing protocols that include this test method.

16.3.2.1 A Type 1 (inter-laboratory) precision was evaluated in 1989. Both repeatability and reproducibility are short-term; a period of a few days separate replica to test results. A test result is the average value as specified by this method, obtained

on two determinations or measurements of the property or parameter in question.

(1) Seven different types of hose were used in the inter-laboratory program. These were tested in varying numbers of laboratories as given in Table 1 on two different days.

(2) The results of the precision calculations for repeatability and reproducibility are given in Table 1 in ascending order of average hose burst pressure expressed in MPa.

(3) The precision of this test method may be expressed in the format of the following statements which use an appropriate value of r ; R (r) or (R), to be used in decisions of test results. The appropriate value is that value of r or R associated with a mean value in the precision table closest to the main level under consideration at any given time, for any given hose in routine testing operations.

(4) *Repeatability*—The repeatability, r , of this test method has been established as the appropriate value tabulated in the precision table. Two single test results, obtained under normal test method procedures, that differ by more than this tabulated r (for any given level) must be considered as derived from different or non-identical sample populations.

(5) *Reproducibility*—The reproducibility, R , of this test method has been established as the appropriate value tabulated in the precision table. Two single test results obtained in two different laboratories, under normal test method procedures, that differ by more than the tabulated R (for any given level) must be considered to have come from different or non-identical sample populations.

(6) Repeatability and reproducibility expressed as a per-

centage of the mean level, (r) and (R), have equivalent application statements as above for r and R . For the (r) and (R) statements, the difference in the two single results is expressed as a percentage of the rhythmic mean of the two test results.

16.3.3 *Bias*—In test method terminology, bias is the difference between an average test value and the reference (or true) test property value. Reference values do not exist for this test method since the value (of the test property) is exclusively defined by the test method. Bias, therefore, cannot be determined.

17. Hydrostatic Pressure Tests

17.1 When tests for elongation, contraction, twist, warp, rise, and outside diametrical expansion are required, the hose shall be stretched out straight for inspection, and a pressure of 70 kPa (10 psi) applied. All original observations and measurements shall be taken at this pressure. Measurements shall be made using a graduated tape. The designated test pressure shall be applied at the rate specified in Section 15, without releasing the original pressure of 70 kPa (10 psi), and final measurements taken. The test pressure shall be applied for a minimum of 15 s prior to taking final measurements.

NOTE 5—The application of a pressure of 70 kPa (10 psi) prior to initial measurements is to assure that the hose is round, straight, and at manufactured length at the time of measurement. On very low pressure hose, such as ducting, this initial pressure might have a major effect on the attributes being measured. In such cases a lower initial pressure will provide a more valid evaluation of these attributes.

17.1.1 *Elongation and Contraction*—Measurements for the determination of elongation and contraction shall be based: (1) for hose, on distance between bench marks placed on hose; (2) for assemblies, on “free length,” which is the distance between end connections on the hose. The results shall be reported as elongation if the final length is greater than the original length and as contraction if the final length is less than the original length. All results shall be reported to the nearest 1 %.

17.1.2 *Twist*—The amount of twist may be determined by noting, during the period the pressure is applied, the turns of the fitting at the free end of the hose. A crayon or pencil mark on the top surface of the hose adjacent to the closed coupling should be made so as to aid in determining the twist. Twist sometimes occurs quite rapidly. The amount of twist shall be reported to the nearest 45°. The direction of twist shall be reported as “right” or “left,” a “right” twist being one in the direction that would tend to tighten the couplings.

17.1.3 *Warp*—Warping in hose tests is the deviation from a straight line drawn from fitting to fitting in a plane parallel to the surface on which the hose rests. The amount of warping is the maximum deviation of any portion of the hose from a straight line drawn from center to center of the fittings. The warp is measured as the distance from this line to the center line of the hose at the point of maximum deviation. A tightly stretched cord may be used to establish the straight line from center to center of the fittings. Results shall be reported to the nearest 5 mm or 0.25 in.

17.1.4 *Rise*—The amount the hose rises from the surface of the test table shall be considered as “rise” and recorded as such. Results shall be reported to the nearest 5 mm or 0.25 in.

