



## Standard Test Method for Ring Bendability of Pipeline Coatings (Squeeze Test)<sup>1</sup>

This standard is issued under the fixed designation G 70; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

### 1. Scope

1.1 This method covers testing the relative resistance of pipeline coatings to cracking and spalling from deformation of the pipe by observing the effects of diametral compression of ring samples. The method is limited to thin film coatings having an elongation not exceeding 5.0 %.

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

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

### 2. Referenced Documents

#### 2.1 ASTM Standards:

G 12 Test Method for Nondestructive Measurement of Film Thickness of Pipeline Coatings on Steel<sup>2</sup>

G 62 Test Methods for Holiday Detection in Pipeline Coatings<sup>2</sup>

### 3. Summary of Test Method

3.1 The method consists of compressing coated pipe ring samples in a hydraulic arbor press, universal test machine, or other suitable device. The ring sample is compressed to an approximate oval shape wherein the minor diameter of the oval is produced by a bending force that elongates the coating at the metal interface. The coating elongation or stretch as produced in the test by compressing the ring to a gaged dimension can be calculated to produce the same coating elongation or stretch as would occur in actual bending of the pipe to a given radius. Coating failure in the form of cracking or loss of adhesion is detected by electrical test for holidays while the test is in process.

3.2 Compression of coated ring samples is controlled by use of a dial indicator, micrometer, or other suitable distance-measuring device. Dimensions are then corrected to outside dimensions by subtracting the dial indicator or micrometer reading from the initial pipe diameter.

### 4. Significance and Use

4.1 The method will provide information on the ability of pipeline coatings to resist cracking, spalling, or other mechanical damage as a result of bending. If the test is applied to coated pipe samples from commercial production, the results can be used in the selection of similar materials for service. The test has application as a quality control method when variations in coating application or material formulation may affect bending performance.

### 5. Apparatus

5.1 *Compression Apparatus*—An arbor press, universal test machine, or other device that can apply sufficient force at a controlled rate of movement.

5.2 *Film Thickness Gage*, as described in Test Method G 12.

5.3 *Holiday Detector*—A high- or low-voltage d-c holiday detector as specified in Test Methods G 62 shall be used to locate breaks in the coating film. Low-voltage holiday detectors shall be used on coatings 0.51 mm ( $\leq 20$  mils) thick and high-voltage holiday detectors shall be used on thicker coatings.

### 6. Test Specimens

6.1 The test specimens shall be coated ring samples  $50 \pm 5$  mm ( $2 \pm 0.20$  in.) in length.

6.2 Five samples shall be cut from the same piece of coated pipe by hand saw, power saw, or lathe with care not to damage the coating in the holding device. All edges shall be visually deburred. More samples may be required depending on the testing application.

6.3 Samples shall have areas of coating removed in accordance with Fig. 1.

6.4 The samples shall be free of obvious coating flaws or defects.

### 7. Conditioning

7.1 Where compression testing at room temperature is required, the specimen shall be exposed to these conditions for a sufficient time to ensure thermal equilibrium in the pipe and coating. A temperature in the range from 20 to 25°C (68 to 77°F) shall be considered room temperature. A relative humidity of  $50 \pm 5$  % shall be considered standard.

7.2 Tests at other temperatures shall be made in such a manner as to ensure that thermal equilibrium is maintained between the specimen and its conditioning environment.

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings, Materials, and Applications, and is the direct responsibility of Subcommittee D01.48 on Deterioration of Pipeline Coatings and Linings.

Current edition approved Oct. 30, 1981. Published December 1981.

<sup>2</sup> *Annual Book of ASTM Standards*, Vol 06.02.

