



Designation: D1414 – 22

Standard Test Methods for Rubber O-Rings¹

This standard is issued under the fixed designation D1414; 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 These test methods describe the procedures for determining the physical properties of O-rings and changes in these properties due to aging.

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

1.4 *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.*

2. Referenced Documents

2.1 ASTM Standards:²

D297 Test Methods for Rubber Products—Chemical Analysis

D395 Test Methods for Rubber Property—Compression Set

D412 Test Methods for Vulcanized Rubber and Thermoplastic Elastomers—Tension

D471 Test Method for Rubber Property—Effect of Liquids

D573 Test Method for Rubber—Deterioration in an Air Oven

D865 Test Method for Rubber—Deterioration by Heating in Air (Test Tube Enclosure)

D1329 Test Method for Evaluating Rubber Property—

Retraction at Lower Temperatures (TR Test)

D1415 Test Method for Rubber Property—International Hardness

D2240 Test Method for Rubber Property—Durometer Hardness

D3767 Practice for Rubber—Measurement of Dimensions

D4483 Practice for Evaluating Precision for Test Method Standards in the Rubber and Carbon Black Manufacturing Industries

2.2 Aerospace Standard:

AS568A O-ring Sizes³

3. Terminology

3.1 Definitions:

3.1.1 *O-ring*—a rubber seal of homogeneous composition molded in one piece to the configuration of a torus with circular cross section. The O-ring is used as a dynamic or static seal usually installed in a machined groove.

4. Significance and Use

4.1 These test methods provide acceptable procedures for quality control purposes and for the determination of engineering characteristics.

5. General Methods

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

5.1.1 *Tension Test*—Test Methods **D412**.

5.1.2 *Compression Set*—Test Methods **D395**.

5.1.3 *Low Temperature*—Test Method **D1329**.

5.1.4 *Density*—Test Methods **D297**.

5.1.5 *Fluid Aging*—Test Method **D471**.

5.1.6 *Heat Aging*—Test Methods **D865** and **D573**.

5.1.7 *Hardness*—Test Methods **D2240** and **D1415**.

5.2 In case of conflict between the provisions of these test methods and those of detailed procedures herein, the latter shall take precedence.

¹ These test methods are under the jurisdiction of ASTM Committee **D11** on Rubber and Rubber-like Materials and are the direct responsibility of Subcommittee **D11.37** on Coated Fabrics, Rubber Threads and Seals.

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² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

³ Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

6. Test Conditions

6.1 The temperature of the testing room shall be $23 \pm 2^{\circ}\text{C}$ ($73.4 \pm 3.6^{\circ}\text{F}$). The specimens to be tested shall be kept in this room for a minimum of 30 min previous to the time of testing. For referee tests the minimum time for conditioning shall be 16 h. In cases where this temperature cannot be obtained, the actual temperature shall be reported.

7. Dimensional Measurements

7.1 Thickness:

7.1.1 The thickness or cross section shall be measured by a micrometer in accordance with Practice D3767, Procedure A.

7.1.2 The O-ring specimen shall be measured at four points equally distributed around the circumference in both the radial and axial direction. An average reading shall be used for calculation.

7.2 *Diameter*—A stepped cone or optical comparator may be used for measuring the inside diameter of small rings. The diametric intervals of the stepped cone shall not exceed 2 % of the diameter to be measured (see Fig. 1).

8. Tension Testing

8.1 *Testing Machine*—The testing machine shall conform to the requirements specified in Section 3 of Test Methods D412, with the exception of the grips. Grips for testing rings shall consist of ball-bearing spools at least 9 mm (0.35 in.) in diameter, and be capable of being brought within 19 mm (0.75 in.) center-to-center distance at closest approach. Stresses within the specimen shall be minimized by (1) rotating one

spool one full revolution for each 150 mm (6.0 in.) of travel of the power-driven grips or (2) lubricating the contact surface of the spools with castor oil. Grips for testing straight specimens may be of any type provided breaks do not occur in a portion of the specimen that has been at any time in contact with the grips. For specimens smaller than 25 mm (1 in.) in inside diameter, spools of smaller diameter and closer approach may be employed.

8.2 Test Specimen:

8.2.1 The test specimen shall consist of an entire O-ring except in the following cases: (1) when the diameter is too large to permit a break within the limits of travel of the testing machine, (2) when the specimen has been previously cut open to permit an aging test, and (3) when the specimen is unaged but is to be compared with an aged specimen as described in (2). For these cases a specimen cut from a ring shall be employed.

