INTERNATIONAL

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Standard Test Methods for Polariscopic Examination of Glass Containers[1]

This standard is issued under the fixed designation C148; 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 determination of relative optical retardation associated with the state of anneal of glass containers. Two alternative test methods are covered as follows:

	Sections
Test Method A—Comparison with Reference Standards Using a Polariscope	6 – 9
Test Method B—Determination with Polarimeter	10 – 12

1.2 Test Method A is useful in determining retardations less than 150 nm, while Test Method B is useful in determining retardations less than 565 nm.

NOTE 1—The apparent temper number as determined by these test methods depends primarily on (*1*) the magnitude and distribution of the residual stress in the glass, (*2*) the thickness of the glass (optical path length at the point of grading), and (*3*) the composition of the glass. For all usual soda-lime silica bottle glass compositions, the effect of the composition is negligible. In an examination of the bottom of a container, the thickness of glass may be taken into account by use of the following formula, which defines a real temper number, T_R, in terms of the apparent temper number, T_A, and the bottom thickness, t:

$$T_R = T_A(0.160/t), \text{ where } t \text{ is in inches, or}$$

$$T_R = T_A(4.06/t), \text{ where } t \text{ is in millimetres.}$$

This thickness should be measured at the location of the maximum apparent retardation. Interpretation of either real or apparent temper number requires practical experience with the particular ware being evaluated.

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.*

1.5 *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]
C162 Terminology of Glass and Glass Products
C224 Practice for Sampling Glass Containers
C1426 Practices for Verification and Calibration of Polarimeters

3. Terminology

3.1 *Definitions*— For definitions of terms used in these test methods see Terminology C162.

4. Significance and Use

4.1 These two test methods are provided for evaluating the quality of annealing. These test methods can be used in the quality control of glass containers or other products made of similar glass compositions, where the degree of annealing must be verified to ensure quality products. These test methods apply to glass containers manufactured from commercial soda-lime-silica glass compositions.

5. Sampling

5.1 Methods of sampling a minimum lot from a group of containers of a given type are given in Practice C224 for the various situations to which that method may apply.

TEST METHOD A—COMPARISON WITH REFERENCE STANDARDS USING A POLARISCOPE

6. Apparatus

6.1 *Polariscope,* conforming to the following requirements:

[1] These test methods are under the jurisdiction of ASTM Committee C14 on Glass and Glass Products and are the direct responsibility of Subcommittee C14.07 on Glass Containers.

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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.

6.1.1 The degree of polarization of the field at all points shall not be less than 99 %.

6.1.2 The field shall be a minimum of 51 mm (2 in.) in diameter greater than the diameter of the container to be measured. The distance between the polarizing and analyzing elements shall be sufficient to allow the inside bottle bottom surface to be viewed through the open container finish.

6.1.3 A sensitive tint plate, having a nominal optical retardation of 565 nm, with a variation across the field of view of less than 5 nm and with its slow axis at 45° to the plane of polarization, shall be used. Such an orientation will produce a magenta background in the field of view. The brightness of the polarized field illuminating the sample shall be a minimum of 300 cd/m^2.

NOTE 2—Color discrimination remains satisfactory with retardations between 510 and 580 nm, but optimum conditions are attained at 565 nm.

6.1.4 Samples must be allowed to equilibrate until the entire thickness of glass is at room temperature.

7. Calibration and Standardization

7.1 A set of not less than five standardized glass disks of known retardation stress shall be used to cover the range of commercial container annealing. Such disks shall be circular plates of glass not less than 76 mm (3 in.) nor more than 102 mm (4 in.) in diameter. Each disk shall have a nominal retardation at the calibration point, 6.4 mm (0.25 in.) from the outer circumference of the disk, corresponding to not less than 21.8 nm nor more than 23.8 nm of optical retardation. Each disk shall have a nominal retardation at the calibration point, 6.4 mm (0.25 in.) from the PHYSICAL EDGE of the GLASS disk, corresponding to not less than 21.8 nm nor more than 23.8 nm of optical retardation. If the disk is mounted in a frame that covers the glass edge, refer to the instructions provided by the supplier of the strain disk set with regard to the distance to the calibration point from the frame ID. If unknown, the disks may be removed from the frame, the calibration point marked accordingly, and the disks placed back into their frames.