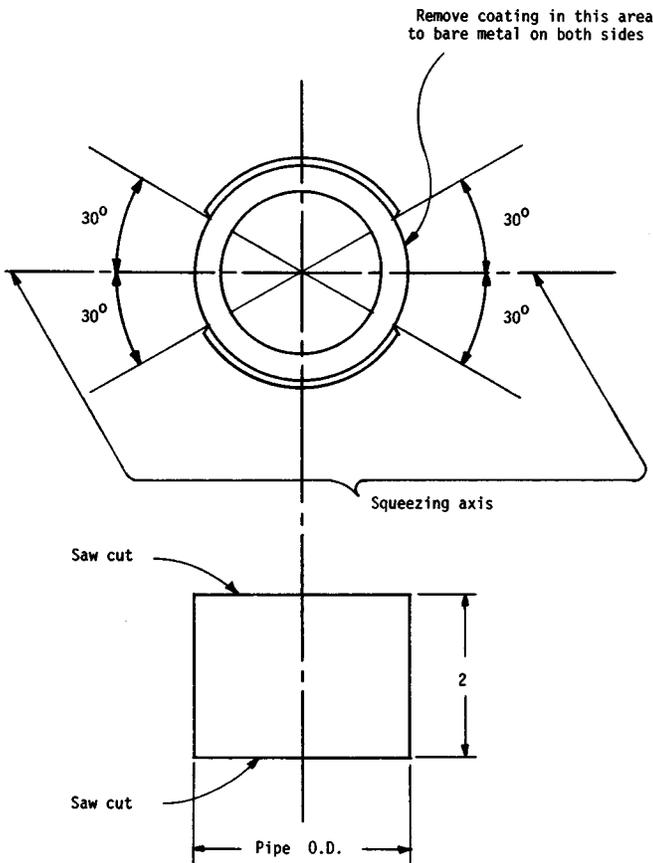


FIG. 1 Specimen

**8. Procedure**

8.1 Measure the outside diameter and wall thickness of each specimen using a suitable measuring instrument.

8.2 Measure the applied coating thickness of each specimen in accordance with Test Method G 12.

8.3 Place specimen between the compression surfaces and apply sufficient compressive force to barely hold the sample. The direction of compression shall be as shown in Fig. 1.

8.4 Apply compressive force by movement of the compression surfaces at a constant rate of speed.

8.4.1 The rate of movement of the compression surfaces shall be in accordance with the following guidelines:

Specimen Diameter, mm	Testing Speed, mm/min
50 to 200	2 to 20
200 to 400	20 to 40
400 to 600	40 to 60
>600	60 to 100

The rate of movement of the compression surfaces can be determined by any suitable method such as a dial indicator, micrometer, caliper, and a stopwatch.

8.5 Examine the specimen during compression with the holiday detector (Test Methods G 62) constantly to determine

the point of cracking of the coating film. Note the number, size, and type of cracks present. Examine the pipe specimen for any loss of coating bond caused by the bending operation.

NOTE 1—The possibility of some coatings developing stress-induced cracks in the period following the bending operation should not be overlooked. If this is a consideration, the bent specimen should be retained for future inspection.

8.6 If a micrometer is used, measure the distance of compression of the specimen.

8.7 After finding the distance of compression, subtract this figure from the initial pipe diameter and determine the percent bend by calculation as shown in the Annex A1.

**9. Report**

9.1 The initial test report shall include the following (see Fig. 2):

9.1.1 Complete identification of the coated pipe tested, including: name and type of coating; average coating thickness; minimum coating thickness; maximum coating thickness; manufacturer's lot number; date of manufacture; nominal pipe diameter.

9.1.2 Rate of compression.

9.1.3 Temperature of the pipe specimen as tested.

9.1.4 Percent bend and corresponding distance of compression at which cracking first occurred.

9.1.5 Description of the type of cracking that is visible, or indicated, or both, by the holiday detector.

9.1.6 Extent of any loss in pipe-to-coating bond.

9.1.7 Number of specimens tested.

9.1.8 Any peculiar characteristics of the specimen noted during the test or after immediate removal from the test apparatus.

9.1.9 Post-bend retention time in days.

**10. Precision**

10.1 Precision data are limited to adjacent specimens taken from the production-coated pipe assuming that the production process was uniform with respect to pipe surface condition and coating material. Specimens that were not adjacent in the as-produced condition or were taken from different lengths of pipe may represent differing process conditions.

10.2 *Repeatability*—When the same instrument is used by the same operator, duplicate measurements on the same specimen shall agree within  $\pm 8\%$ .

10.3 *Reproducibility*—Different operators using different holiday detectors set at the same voltages, inspecting the same specimen shall obtain average results agreeing with each other within  $\pm 15\%$ .