8.2.2 Specimens that exhibit obvious flaws at any point on the surface, such as might result from imperfect molding or flash removal, shall not be tested.

8.3 Procedure for Determination of Tensile Strength, Ultimate Elongation, and Tensile Stress:

8.3.1 Bring the grips close enough together so the specimen can be installed without stretching. Set the machine for a speed of 500 ± 50 mm (20 ± 2 in.)/min, set the chart recorder, and engage the clutch. (If a recorder is not used, note the spool center-to-center distance continually by means of a suitable scale). The stressed inside circumference, L , is equal to twice the distance between spools plus the circumference of one spool. Record the breaking force value, F , at the elongation specified for tensile stress and at the time of rupture. Measure the center-to-center distance between the spools at rupture to the nearest 2.5 mm (0.1 in.) and record as the value for D .

8.3.2 For the application of bench marks to segmented specimens as described in 8.2, hold the piece as straight as possible being careful not to apply excessive stress. Follow the procedure described in 8.3.1. Discard results for any specimen that breaks at a point that has at any time contacted the grip, and test an additional specimen. A suitable extensometer may be employed for elongation determination.

8.4 Calculations:

8.4.1 *Tensile Strength*—Calculate the tensile strength as follows:

8.4.1.1 For O-rings on spool grips:

$$T = F/A \quad (1)$$

where:

T = tensile strength,

F = breaking force, and

A = twice the cross-sectional area calculated from axial thickness, W , as follows:

$$A = \pi W^2/2 = 1.57 W^2 \quad (2)$$

therefore:

$$T = F/1.57 W^2 \quad (3)$$

8.4.1.2 For straight or single-strand specimens

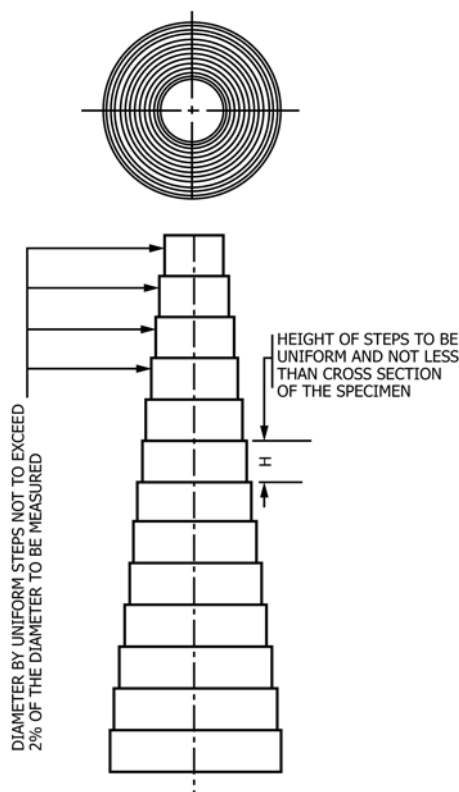


FIG. 1 Stepped Cone Gage

$$A = 0.785 W^2 \quad (4)$$

$$T = F/0.785 W^2 \quad (5)$$

8.4.2 *Ultimate Elongation*—Calculate the ultimate elongation as follows:

8.4.2.1 For rings:

$$\text{Ultimate elongation, \%} = [(2D + G - C)/C] \times 100 \quad (6)$$

where:

D = distance between centers of the spool grips at the time of rupture of specimen,

G = circumference of one spool (spool diameter $\times$ 3.14), and

C = inside circumference of the specimen (or inside diameter $\times$ 3.14).

8.4.2.2 For straight or single-strand specimen cut from an O-ring:

$$\text{Ultimate elongation, \%} = [(L - L_o)/L_o] \times 100 \quad (7)$$

where:

L = observed distance between bench marks of stressed specimen, and

L_o = original distance between bench marks.

8.4.3 *Tensile Stress*— Calculate the tensile stress as in the case of tensile strength except the stress is reported at a predetermined elongation below the ultimate elongation. Calculate the center-to-center distance of the spool grips, D , where the prescribed elongation, E , occurs, as follows:

$$D = 1/2[(EC/100) + C - G] \quad (8)$$

NOTE 1—This value of tensile stress at a predetermined elongation is based upon inside circumference and differs from that determined by Test Methods D412, which is based on the mean circumference.