8. Procedure

8.1 *Examination of the Bottom of Cylindrical Flint Containers*—View the inside bottom of the container through the open container finish. Rotate the container to determine the location of the highest order of retardation color at the inside knuckle position. Compare the highest order retardation color observed at the bottom of the container to the retardation color seen at the calibration point in various numbers of the standard disks stacked one on top of the other and held parallel to the surface of the polarizer. Determine whether the maximum order of retardation color in the container bottom is less than that in one disk, less than that in two and greater than one, less than that in three and greater than two, and so forth. It is seldom possible to obtain an exact match of the order of retardation color scheme in the container with the reference standards. Accordingly, record the temper number of the container using the following procedure:

8.1.1 *Temper Number Determination*—When a maximum order retardation color observed in the container bottom is greater than that of N disks but less than $N + 1$ disks, the apparent temper grade is judged to be that of $N + 1$ disks. The apparent temper number is always determined to be the next integral temper number greater in value than the actual observed value as seen in the following table:

Apparent Temper Number	Observed Temper
1	less than 1 disk
2	less than 2, greater than 1 disk
3	less than 3, greater than 2 disks
4	less than 4, greater than 3 disks
5	less than 5, greater than 4 disks
6	less than 6, greater than 5 disks
7	[A]

[A]Evaluation by polarimeter (Test Method B) should be used for apparent temper numbers greater than six.

8.2 *Examination of Square, Oval, and Irregular Shapes*—Make the polariscopic examination of that container curve or corner that shows the maximum order of retardation color and record the temper number in accordance with the procedure outlined in 8.1.

8.3 *Examination of the Container Sidewalls*—Match the maximum retardation color observed in the container sidewall with the maximum retardation color at the calibration point of the standard reference disks, and record the apparent temper number in accordance with the procedure outlined in 8.1.1.

8.4 *Examination of Colored Ware*—Using the polariscope with the tint plate in the field of view, rotate the container to determine the location of the highest order retardation color at the inside knuckle position. View the bottom of the container through the open container finish and select as a reference area the darkest appearing area of the container bottom having minimum retardation, usually found at the center of the container bottom. Then, with the tint plate in position, hold a standard reference disk under the reference area in the bottom of the container such that the calibration point on the disk is directly under the reference area in the center bottom of the container. Compare the retardation color of the reference area in the container center bottom as modified by the standard reference disk with the maximum retardation color as normally observed at the inside knuckle of the container bottom. If this color is greater than the modified color of the reference area, use two or more disks and grade the annealing in accordance with the procedure outlined in 8.1.1.

9. Report

9.1 Report the temper number (real or apparent) obtained for each container.

TEST METHOD B—DETERMINATION WITH POLARIMETER

10. Apparatus

10.1 *Polarimeter,* conforming to the following requirements:

10.1.1 The degree of polarization of the field shall be at all points not less than 99 %.

10.1.2 The field shall be a minimum of 51 mm (2 in.) in diameter greater than the diameter of the container to be measured. The distance between the polarizing and analyzing elements shall be sufficient to allow the container to be positioned to permit the inside bottle bottom surface to be viewed through the open container finish.

10.1.3 A quarterwave plate with an optical retardation of 141 ± 14 nm shall be inserted between the specimen and the analyzer with the slow axis aligned with the plane of polarization of the polarimeter. The brightness of the polarized field illuminating the sample shall be a minimum of 300 cd/m^2.

NOTE 3—The retardation measurement will be affected by the combined effect of the quarterwave-plate deviation from its nominal value of 141 nm and by the deviation of the orientation of the measured stress direction from its ideal position of 45° to the polarizer axis.
A 14-nm deviation of the quarterwave plate and a stress-direction deviation of 10° will introduce an error not greater than 8 nm.

10.1.4 The analyzer shall be mounted so that it can be rotated with respect to the polarizer and the quarterwave plate and the angle of rotation determined.