**11. Keywords**

11.1 bendability; coating; compression; deformation; pipe-line; ring sample; squeeze

DATA SHEET AND REPORT

Squeeze Test for Bendability of Pipeline Coatings

Report No. \_\_\_\_\_  
 Specimen No. \_\_\_\_\_  
 Date \_\_\_\_\_

Pipe OD mm (in.) Wall mm (in.)  
 Type Grade Manufacturer Initials  
 Coating: Thickness, mm (in.): max min avg

Applied by		Manufacturer										Method					
Holiday Detector: Type												Voltage					
Line	Run No	Results				Observed			Temperature		Cracks		Spalling		Holiday Detector		
		Initial Distance A, mm (in.)	Compressed State Final Distance B mm (in.)		Percent Stretch	Date	Elapsed Time, min: s	Testing Speed, mm/min (in./min)	°C	°F	Not visible	Visible	No	Yes	Negative	Positive	
1																	
2																	
3																	
4																	
5																	
6																	
7																	
8																	
9																	
10																	
11	Comments: Apply to Line ( )																
12	Summary																

FIG. 2 Suggested Form for Recording Data

ANNEX

(Mandatory Information)

A1. ASSUMPTIONS AND CALCULATIONS NECESSARY TO DEVELOP A CURVE TO RELATE PERCENT COATING ELONGATION TO RING SAMPLE DEFLECTION

A1.1 *Given*—Squeeze a ring in a vise a limited amount, forming an oblate. See Fig. A1.1.

A1.2 *Assumptions*:

A1.2.1 That when a ring specimen is squeezed (compressed) between two parallel platens a limited amount, por-

tions of the specimen will be reduced to portions of a ring having smaller radii than the original ring. The new, small ring portions will have radii close enough to a true circle that it may be assumed that true circle portions are represented.

NOTE A1.1—It may be argued that the original pipe section is not a

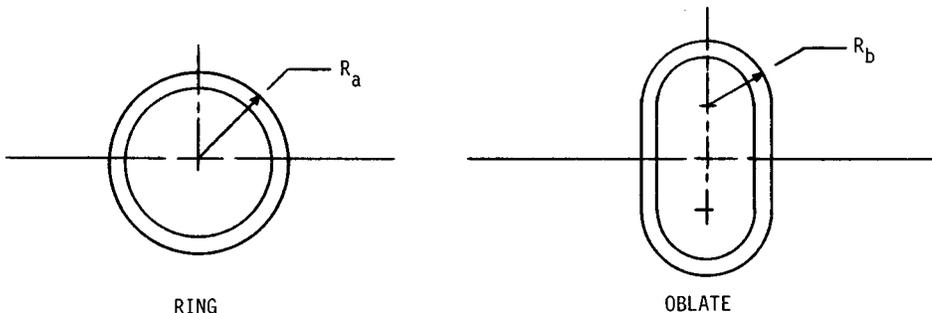


FIG. A1.1 Ring Sample

perfect circle but is so regarded when Barlow's formula is applied.

A1.2.2 That when a portion of a ring is deformed into ring having a smaller radius, the part of the surface of the original ring that is deformed into a smaller ring is elongated uniformly.

A1.2.3 If the original ring outer surface is coated and that surface is elongated, the adhered coating must not only elongate but the new adhered surface must be less than the original adhered surface. Hence the adhered surface must be reduced. The only exception to this would occur with a sticky coating wherein the coating is an adhesive that will flow to accommodate the larger surface.

A1.2.4 That the adhering property of the coating will be the same whether the metal surface interface is longitudinal or peripheral with the pipe.

A1.2.5 That the wall thickness of the ring is not changed when the ring is squeezed.

NOTE A1.2—If any of these assumptions are known to be questionable, the percent stretch (elongation) must be calculated in a different way. Other ways of determining the percent elongation would be by direct measurement while the ring is compressed or by comparison to standard radii bends.

A1.3 Calculations (See Fig. A1.2 and Fig. A1.3):

A1.3.1 In Fig. A1.2:

Let:

- $D$  = outside diameter of the large ring,
- $t$  = wall thickness of ring,
- $\theta$  = arc of large ring measured as a fraction of  $360^\circ$ ,
- $b$  = length along neutral axis subtended by arc  $\theta$ , and
- $d$  = length along outer surface subtended by arc  $\theta$ .