8.5 *Characteristics of Sample Tested*—The median of the values for three specimens shall be taken as the characteristics of the sample tested, except that under the following conditions the median of the values for five specimens (two additional) shall be used:

8.5.1 If one or more values do not meet the specified requirements when testing for compliance with specifications.

8.5.2 If referee tests are being made.

8.6 *Report*:

8.6.1 The report shall include the following:

8.6.1.1 Results calculated as in 8.4,

8.6.1.2 Date of test,

8.6.1.3 Temperature of test room if other than provided for in Section 6,

8.6.1.4 Type of testing machine used, including diameter of spool grip if other than standard, and speed, if other than 8.3 ± 0.8 mm (20.0 $\pm$ 2 in.)/min, and

8.6.1.5 Type of specimen (ring or straight).

9. Tension Testing Precision and Bias

9.1 These precision statements have been prepared in accordance with Practice D4483. Refer to this practice for terminology and other statistical details.

9.2 *Precision*—The precision results in this precision and bias section give an estimate of the precision of these test methods with the materials (rubbers, carbon blacks, etc.) used in the interlaboratory program described in Table 1A and Table 1B. The precision parameters should not be used for acceptance or rejection testing of any group of materials without documentation that they are applicable to those particular materials and the specific testing protocols of these test methods.

9.3 A type 1 inter-laboratory precision program for tensile strength was conducted during the periods listed with the number of laboratories listed and the o-ring materials listed in Table 1A. In each laboratory, two single tests were performed on the o-rings by 2 different technicians on 2 different days for a total of four replicates. A test result is the value obtained from a single determination. Both repeatability and reproducibility represent short-term (daily) testing conditions. Acceptable difference values were not measured.

9.4 *Tensile Strength Repeatability*—The **relative** repeatability limits, (r), of this test method are as shown in Table 1A for each of the materials listed in the table. The difference between two single test results (or determinations) found on identical test material under the repeatability conditions prescribed for this test will exceed the repeatability value on an average of not more than once in 20 determinations in the normal and correct

TABLE 1 A Precision Parameters for Test Methods D1414, Tensile Strength (Type 1 Precision), Size 2-214 O-rings

Material	Period	Units Number of Laboratories (M/V) ^A	MPa		Sr	r	(r)	SR	R	(R)
			Mean Level							
FVMQ; MIL-DTL-25988C; T1, C1, G60	Sep 2020	6(0/0)	7.1	0.66	1.87	26.3	0.70	1.99	27.9	
FVMQ; MIL-DTL-25988C; T1, C3, G75	Oct '19; Feb '20	7(0/1)	8.2	0.24	0.68	8.2	0.74	2.09	25.3	
FKM; AMS7259E	April 2021	3(0/0)	12.1	1.98	5.61	46.4	2.22	6.30	52.0	
NBR; AMS-P-5315B	Sep-Dec 2018	10(1/0)	12.2	0.45	1.28	10.5	0.54	1.54	12.6	
FKM; AMS7287	May-Jun 2019	8(1/1)	12.5	0.80	2.28	18.3	0.80	2.28	18.3	
Average Pooled Values			10.4		1.03	27.9	1.18	3.33	31.9	

^A M=Mean outliers; V=Variability outliers

TABLE 1 B Precision Parameters for Test Methods D1414, Ultimate Elongation (Type 1 Precision), Size 2-214 O-rings (continued)

Material	Period	Units Number of Laboratories (M/V) ⁴	Percent		Sr	r	(r)	SR	R	(R)
			Mean Level							
FKM; AMS7259E	April 2021	3(0/0)	165.2	22.61		63.97	38.7	23.54	66.63	40.3
FVMQ; MIL- DTL-25988C; T1, C3, G75	Oct '19; Feb '20	7(1/1)	176.9	8.98		25.41	14.4	11.72	33.17	18.8
FKM; AMS7287	May-Jun 2019	8(1/0)	233.8	19.07		53.97	23.1	19.07	53.97	23.1
NBR; AMS-P- 5315B	Sep-Dec 2018	10(1/1)	248.9	7.82		22.13	8.9	16.87	47.75	19.2
FVMQ; MIL- DTL-25988C; T1, C1, G60	Sep 2020	6(0/0)	285.6	21.94		62.10	21.7	27.23	77.05	27.0
Average			222.1							
Pooled Values				17.31		48.98	22.1	20.40	57.74	26.0

^A M=Mean outliers; V=Variability outliers

operation of the method. Two single test results that differ by more than the appropriate value from **Table 1A** or **Table 1B** must be suspected of being from different populations and some appropriate action taken.