10.1.5 The polarimeter/polariscope should be calibrated or verified according to Practices C1426.

10.1.6 Samples must be allowed to cool until the entire thickness of the glass is at room temperature.

11. Procedure

11.1 *Examination of Bottom of Cylindrical Flint Containers*—Rotate the analyzer initially so as to have the analyzer plane of polarization perpendicular to the polarizing plane of polarization. This is the zero position in which the field of view should be at maximum darkness or extinction. Introduce the container to be evaluated into the field of view with the tint plate in position. Rotate the container to determine the location of the highest order retardation color at the inside knuckle position. Remove the tint plate. View the inside container bottom through the open container finish. A darkened extinction cross will appear in the container bottom, with lightened areas between the mutually perpendicular, darkened legs of the cross. In containers having a low retardation, the extinction cross will appear to be hazy and indistinct. The extinction cross would appear to be colored magenta rather than appear darkened if the tint plate were in position, or if the container were being observed in a sensitive tint plate polariscope. Rotating the analyzer causes the darkened extinction cross to separate into two darkened arcs which move outward in opposite directions toward the inside knuckle of the container, each arc paralleling the same diameter in the container bottom. As the two arcs move outward, they develop a blue-gray color on the concave side and a brownish color on the convex side of each arc. When determining the retardation at a selected point in a container, rotate the analyzer until the blue-gray color is just displaced by the brownish color at the selected point of grading. Rotate the container about its longitudinal axis to confirm that the selected point corresponds to the location of maximum retardation. If another area of higher retardation is revealed by the reappearance of the blue-gray color, rotate the analyzer further to displace the blue-gray color by the brownish color. Convert the angle of rotation of the analyzer to the apparent temper number as follows:

Apparent Temper Number	Analyzer Rotation, °[A]
1	0.0–7.3
2	7.4–14.5
3	14.6–21.8
4	21.9–29.0
5	29.1–36.3
6	36.4–43.6
7	43.7–50.8
8	50.9–58.1
9	58.2–65.4
10	65.5–72.6

[A] One degree of rotation of the analyzer is equivalent to about 3.14–nm optical retardation when using a tungsten filament white light source having an effective wavelength of 565 nm. Thus, the equivalent value is taken to be approximately 7.26° rotation per disk as used in Test Method A.

12. Examination of Square, Oval, and Irregular Shapes

12.1 Make the examination at the curve or corner that reveals the most birefringence when examined in accordance with the procedure given in 11.1.

12.2 *Examination of Bottle Sidewalls*—Insert the container in the polarimeter with the longitudinal axis of the container at a 45° angle to the plane of the polarization. No dark extinction cross should be visible in the field of view. Rather, broad areas of varying extinction, corresponding to areas of lightness and darkness, will be visible in the sidewall of the container. Rotate the container until the point of maximum retardation is located in the container sidewall, as evidenced by an area of maximum brightness in the field of view. Rotate the analyzer until a darkened extinction region converges on and displaces the brightened area in the container sidewall at the selected point of grading. Convert the degrees of rotation of the analyzer to an apparent temper number in accordance with the tabulations in 11.1.

12.3 *Examination of Colored Ware*—Use the same procedure as in flint ware. The point of extinction is usually more difficult to determine in colored ware because of the absence of the blue-gray and brownish colors, as well as the reduced light intensity caused by preferential absorption of light in the colored ware. First, rotate the analyzer until the darkened cross separates and the darkened area just extinguishes the lightened area of the selected point of grading. Record the degrees of rotation. Then continue rotating the analyzer in the same direction until well past the extinction point. Now reverse the rotation of the analyzer and redetermine the extinction point by stopping rotation when the lightened area again appears dark. Record the degree of rotation. Average the degrees of rotation achieved in both measurements.

13. Report

13.1 Report the temper number (real or apparent) or analyzer rotation obtained for each container examined.

14. Precision and Bias

14.1 *Precision*—The precision of both of these test methods has been determined by round-robin testing to be within one standard temper disk.

14.2 *Bias*—The bias of these test methods cannot be established in that the test methods contained herein are comparative and yield a result relative to the standards being used.