17.1.5 *Outside Diameter Expansion*—Change in

TABLE 1 Precision for Hose Burst Strength^A

Type Hose	No. of Labora- tories ^B	Average Burst Pressure, MPa	Within Laboratories			Between Laboratories		
			<i>Sr</i>	<i>r</i>	(<i>r</i>)	<i>SR</i>	<i>R</i>	(<i>R</i>)
500	13	2.82	0.121	0.34	12.2	0.229	0.65	23.2
800	14	5.51	0.346	0.98	17.8	0.455	1.29	23.4
1600	13	15.2	0.558	1.58	10.4	1.21	3.42	22.5
2500	10	15.9	0.294	0.83	5.21	0.821	2.32	14.6
8000	9	75.7	1.53	4.32	5.71	2.67	7.58	10.05
14 000	11	134.4	3.51	9.92	7.38	4.08	11.54	8.59
20 000	10	179.8	5.74	16.2	9.01	12.1	34.2	19.01

Hose Pressure	No. of Labora- tories	Average Burst Pressure, psi	Within Laboratory			Between Laboratories		
			<i>Sr</i>	<i>r</i>	(<i>r</i>)	<i>SR</i>	<i>R</i>	(<i>R</i>)
500	13	410	17.6	50	12.2	33	94	23.0
800	14	800	50	142	17.8	66	187	23.4
1600	13	2210	81	229	10.4	175	496	22.4
2500	10	2310	42	120	5.2	119	337	14.6
8000	9	10 980	222	627	5.7	388	1099	10.0
14 000	11	19 510	508	1440	7.4	592	1675	8.6
20 000	10	26 100	832	2356	9.0	1755	4967	19.0

^A Symbols are defined as follows:

- Sr* = Within laboratory standard deviation.
- r* = Repeatability (in measurement units).
- (*r*) = Repeatability (in percent).
- SR* = Between laboratory standard deviations.
- R* = Reproducibility (in measurement units).
- (*R*) = Reproducibility (in percent).

^BNumber of laboratories participating in testing this type of hose.

Circumference—While the hose is under the specified original pressure, make three crayon or pencil marks equally spaced along its length. Measure the circumference at each of these marks, using a suitable tape, and record the average of these values. After the specified test pressure has been applied for the required time, again make circumference measurements at the same three places on the hose and record the average for these three readings. Calculate the expansion, and report results to the nearest 1 %.

17.2 When tests for elongation and contraction are required on wire-braided reinforced hose, such hose shall be tested by applying a pressure equivalent to the maximum pressure to which the hose is to be used for 30 s, at which time the length shall be measured. A second reading between 20 and 30 s after the pressure has been released to zero shall then be designated as the original length and the change in length (contraction or elongation) calculated as a percentage of the original length.

17.3 Proof Pressure Tests (except for woven-jacketed fire hose)—When proof pressure tests to determine leakage of hose or couplings are required, the proof pressure shall be applied in accordance with Section 15, and held 1 min. The proof pressure shall not exceed 50 % of the specified minimum bursting strength.

17.4 Kink Tests—When kink tests are required, each length of hose selected shall be filled with water with the petcock open to allow all air to escape. The petcock shall then be closed and the hose shall be kinked 450 mm (18 in.) from the coupling by tying the coupling back against the hose so that there will be a sharp kink. The pressure shall then be raised as specified in Section 15, to the required pressure and immediately released.

17.5 Hold Test—When a hold test is specified instead of a bursting test, pressure shall be applied as specified in Section 15 until the required pressure is reached. The specimen shall withstand the specified pressure for a 10-min period without bursting, leaking, or developing other defects. Specimens that have been subjected to this test shall not be considered fit for service.

17.6 Precision and Bias—No statement is made about either the precision or bias of the proof pressure, kink, and hold tests since the results merely indicate whether there is conformance to the criteria specified in the procedure. Data are being collected to determine the precision and bias of the other hydrostatic pressure tests.