NOTE 2—Appropriate action may be an investigation of the test method procedure or apparatus for faulty operation or the declaration of a significant difference in the two materials, samples, etc., which generated the two test results.

9.5 Tensile Strength Reproducibility—The **relative** reproducibility limits, (R), of this test method are as shown in **Table 1A** for each of the materials listed in the table. The difference between two single and independent test results found by two operators working under the prescribed reproducibility conditions in different laboratories on identical test material will exceed the reproducibility value on an average of not more than once in 20 determinations in the normal and correct operation of the method. Two single test results produced in different laboratories that differ by more than the appropriate value from **Table 1A** must be suspected of being from different populations and some appropriate investigative or technical/commercial action taken.

NOTE 3—Appropriate action may be an investigation in each laboratory of the test method procedure or apparatus for faulty operation or the declaration of a significant difference in the two materials, samples, laboratories, etc., which generated the two test results. Technical/commercial actions are mutually resolved by the laboratories.

9.6 Bias—Bias is the difference between a test value and a reference value. However, for this test method, bias has not been determined.

9.7 A type 1 inter-laboratory precision program for ultimate elongation was conducted during the periods listed with the number of laboratories listed and the o-ring materials listed in **Table 1B**. In each laboratory, two single tests were performed on the o-rings by 2 different technicians on 2 different days for a total of four replicates. A test result is the value obtained from a single determination. Both repeatability and reproducibility represent short-term (daily) testing conditions. Acceptable difference values were not measured.

9.8 Relative versus absolute repeatability and reproducibility limits. For ultimate elongation, relative precision is statistically preferred. However, since the measurement units are in

percent and relative precision is a percent, the expression of relative precision would be calculated as a percent of a percent. This can be difficult to apply when evaluating the testing precision. Therefore, absolute precision is preferred for practical applications.

9.9 Ultimate Elongation Repeatability—The **absolute** repeatability limits, r, of this test method are as shown in **Table 1B** for each of the materials listed in the table. The difference between two single test results (or determinations) found on identical test material under the repeatability conditions prescribed for this test will exceed the repeatability value on an average of not more than once in 20 determinations in the normal and correct operation of the method. Two single test results that differ by more than the appropriate value from **Table 1B** must be suspected of being from different populations and some appropriate action taken.

NOTE 4—Appropriate action may be an investigation of the test method procedure or apparatus for faulty operation or the declaration of a significant difference in the two materials, samples, etc., which generated the two test results.

9.10 Ultimate Elongation Reproducibility—The **absolute** reproducibility limits, R, of this test method are as shown in **Table 1B** for each of the materials listed in the table. The difference between two single and independent test results found by two operators working under the prescribed reproducibility conditions in different laboratories on identical test material will exceed the reproducibility value on an average of not more than once in 20 determinations in the normal and correct operation of the method. Two single test results produced in different laboratories that differ by more than the appropriate value from **Table 1B** must be suspected of being from different populations and some appropriate investigative or technical/commercial action taken.

NOTE 5—Appropriate action may be an investigation in each laboratory of the test method procedure or apparatus for faulty operation or the declaration of a significant difference in the two materials, samples, laboratories, etc., which generated the two test results. Technical/commercial actions are mutually resolved by the laboratories.

9.11 Bias—Bias is the difference between a test value and a reference value. However, for this test method, bias has not been determined.

10. Tension Set Test

10.1 Procedure:

10.1.1 Stretch the O-ring specimens to 100 % elongation and hold at this strain for 10 min. At the end of this period release the specimen and allow it to recover for 10 min. At the end of this recovery period, measure the inside diameter with a step gage reference in 7.2 and shown in Fig. 1.

10.1.2 Apply the strain by (1) stretching the specimen over a tapered cone which has a step at the required 100 % elongation, or (2) by means of a tension test machine stopping the machine at 100 % elongation, or (3) by the use of any special fixture capable of holding the O-ring over two spools at constant distance between spool centers.

10.2 Calculation— Calculate tension set as follows:

$$\text{Tension set, \%} = [(L_1 - L_o)/L_o] \times 100 \quad (9)$$

where:

L_1 = diameter after testing, and
 L_o = original diameter.

10.3 Straight specimens cut from large O-rings may be tested and calculated in accordance with Test Methods D412.

11. Compression Set Test

11.1 Nature of Test— The compression set of O-ring specimens shall follow the general procedures of Method B of Test Methods D395, with the following exceptions:

11.2 Apparatus:

11.2.1 Spacers—The spacers shall be adjusted to within 0.025 mm (0.01 in.). This can be done by employing shim stock of various thickness.

