Designation: C1652/C1652M – 21

Standard Test Method for Measuring Optical Distortion in Flat Glass Products Using Digital Photography of Grids[1]

This standard is issued under the fixed designation C1652/C1652M; 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.

INTRODUCTION

Transmitted and reflected distortion in annealed, heat strengthened, and tempered glass can be measured by several methods.(**1**, **2**, **3**, **4**)[2] Qualitative methods are based on the observation of waviness in the glass as viewed in of reflected or transmitted images in a set of equidistant lines, called Zebra Lines. Quantitative measuring techniques are based on several methods, some of which are:
(1) Measuring local curvature using mechanical radius gauges (**1**, **5**, **6**, and Test Method C1651).
(2) Moiré Fringe analysis (**7**, **8**).
(3) Double exposure of transmitted grid images (Practice F733).
(4) Projection of an array of round dots (**9**).
(5) Dual laser beams (**10**).
The user should be familiar with techniques that are available so as to select the most suitable after considering the precision, speed, and test specification requirements. The test method described in this document uses a digital camera to capture a transmitted or reflected image of a set of equidistant lines. Changes in the spacing of lines are used to quantifying the distortion.

1. Scope

1.1 This test method covers the determination of optical distortion of heat-strengthened and fully tempered architectural glass substrates which have been processed in a heat controlled continuous or oscillating conveyance oven. See Specifications C1036 and C1048 for discussion of the characteristics of glass so processed. In this test method the reflected image of processed glass is photographed and the photographic image analyzed to quantify the distortion due to surface waviness. The test method is also useful to quantify optical distortion observed in transmitted light in laminated glass assemblies.

1.2 The values stated in either SI units or inch-pound units are regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

1.3 There is no known ISO equivalent to this test method.

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, health, and environmental 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:*[3]
C162 Terminology of Glass and Glass Products
C1036 Specification for Flat Glass
C1048 Specification for Heat-Strengthened and Fully Tempered Flat Glass
C1651 Test Method for Measurement of Roll Wave Optical Distortion in Heat-Treated Flat Glass
F733 Practice for Optical Distortion and Deviation of Transparent Parts Using the Double-Exposure Method

[1] This test method is under the jurisdiction of ASTM Committee C14 on Glass and Glass Products and is the direct responsibility of Subcommittee C14.11 on Optical Properties.

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[2] The boldface numbers in parentheses refer to a list of references at the end of this standard.

[3] 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.

2.2 *Other Standards:*[4]
U.S. Patent 7345698 Optical System for Imaging Distortions in Moving Reflective Sheets (2003)

3. Terminology

3.1 See Terminology C162 of Glass and Glass Products.

3.2 *Definitions:*

3.2.1 *focal length, F*—The focal length of a specular reflector, due to the curvature at a point equals R/2 (see 3.2.3); in transmitted light, local thickness changes introduce a convergence or divergence, equivalent to a lens with a focal length F.

3.2.2 *optical power, D*—The optical power due to the curvature at a point is D = 1/F; the optical power is expressed in diopters, (Units 1/m), or as is typical, in millidiopters; the optical power is also used to quantify optical distortion, the deformation of images reflected from flat glass, or transmitted by laminated or bent glass, or both.

3.2.3 *radius of curvature, R*—The local radius of curvature at a point on the surface, in meters; R_x and R_y are respectively measured in planes x (usually horizontal) and y (usually vertical).

3.2.4 *roll wave*—A repetitive, wave-like departure from flatness in otherwise flat glass that results from heat-treating the glass in a horizontal conveyance system; roll wave excludes edge effects such as edge kink, and distortion induced by assembly or installation.

[4] Available from the U.S. Patent and Trademark Office, https://www.uspto.gov.

4. Summary of Test Method

4.1 This test procedure was designed to provide an accurate method of quantifying the optical distortion of glass as it is revealed in reflected or transmitted images. The optical distortion in reflected light can be related to a surface waviness, known as roll wave in tempered glass products, or, in transmitted light, related to curvature and local thickness variations in laminated glass products. The test method is based on the use of a digital camera which is used to record the appearance of an accurately printed grid pattern which has been reflected from or transmitted through a lite of glass. Mathematical analyses performed on computer of the changes in the grid pattern along with the laws of optics and the geometrical arrangement makes it possible to quantify the lens power or optical distortion of each element of the glass surface defined by the grid.

4.2 A uniformly spaced set of parallel lines, usually set at 45° angle to horizontal, may be used instead of a grid. If such a set of lines is used, the mathematics of calculation will be slightly altered from those expressed in Appendix X1.

5. Significance and Use

5.1 This test method provides accurate data for evaluation of the optical properties of the glass being inspected.

5.2 The procedure described is useful for observing the roll wave introduced during the tempering process of flat architectural glass. (**1**)

5.3 This test method is also useful for inspection of laminated and tempered automotive glass in transmitted light, in both flat and curved geometries.

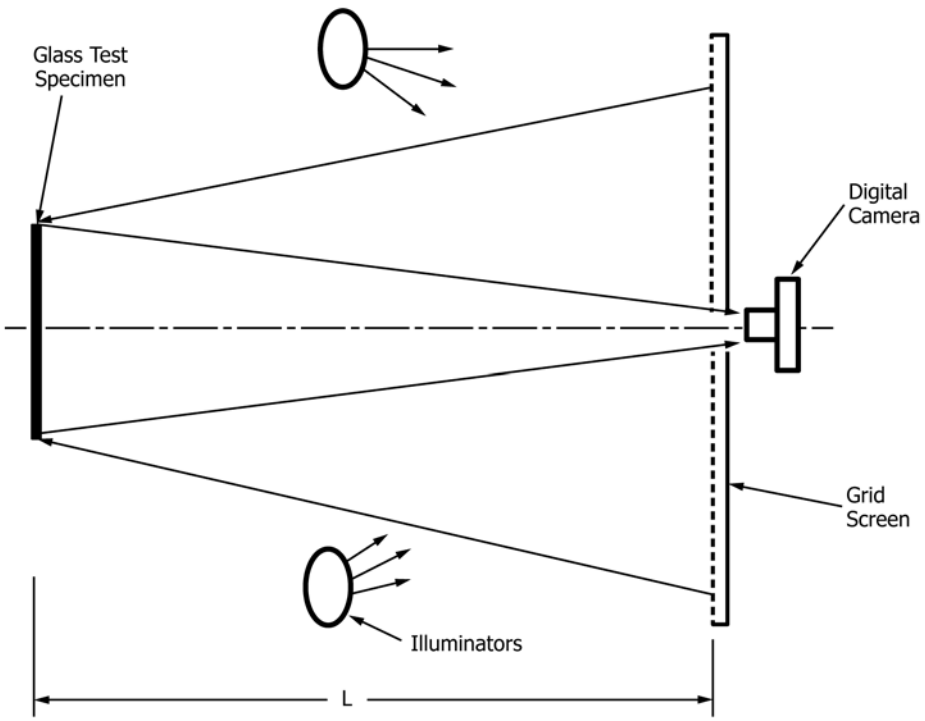

FIG. 1 Test Configurations of Reflective Analysis