18. Volumetric Expansion Test

18.1 Apparatus—The test apparatus used shall consist essentially of the following: A suitable source for the required fluid pressures, pressure gages, piping, valves, fittings in which the hose assembly may be mounted in a vertical position for application of pressure under controlled conditions, and a graduated buret for measuring the volume of liquid corresponding to the expansion of the hose under pressure. All piping and connections shall be smooth bore without recesses or offsets, so that all air may be freely removed from the system before running each test. The valves shall be of such design as to open and close with minimum displacement of

liquid.⁵ The apparatus shall be capable of applying the pressure at a rate of increase of $3 \pm \text{mPa/s}$ [$25\,000 \pm 10\,000 \text{ lbf}/(\text{in}^2 \cdot \text{min})$]. A suitable apparatus is shown in Fig. 1.

18.2 Calibration of Apparatus—The apparatus shall be tested prior to use to determine its calibration correction factor. For this purpose, 6.3-mm (0.25-in.)-diameter Bundy steel tubing or its equivalent shall be used in place of the hose assembly. Calibration correction factors shall be established at specified expansion pressure, and these shall be subtracted from the expansion readings obtained on the test specimens. The maximum permissible calibration correction factor shall be 0.08 cm^3 at 10 MPa (1500 psi).

18.3 Procedure—Carefully thread the test specimen into position on the apparatus in such a way as to provide a leak-proof seal, taking care to avoid twisting and to maintain the hose in a vertical position without tension while under pressure. Fill the tank, *C*, Fig. 1, with alcohol or distilled water, taking care that it is free of air or dissolved gases. Then open valve *B* and turn crank *D* to the left to allow the maximum amount of liquid to flow into the master cylinder. Next open valves *E*, *F*, and *G*, allowing the liquid to run from tank *C* through buret *K* until no air bubbles are seen in the buret. Removal of air bubbles may be facilitated by moving the hose back and forth. Then close valves *B* and *F* and raise the pressure in the hose to proof pressure for not more than 10 s. After inspection for leaks at the connections, completely release the pressure in the hose by opening valve *F*, which shall then be closed before proceeding with the next step. Now adjust the liquid level in buret *K* to zero by means of valve *G*. Turn crank *D* to the right until gage *A* shows the desired expansion pressure. Seal this pressure in the hose by closing valve *E*, after which take the expansion immediately by opening valve *F* and allowing the liquid in the expanded hose to rise in the buret. As soon as the liquid level has become constant, close valve *F* and take the reading on buret *K*. This operation shall be repeated so that the final reading taken on buret *K* will be the total of three expansions. This reading, divided by three minus the calibration factor, shall be considered as the final volumetric expansion of the hose. If the pressure in the hose should inadvertently be raised just prior to the expansion reading to a value above that specified, no reading shall be taken, but instead, the pressure shall be completely released and the procedure repeated.

18.4 Precision and Bias—Data are being collected to determine the precision and bias of the volumetric expansion test.

IMMERSION TESTS FOR CHANGE IN VOLUME AND DETERIORATION OF HOSE USED FOR PETROLEUM PRODUCTS

19. Types of Tests

19.1 Immersion tests for evaluating the change in volume and deteriorating effects of petroleum products on rubber hose consist of subjecting suitable test specimens from the rubber portion having known physical properties to the action of

⁵ Crane Glove Valve No. 222X, or equivalent, has been found satisfactory for this purpose.