11.2.2 Measurement— The cross section before and after test shall be measured in the same marked location with a ball-point (tubing) micrometer or other method as described in 7.1.

11.3 Test Specimen— The specimen shall be a suitable section cut from the sample O-ring. A52-mm (2-in.) section has been found to be satisfactory on sample O-rings of 17-mm (0.67-in.) or larger inside diameter. On smaller O-rings, a section of approximately 3 mm (1/8 in.) shall be cut from the sample and discarded.

NOTE 6—Testing a whole O-ring for compression set is always avoided because air trapped inside the O-ring results in a different set of conditions on the inside and outside surface of the specimen.

11.4 Procedure—Measure the actual specimen to within 0.025 mm (0.001 in.) and calculate the spacer to be 75 % of this thickness, to within 0.025 mm (0.001 in.). Close the plates, employing a sufficient number of bolts to prevent deflection upon heating. At the end of the heating period, release the plates as soon as possible and allow the specimens to cool to room temperature under the conditions described in Test Methods D395.

12. Compression Set Test Precision and Bias

12.1 These precision statements have been prepared in accordance with Practice D4483. Refer to this practice for terminology and other statistical details.

12.2 Precision—The precision results in this precision and bias section give an estimate of the precision of this test method with the materials (rubbers, carbon blacks, etc.) used in the interlaboratory program described in Table 2. The precision parameters should not be used for acceptance or rejection testing of any group of materials without documentation that they are applicable to those particular materials, test conditions, and the specific testing protocols of this test method.

12.3 A type 1 inter-laboratory precision program for compression set was conducted during the periods listed with the number of laboratories listed with the o-ring materials listed

TABLE 2 Precision Parameters for Test Methods D395, Method B, Compression Set (Type 1 Precision), Size 2-214 O-rings

Material	Period	Units Test Con- ditions	Percent Number of Laboratories (M/V) ^A	Mean Level	Sr	r	(r)	SR	R	(R)
FVMQ; MIL- DTL-25988C; T1, C1, G60	Sep 2020	Air; 23.9°C; 70 h	5(1/1)	8.4	1.54	4.37	52.0	1.54	4.37	52.0
FKM; AMS7287	May-Jun 2019	Air; 200°C; 22 h	8(1/1)	9.0	0.47	1.33	14.8	0.67	1.88	20.9
FKM; AMS7276H	Apr 2017	Air; 200°C; 22 h	8(0/0)	9.7	1.02	2.87	29.6	1.53	4.32	44.5
FVMQ; MIL- DTL-25988C; T1, C3, G75	Oct '19; Feb '20	Air; 175°C; 22 h	5(0/0)	10.9	1.28	3.61	33.1	1.75	4.96	45.5
FVMQ; MIL- DTL-25988C; T1, C3, G75	Oct '19; Feb '20	Air; 23.9°C; 70 h	5(0/1)	12.3	1.33	3.77	30.6	2.79	7.88	64.0
FVMQ; MIL- DTL-25988C; T1, C1, G60	Sep 2020	Air; 175°C; 22 h	5(0/0)	18.8	3.59	10.16	54.2	3.62	10.25	54.6
FKM; AMS7259E	April 2021	Air; 200°C; 22 h	3(0/0)	19.6	2.11	5.98	30.6	2.73	7.72	39.4
NBR; AMS-P- 5315B	Sep-Dec 2018	Air; 70°C; 70 h	10(1/0)	20.7	1.11	3.14	15.2	1.22	3.46	16.7
Average				13.7						
Pooled Values					1.79	5.07	37.1	2.18	6.17	45.1

^A M=Mean outliers; V=Variability outliers

and the test conditions listed in **Table 2**. In each laboratory, two single tests were performed on the o-rings by 2 different technicians on 2 different days for a total of four replicates. A test result is the value obtained from a single determination. Both repeatability and reproducibility represent short-term (daily) testing conditions. Acceptable difference values were not measured.

12.4 Relative versus absolute repeatability and reproducibility limits. For compression set, relative precision is statistically preferred. However, since the measurement units are in percent and relative precision is a percent, the expression of relative precision would be calculated as a percent of a percent. This can be difficult to apply when evaluating the testing precision. Therefore, absolute precision is preferred for practical applications.