Then:

$$b = \theta\pi(D - t), \text{ and} \tag{A1.1}$$

$$d = \theta\pi D \tag{A1.2}$$

A1.3.2 In Fig. A1.3:

Let:

- $D_1$  = outside diameter of the small ring,
- $t$  = wall thickness of ring (same as Fig. 1),
- $\delta$  = arc of small ring measured as a fraction of  $360^\circ$ ,
- $a$  = length along neutral axis subtended by arc  $\delta$ , and
- $c$  = length along outer surface subtended by arc  $\delta$ .

Then:

$$a = \delta\pi(D_1 - t), \text{ and} \tag{A1.3}$$

$$c = \delta\pi D_1 \tag{A1.4}$$

A1.3.3 Select an arbitrary value for arc  $\theta$ . Any value is

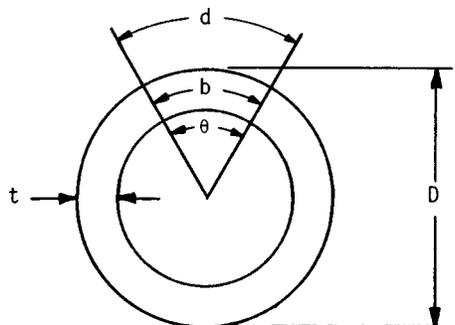


FIG. A1.2 Large Ring

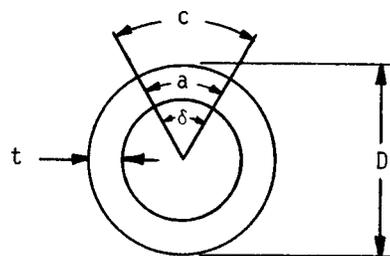


FIG. A1.3 Small Ring

suitable as long as it is always less than the arc subtended outside the platens of the vise because the arc  $\delta$  will be obtained as a ratio of  $\theta$ . For example, let  $\theta = 4\frac{1}{2}^\circ = 4.5/360 = 0.0125$ . Now find  $\delta$  by letting  $a = b$ .

$$a = b \tag{A1.5}$$

Then:

$$\delta\pi(D_1 - t) = \theta\pi(D - t) \tag{A1.6}$$

Since  $\theta = 0.0125$ :

$$\delta = 0.0125 \frac{(D - t)}{(D_1 - t)} \tag{A1.7}$$

$$c = \delta\pi D_1 = 0.0125 \frac{(D - t)}{(D_1 - t)} \pi D_1 \tag{A1.8}$$

which is the elongated surface.

If  $P$  is the percent of elongation or stretch:

$$P = \frac{c - d}{d} \times 100 \tag{A1.9}$$

$$P = \frac{0.0125 \frac{(D - t)}{(D_1 - t)} \pi D_1 - 0.0125\pi D}{0.0125\pi D} \tag{A1.10}$$

$$P = \frac{\frac{(D - t)}{(D_1 - t)} D_1 - D}{D} \times 100 \tag{A1.11}$$

percent of elongation in the compressed ring.

NOTE A1.3—While the selected value for  $\theta$  appears to drop out of the equation at this point along with  $\pi$ , it will be needed for evaluating the equations in order to limit the functions to arcs formed outside the platens of the compressive device.

A1.3.4 Development of Percent Stretch vs Ring Deflection Curve—In Eq A1.11, we know  $t$  as the wall thickness and  $D$  as the outside diameter of the ring. Eq A1.11 is used to calculate the  $P$  or percent stretch value for a given ring deflection as in the sample calculation below.

$$P = \frac{\frac{(D - t)^{D_1}}{(D_1 - t)} - D}{D} \times 100 \tag{A1.12}$$

For 73 mm outside diameter – 5.2 mm wall steel pipe,  $t = 5.2$  mm,  $D = 73$  mm, we desire to know what the percent stretch of the coating when the ring is compressed to 51 mm.

$$P = \frac{\frac{(73 - 5.2)(51)}{(51 - 5.2)} - 73}{73} \times 100 \tag{A1.13}$$

$$P = 3.42 \%$$

In this way one continues to obtain as many points as necessary to make an acceptable calibration curve.

 **G 70**

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