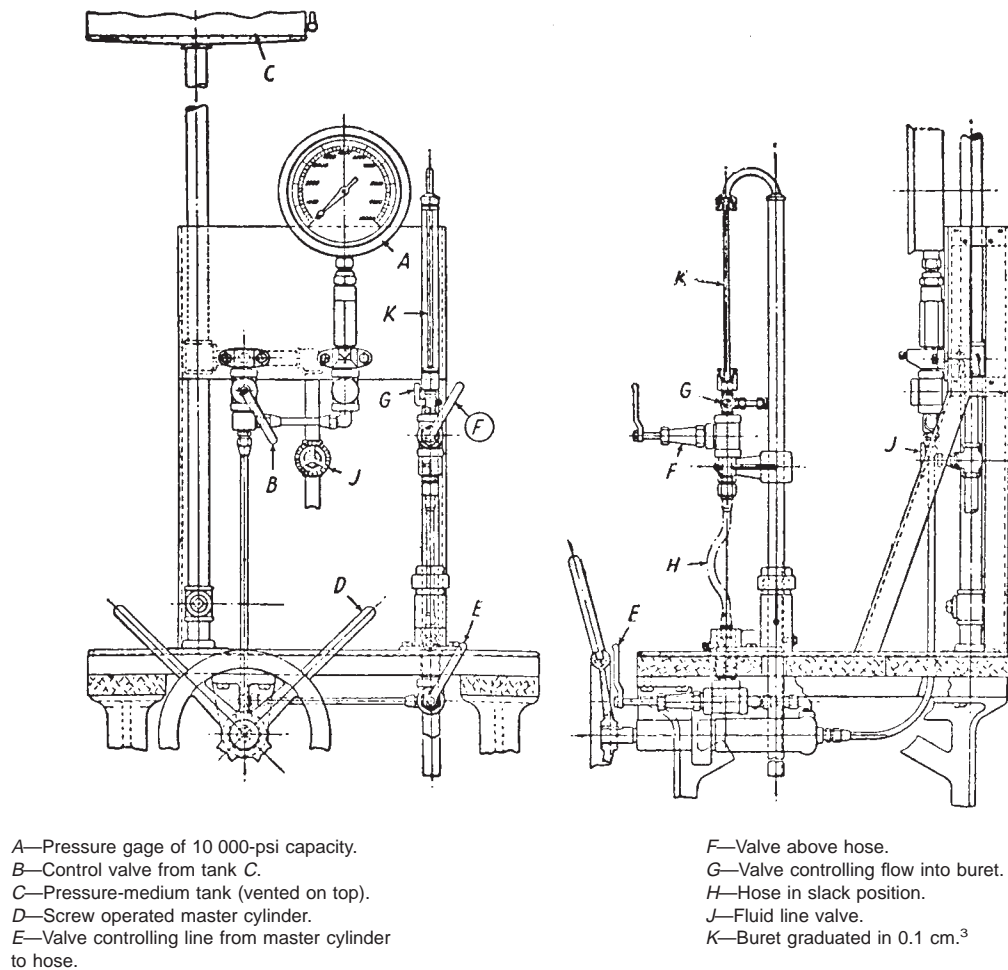


FIG. 1 Apparatus for Expansion Test

selected test liquids by immersing the specimens completely in the liquid under controlled conditions for definite periods, after which the physical properties are again determined and the changes noted. Two types of test are covered, as follows:

19.1.1 *Change in Volume Test*—This type of test involves measurement of the change in volume of the rubber caused by the action of the liquid.

19.1.2 *Strength Deterioration Test*—This test measures changes in strength.

19.2 In any of the immersion tests, the choice of test method and test liquid depends upon the nature of the actual service and the petroleum product which is being used.

20. Test Liquids

20.1 Consider the reference fuels and oils described in the Standard Test Liquids section of Test Method D 471 as standard immersion test media for hose, and make the choice appropriate for the test from them unless other liquids are specifically required. In any case, report the liquid actually used with the test results.

21. Test Conditions

21.1 *Temperature*— Unless otherwise specified in the applicable specifications, the test temperatures shall be selected from the following, depending upon the anticipated service temperature:

Celsius Temperature	Fahrenheit Temperature
21 to 32	70 to 90
70 ± 2	158 ± 3.6
100 ± 2	12 ± 3.6
125 ± 2	257 ± 3.6
150 ± 2	302 ± 3.6

Generally when the test liquid is a fuel, for example, the temperature during the immersion period shall be 21 to 32°C (70 to 90°F). When the test liquid is an oil, any one of the three elevated temperatures may be used.

21.2 *Immersion Periods*—Immersion periods of 22 ± 0.25 h and 70 ± 0.7 h are recommended. Immersion tests shall be made in the absence of direct light.