12.5 Compression Set Repeatability—The **absolute** repeatability limits, *r*, of this test method are as shown in **Table 2** for each of the materials and conditions listed in the table. The difference between two single test results (or determinations) found on identical test material under the repeatability conditions prescribed for this test will exceed the repeatability value on an average of not more than once in 20 determinations in the normal and correct operation of the method. Two single test results that differ by more than the appropriate value from **Table 2** must be suspected of being from different populations and some appropriate action taken.

NOTE 7—Appropriate action may be an investigation of the test method procedure or apparatus for faulty operation or the declaration of a significant difference in the two materials, samples, etc., which generated the two test results.

12.6 Compression Set Reproducibility—The **absolute** reproducibility limits, *R*, of this test method are as shown in **Table 2** for each of the materials and conditions listed in the table. The difference between two single and independent test results found by two operators working under the prescribed reproducibility conditions in different laboratories on identical test material will exceed the reproducibility value on an average of not more than once in 20 determinations in the normal and correct operation of the method. Two single test results produced in different laboratories that differ by more than the appropriate value from **Table 2** must be suspected of being

from different populations and some appropriate investigative or technical/commercial action taken.

NOTE 8—Appropriate action may be an investigation in each laboratory of the test method procedure or apparatus for faulty operation or the declaration of a significant difference in the two materials, samples, laboratories, etc., which generated the two test results. Technical/commercial actions are mutually resolved by the laboratories.

12.7 Bias—Bias is the difference between a test value and a reference value. However, for this test method, bias has not been determined.

13. Compression Set in Liquids

13.1 Compression set may be conducted immersed in any liquid provided a suitable container is available. The container needs to be large enough to hold the plates and withstand the vapor pressure of the liquid at test temperature.

13.2 The specimen is prepared in accordance with **11.3**, and at the termination of the heating period the plates are released immediately and the specimens are allowed to cool to room temperature for 30 min in a fresh cool portion of the test liquid. Measurement and reporting are the same except the type of liquid is listed in the report.

14. Compression Set Test in Lubricants Precision and Bias

14.1 These precision statements have been prepared in accordance with Practice **D4483**. Refer to this practice for terminology and other statistical details.

14.2 Precision—The precision results in this precision and bias section give an estimate of the precision of this test method with the materials (rubbers, carbon blacks, etc.) used in the interlaboratory program described in **Table 3**. The precision parameters should not be used for acceptance or rejection testing of any group of materials without documentation that they are applicable to those particular materials, test conditions, and the specific testing protocols of this test method.

14.3 A type 1 inter-laboratory precision program for compression set in lubricants was conducted during the periods listed with the number of laboratories listed with the o-ring materials listed and the test conditions with lubricants listed in

TABLE 3 Precision Parameters for Test Methods **D395, Method B, Compression Set (Type 1 Precision), Size 2-214 O-rings**

Material	Period	Units Test Con- ditions	Percent Number of Laboratories (M/V) ^A	Mean Level	Sr	r	(r)	SR	R	(R)
FKM; AMS7259E	April 2021	AMS 3023 at 200°C for 70 h	2(0/0)	12.4	1.62	4.59	37.1	1.62	4.59	37.1
FVMQ; MIL- DTL-25988C; T1, C3, G75	Oct '19	AMS 3021 at 175°C for 70 h	4(0/0)	29.8	3.25	9.19	30.9	5.18	14.67	49.3
FVMQ; MIL- DTL-25988C; T1, C1, G60	Sep 2020	AMS 3021 at 150°C for 70 h	4(0/1)	31.1	2.53	7.15	23.0	8.37	23.67	76.2
Average				24.4						
Pooled Values					2.55	7.23	29.6	5.76	16.30	66.8

^A M=Mean outliers; V=Variability outliers

Table 3. In each laboratory, two single tests were performed on the o-rings by 2 different technicians on 2 different days for a total of four replicates. A test result is the value obtained from a single determination. Both repeatability and reproducibility represent short-term (daily) testing conditions. Acceptable difference values were not measured.

14.4 Relative versus absolute repeatability and reproducibility limits. For compression set in lubricants, relative precision is statistically preferred. However, since the measurement units are in percent and relative precision is a percent, the expression of relative precision would be calculated as a percent of a percent. This can be difficult to apply when evaluating the testing precision. Therefore, absolute precision is preferred for practical applications.

14.5 *Compression Set in Lubricants Repeatability*—The **absolute** repeatability limits, *r*, of this test method are as shown in **Table 3** for each of the materials and conditions listed in the table. The difference between two single test results (or determinations) found on identical test material under the repeatability conditions prescribed for this test will exceed the repeatability value on an average of not more than once in 20 determinations in the normal and correct operation of the method. Two single test results that differ by more than the appropriate value from **Table 3** must be suspected of being from different populations and some appropriate action taken.

NOTE 9—Appropriate action may be an investigation of the test method procedure or apparatus for faulty operation or the declaration of a significant difference in the two materials, samples, etc., which generated the two test results.

14.6 *Compression Set in Lubricants Reproducibility*—The **absolute** reproducibility limits, *R*, of this test method are as shown in **Table 3** for each of the materials and conditions listed in the table. The difference between two single and independent test results found by two operators working under the prescribed reproducibility conditions in different laboratories on identical test material will exceed the reproducibility value on an average of not more than once in 20 determinations in the normal and correct operation of the method. Two single test results produced in different laboratories that differ by more than the appropriate value from **Table 3** must be suspected of

being from different populations and some appropriate investigative or technical/commercial action taken.

NOTE 10—Appropriate action may be an investigation in each laboratory of the test method procedure or apparatus for faulty operation or the declaration of a significant difference in the two materials, samples, laboratories, etc., which generated the two test results. Technical/commercial actions are mutually resolved by the laboratories.

14.7 *Bias*—Bias is the difference between a test value and a reference value. However, for this test method, bias has not been determined.

15. Low-Temperature Test

15.1 *Nature of Test*—The TR-10 or Temperature Retraction Test shall be in accordance with Test Method **D1329** with the exceptions given in **15.2** to **15.4**.

15.2 *Test Specimen*—The test specimen shall be an O-ring of 1.5 to 3.8-mm (0.06 to 0.15-in.) cross-sectional diameter and of sufficient length to reach from clamp to clamp when the ring is cut and held in straight position.

15.3 *Procedure*—Stretch the mounted specimen 50 % as standard. If a greater or lesser stretch is used, report the actual stretch.

15.4 *Report*—The report shall include the following:

15.4.1 Testing elongation, in percent, and

15.4.2 Temperature at which the specimen retracts 10 %, designated as TR-10 and at other points, such as 30, 50, or 70 %, or all, if required.

16. Low-Temperature (TR10) Test Precision and Bias

16.1 These precision statements have been prepared in accordance with Practice **D4483**. Refer to this practice for terminology and other statistical details.

16.2 *Precision*—The precision results in this precision and bias section give an estimate of the precision of this test method with the materials (rubbers, carbon blacks, etc.) used in the interlaboratory program described in **Table 4**. The precision parameters should not be used for acceptance or rejection testing of any group of materials without documentation that

TABLE 4 Precision Parameters for Test Method **D1329, TR10, Retraction at Lower Temperature (Type 1 Precision), Size 2-214 O-rings**

Material	Period	Units Number of Laboratories (M/V) ^A	°C	Sr	r	(r)	SR	R	(R)
			Mean Level						
FVMQ; MIL- DTL-25988C; T1, C3, G75	Oct '19; Feb '20	4(0/1)	-63.1	0.29	0.82	-1.3	2.10	5.95	-9.4
FVMQ; MIL- DTL-25988C; T1, C1, G60	Sep 2020	2(0/0)	-60.5	0.38	1.08	-1.8	1.40	3.96	-6.6
NBR; AMS-P- 5315B	Sep-Dec 2018	6(1/1)	-45.0	0.16	0.46	-1.0	0.93	2.64	-5.9
FKM; AMS7287	May-Jun 2019	6(1/1)	-29.9	0.19	0.54	-1.8	0.31	0.88	-2.9
FKM; AMS7259E	April 2021	2(0/0)	-19.2	1.70	4.82	-25.1	2.07	5.85	-30.5
Average			-43.5						
Pooled Values				0.80	2.26	-5.2	1.52	4.31	-9.9

^A M=Mean outliers; V=Variability outliers

they are applicable to those particular materials, test conditions, and the specific testing protocols of this test method.

16.3 A type 1 inter-laboratory precision program for low temperature test (TR10) was conducted during the periods listed with the number of laboratories listed with the o-ring materials listed in **Table 4**. In each laboratory, two single tests were performed on the o-rings by 2 different technicians on 2 different days for a total of four replicates. A test result is the value obtained from a single determination. Both repeatability and reproducibility represent short-term (daily) testing conditions. Acceptable difference values were not measured.