22. Change in Volume Test

22.1 *Test Specimens*— The test specimens shall be rectangular rubber blocks, 50 by 25 mm (2 by 1 in.), having a thickness not over 1.6 mm (0.063 in.). They shall be cut from the hose and buffed on both faces only to the extent necessary to ensure smoothly buffed faces, except when the material is too thick, in which case the buffing shall be sufficient to reduce the specimens to 1.6 mm (0.063 in.). Three specimens shall be used for each test and the results averaged.

22.2 *Procedure*—Test in accordance with the Procedure for Change in Volume section of Test Method D 471.

22.3 *Calculation*— Calculate the percentage change in volume in accordance with the Calculation section of Test Method D 471.

23. Strength Deterioration Test

23.1 *Test Specimens*— Six dumbbell-shaped test specimens, prepared as described in Test Methods D 412, except minimum specimen thickness of 0.80 mm (0.031 in.), shall be required. Both faces of dumbbell shall be buffed.

23.2 *Procedure*—Test three specimens for tensile strength and elongation in accordance with Test Methods D 412, except average the results to give the properties of the rubber before immersion. Follow the Properties After Evaporation of Test Liquid section of Test Method D 471 for immersion procedure on the remaining three dumbbells. Express the deterioration shown by the difference between the determinations before and after immersion as a percentage of the original property.

23.3 *Precision and Bias*—The precision and bias of the test for deterioration on fluid immersion are given in Test Method D 471.

LOW-TEMPERATURE TESTS

24. Types of Tests

24.1 Low-temperature tests are made on complete sections of hose as described in Section 25, or on the tube and cover, as described in Section 26.

25. Low-Temperature Test on Complete Hose

25.1 *Conditioning*— Condition the hose while laid out straight in a cold chamber at the specified temperature for a period of 72 h. The cold chamber shall be capable of maintaining within it a uniform atmosphere of cold, dry air or a mixture of air and carbon dioxide at specified temperature (Note 6) within a tolerance of $\pm 2^{\circ}\text{C}$ ($\pm 3.6^{\circ}\text{F}$).

NOTE 6—Temperatures of -40 and -55°C (-40 and -67°F) are commonly used.

25.2 *Procedure*—After conditioning and without removal from the cold chamber, bend the nose around a mandrel having a diameter ten times the outside diameter of the hose; it shall not break or crack. Bending shall be completed within 5 s. The mandrel size shall be by 25-mm (1-in.) increments. Where ten times the hose outside diameter is not an even 25 mm (1 in.), the next larger mandrel shall be used. This test shall be applicable to hose having a maximum nominal inside diameter of 76 mm (3 in.).

25.3 To aid in determining whether or not the hose has failed the bend test, the hose, after the test, may be placed under a hydrostatic pressure equivalent to the hose proof pressure.

26. Low-Temperature Test on Tube and Cover

26.1 Apparatus:

26.1.1 *Cold Chamber*— The cold chamber in which the test specimens are exposed to the low temperature shall be of sufficient size to contain the flexing fixture when loaded with specimens, and so arranged as to permit the operation of the fixture to bend specimens without removal from the chamber. It shall be capable of maintaining within it a uniform atmosphere of cold, dry air or a mixture of air and carbon dioxide at specified temperatures (Note 7) within a tolerance of $\pm 2^{\circ}\text{C}$ ($\pm 3.6^{\circ}\text{F}$).

26.1.2 *Flexing Fixture*— The flexing fixture shall consist of two parallel plates each having a width of at least 50 mm (2 in.), so supported in guides that they may be rapidly moved from a position 63.5 mm (2.5 in.) apart until they are separated by a distance of 25 mm (1 in.). Suitable clamping bars or devices shall be provided for holding the ends of the specimens for a distance of 6.3 mm (0.25 in.) at the corresponding edge of each plate so that, when mounted, the specimens form similar bent loops between the plates. A satisfactory flexing fixture is shown in Fig. 2.

26.2 *Test Specimens*— Specimens of hose tube and cover shall be taken from hose in accordance with Section 10. They

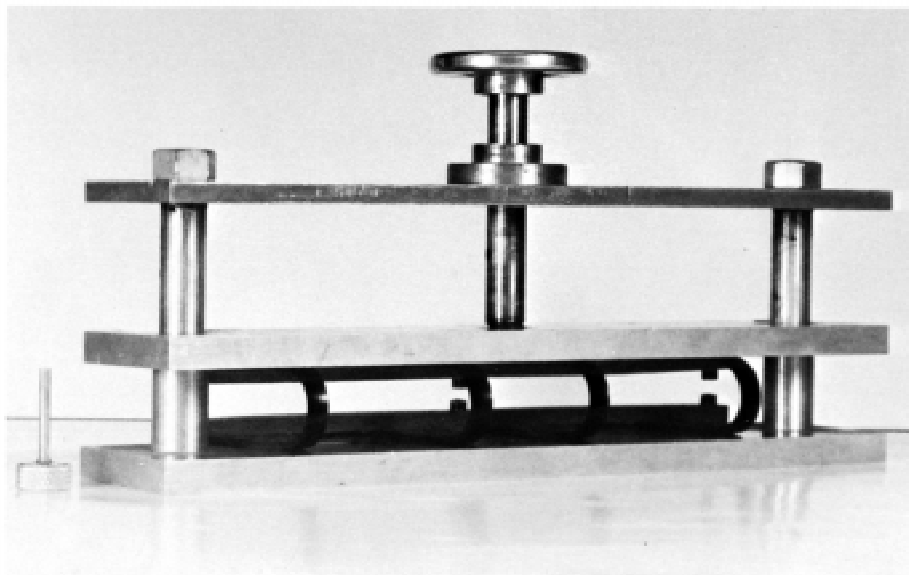


FIG. 2 Flexing Fixture for Low-Temperature Brittleness Test

shall be buffed to a maximum thickness of 2.3 mm (0.09 in.), then cut to shape, using die C as specified in Test Method D 412. At least two specimens from each tube and cover shall be tested.

26.3 Procedure—Mount the test specimens in loop position between the plates of the flexing fixture, with the enlarged ends spaced at least 3.2 mm (0.125 in.) apart and held in the clamps for a distance of 6.3 mm (0.25 in.). With the plates in the open position separated 63.5 mm (2.5 in.), place the fixture containing the specimens in the cold chamber and expose for the specified period to cold, dry air or a mixture of air and carbon dioxide at the specified temperature. The standard exposure period shall be 5 h (Note 7). At the termination of the exposure period and while still in the cold chamber, move the plates of the flexing fixture as rapidly as possible from the 63.5-mm (2.5-in.) distance of separation to a position where they are 25 mm (1 in.) apart. Then examine the specimens for fracture or visible cracks.

NOTE 7—Formerly two periods were specified, 96 h for natural rubber compounds and 5 h for synthetic rubber compounds. It was found that 5 h is adequate for either class of compounds within the intent of this test method.

26.4 Results—When two specimens are tested and neither one fractures nor shows cracks after being tested, the compound shall be considered as having passed the brittleness test. If both specimens crack, the compound shall be considered to have failed. If only one specimen fractures or cracks, the result is inconclusive and two additional specimens shall be tested. If either one of these cracks, the compound shall then be considered to have failed.

26.5 Report—The report shall include the following:

- 26.5.1 Results of the test, expressed as “passed” or “failed,”
- 26.5.2 Temperature of the cold chamber,
- 26.5.3 Duration of the exposure period,
- 26.5.4 Identification of the material tested, including description of any special treatment prior to test, and
- 26.5.5 Date of manufacture of the material, if known, and date of test.

AGING TESTS OF RUBBER

27. Types of Tests

27.1 Air-Heat Test—Determine the change in tensile strength and elongation of rubber parts of hose due to aging at atmospheric pressure and elevated temperature as described in Test Method D 573 or Test Method D 865, as specified in the detail specification. Unless otherwise specified in the detail specification, age the specimen at a temperature of $70 \pm 2^\circ\text{C}$ ($158 \pm 3.6^\circ\text{F}$) or $100 \pm 2^\circ\text{C}$ ($212 \pm 3.6^\circ\text{F}$) for 166 ± 1 h.