16.4 *Low Temperature (TR10) Repeatability*—The **absolute** repeatability limits, *r*, of this test method are as shown in **Table 3** for each of the materials and conditions listed in the table. The difference between two single test results (or determinations) found on identical test material under the repeatability conditions prescribed for this test will exceed the repeatability value on an average of not more than once in 20 determinations in the normal and correct operation of the method. Two single test results that differ by more than the appropriate value from **Table 4** must be suspected of being from different populations and some appropriate action taken.

NOTE 11—Appropriate action may be an investigation of the test method procedure or apparatus for faulty operation or the declaration of a significant difference in the two materials, samples, etc., which generated the two test results.

16.5 *Low Temperature (TR10) Reproducibility*—The **absolute** reproducibility limits, *R*, of this test method are as shown in **Table 4** for each of the materials and conditions listed in the table. The difference between two single and independent test results found by two operators working under the prescribed reproducibility conditions in different laboratories on identical test material will exceed the reproducibility value on an average of not more than once in 20 determinations in the normal and correct operation of the method. Two single test results produced in different laboratories that differ by more than the appropriate value from **Table 4** must be suspected of being from different populations and some appropriate investigative or technical/commercial action taken.

NOTE 12—Appropriate action may be an investigation in each labora-

tory of the test method procedure or apparatus for faulty operation or the declaration of a significant difference in the two materials, samples, laboratories, etc., which generated the two test results. Technical/commercial actions are mutually resolved by the laboratories.

16.6 *Bias*—Bias is the difference between a test value and a reference value. However, for this test method, bias has not been determined.

17. Relative Density Test

17.1 *Test Specimen*—Any O-ring, O-rings, or segment of an O-ring may be considered as the specimen. The minimum mass of the specimen shall be 0.005 N (0.5 gf). In the case of very small O-rings, two or more pieces may be used as the specimen to accomplish this total minimum mass.

17.2 *Procedure*—Employ the procedure outlined in Test Methods **D297**, density hydrostatic method.

NOTE 13—Extreme accuracy is required in making relative density determinations on small O-rings 0.001 N (1 g or less). The surface tension on the suspending wire is critical; this wire should be of the smallest diameter corrosion-resistant wire that will support the specimen weight. This surface tension on the wire and the elimination of small air bubbles on the surface of the specimen can be reduced by the addition of a few drops of wetting agent to the water in the weighing beaker.

18. Relative Density Test Precision and Bias

18.1 These precision statements have been prepared in accordance with Practice **D4483**. Refer to this practice for terminology and other statistical details.

18.2 *Precision*—The precision results in this precision and bias section give an estimate of the precision of these test methods with the materials (rubbers, carbon blacks, etc.) used in the interlaboratory program described in **Table 5**. The precision parameters should not be used for acceptance or rejection testing of any group of materials without documentation that they are applicable to those particular materials and the specific testing protocols of these test methods.

18.3 A type 1 inter-laboratory precision program for tensile strength was conducted during the periods listed with the number of laboratories listed and the o-ring materials listed in **Table 5**. In each laboratory, two single tests were performed on the o-rings by 2 different technicians on 2 different days for a

TABLE 5 Precision Parameters for Test Methods **D297, Density (Type 1 Precision), Size 2-214 O-rings**

Material	Period	Units Number of Laboratories (M/V) ^A	Mg/cm ³		r	(r)	SR	R	(R)
			Mean Level	Sr					
NBR; AMS-P-5315B	Sep-Dec 2018	10(0/1)	1.2665	0.00268	0.00758	0.5983	0.00584	0.01652	1.3040
FVMQ; MIL-DTL-25988C; T1, C1, G60	Sep 2020	5(1/0)	1.4783	0.00362	0.01024	0.6925	0.00362	0.01024	0.6925
FVMQ; MIL-DTL-25988C; T1, C3, G75	Oct '19; Feb '20	8(0/0)	1.5029	0.00346	0.00979	0.6512	0.00604	0.01709	1.1372
FKM; AMS7287	May-Jun 2019	9(1/1)	1.7654	0.00524	0.01483	0.8402	0.00941	0.02663	1.5083
FKM; AMS7259E	April 2021	3(0/0)	1.8406	0.00483	0.01365	0.7419	0.00483	0.01365	0.7419
Average			1.5707						
Pooled Values				0.00407	0.01153	0.7339	0.00625	0.01769	1.1264

^A M=Mean outliers; V=Variability outliers