27.2 Ozone Test—Determine if surface cracks appear after exposure to ozone.

27.2.1 Apparatus:

27.2.1.1 Ozone Test Chamber, in accordance with Test Method D 1149.

27.2.1.2 Jig or Holder, that permits elongation of specimen.

27.2.1.3 Mandrels.

27.2.1.4 Tie Wire.

27.2.1.5 Plugs or Caps.

27.2.1.6 Any apparatus placed in the test chamber shall be

non-ozone absorbant material.

27.2.2 Procedure:

27.2.2.1 Specimen Preparation—For hose 25 mm (1 in.) in inside diameter or smaller, bend a specimen of hose of full circumference around the mandrel and tie ends together where they cross one another. The mandrel shall have a diameter eight times the nominal outside diameter of the hose. The specimen length shall be about 250 mm (10 in.) longer than the mandrel circumference. Seal the ends of the hose with plugs or caps in such a manner that the reinforcement and inner liner will not be exposed to ozone. This will allow for more uniform control of ozone concentration in the test chamber, since ozone will not be consumed by material not under test. For hose over 25 mm in inside diameter, transversely remove a 25-mm width of the hose cover. Lightly buff the under side of the specimen to remove any reinforcement impressions. Place the specimen in a jig or holder and elongate 12.5 %.

27.2.2.2 Conditioning—The specimen under relevant stress shall be conditioned 48 to 72 h in a substantially ozone-free atmosphere maintained at the standard laboratory temperature.

27.2.2.3 Exposure—Unless otherwise specified, the specimen shall be exposed to 50 ± 5 mPa partial pressure of ozone in the test chamber at $40 \pm 2^\circ\text{C}$ ($104 \pm 3.6^\circ\text{F}$) for 70 to 72 h.

27.2.2.4 Examination—After exposure and prior to removal of specimen from mandrel or holder, examine for surface cracks under $2\times$ magnification. For hose on mandrel, ignore the area adjacent to the tie point. For specimen in holder, examine the unbuffed side and ignore areas adjacent to clamp points.

27.2.3 Report—The report shall include the following:

27.2.3.1 Ozone concentration,

27.2.3.2 Exposure time,

27.2.3.3 Ambient test chamber temperature, and

27.2.3.4 Specimen surface condition (cracks or no cracks).

27.3 Precision and Bias—The precision and bias of the air heat test are given in Test Method D 573 and Test Method D 865. No statement is made about either the precision or bias of the ozone test since the results merely indicate whether there is conformance to the criteria specified in the procedure.

TENSION TEST

28. Summary of Test Method

28.1 This tension test consists of subjecting the hose assembly to increasing tension load in a suitable testing machine until failure occurs, either by separation of the specimen from the end fittings or by failure of the hose structure.

28.2 Apparatus:

28.2.1 Tension Testing Machine, conforming to the requirements of Practice E 4, and provided with an indicating device to give the total pull in newtons (pounds) at the conclusion of the test.

28.2.2 Hose Assembly, attached to the test machine by suitable fixtures so that the hose and fittings shall have a straight center line corresponding to the direction of the machine pull.

28.3 Procedure—Apply a steady tension load at a speed such that the moving head of the testing machine travels at the rate of 25 ± 3 mm (1.0 ± 0.1 in.)/min until failure. Record the

total load at the time of failure and note the type of failure.

28.4 *Precision and Bias*—Data are being collected to determine the precision and bias of the tension test.

29. Inspection

29.1 Make all tests and inspection at the place of manufacture prior to shipment, unless otherwise specified. The manufacturer shall afford the purchaser, inspector, or representative of the purchaser reasonable facilities to test and inspect the hose without charge.

29.2 The purchaser may make the tests and inspection to govern the acceptance or rejection of the material in his own laboratory or elsewhere. Make such tests and inspection at the

expense of the purchaser not later than 60 days after receipt of the material.

30. Retests and Rejection

30.1 Any material that fails in one or more tests may be resampled and retested at the expense of the manufacturer. For this purpose select two additional samples from the hose. Failure of either of the retested samples shall be cause for final rejection.

30.2 Rejected material shall be disposed of as directed by the manufacturer and at his expense.

31. Keywords

31.1 rubber hose

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