Designation: F2469 – 15

Standard Test Method for Measuring Optical Angular Deviation of Transparent Parts Using the Double-Exposure Method[1]

This standard is issued under the fixed designation F2469; 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 test method covers the measurement of the optical angular deviation of a light ray imposed by flat transparent parts such as a commercial or military aircraft windshield, canopy, or cabin window.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.2.1 *Exceptions*—The values given in parentheses are for information only. Also, print size is provided in inch-pound measurements.

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:*[2]

F801 Test Method for Measuring Optical Angular Deviation of Transparent Parts

F1181 Test Method for Measuring Binocular Disparity in Transparent Parts

F733 Practice for Optical Distortion and Deviation of Transparent Parts Using the Double-Exposure Method

3. Terminology

3.1 *Definitions:*

3.1.1 *angular deviation*—the angular displacement of a light ray from its original path caused by non-parallelism of opposite surfaces as it passes through a transparent material, which is expressed in units of angle (degree, minutes of arc, milliradians) and is a function of the angle of incidence at each surface of the material and the index of refraction of the material.

3.1.2 *grid board*—an optical evaluation tool used to detect the presence of distortion in transparent parts. It is usually, but not always, a vertical rectangular backboard with horizontal and vertical intersecting lines with maximum contrast between the white lines and the black background.

4. Summary of Test Method

4.1 The flat transparent part is mounted at a specified distance from a grid board test pattern with its surface parallel with the plane of the grid board test pattern. A camera is placed so as to record a double exposure photograph of the grid pattern as viewed through the transparency from a specified viewing distance from the grid board test pattern. The image is then measured to assess the level of optical deviation present. This method basically measures the amount of angular deviation present in a flat transparent part when viewing through it perpendicular to its surface. The part to be measured must be essentially flat and mounted such that its surface is perpendicular to the camera axis. This is an alternate method to Test Method F801 and is essentially the same as the portion of Practice F733 that deals with optical deviation.

5. Significance and Use

5.1 The optical angular deviation of flat transparent parts, such as aircraft windshields, canopies, cabin windows, and visors, can be measured using these methods. Angular deviation in a windscreen or visor can cause objects to appear at a location different from where they actually are. Variations in angular deviation can be used to characterize distortion and magnification in transparent parts. Also, angular deviation measurements made from the typical right and left eye positions for a windscreen or other transparent medium can be used to determine binocular disparity differences (see Test Method F1181).

6. Apparatus

6.1 *Test Room*—The test room must be large enough to properly locate the required testing equipment.

6.1.1 The walls, ceiling, and floor shall have low reflectance. A flat black paint or coating is preferred.

[1] This test method is under the jurisdiction of ASTM Committee F07 on Aerospace and Aircraft and is the direct responsibility of Subcommittee F07.08 on Transparent Enclosures and Materials.

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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.

6.2 *Grid Board*—The grid board provides a defined pattern against which the transparent part is examined (see Fig. 1). Grid boards are of the following types:

6.2.1 *Type 1*—The grid board is composed of white strings held taut, each spaced at a specific interval, with the strings stretched vertically and horizontally. The grid board frame and background shall have a flat black finish to reduce light reflection. A bank of fluorescent lights at each side provides illumination of the strings.

6.2.1.1 *Type 1a*—The string board is composed of white strings held taut, each spaced at a specific interval, with the strings stretched horizontally only. The string board frame and background shall have a flat black finish to reduce light reflection. A bank of fluorescent lights at each side provides even illumination of the strings. This can also be used outside under natural sunlight conditions.

6.2.2 *Type 2*—The grid board is a transparent sheet having an opaque, flat black outer surface except for the grid lines. The grid lines remain transparent, and when backlit with fluorescent or incandescent lights, provide a bright grid pattern against a black background with excellent contrast characteristics.

6.2.3 *Type 3*—The grid board is a rigid sheet of material which has a grid pattern printed on the front surface. Details of the grid lines, pattern, and lighting shall be as specified by the procuring activity.

6.2.4 *Type 4*—The grid board shall have a width and height large enough so that the area of the part to be imaged can be superimposed within the perimeter of the grid board. Details of the grid square size shall be as specified by the procuring agency. The recommended grid line spacing is not less than 1.27 cm (½ in.), or more than 2.54 cm (1 in.).

6.3 *Camera*—The camera is used to photograph optical deviation through the transparency using a double-exposure method. It is recommended that a large format camera be used, although a high resolution digital camera is acceptable. The camera shall be firmly mounted to prevent any movement during the photographic exposure.

7. Test Specimen

7.1 The transparency to be measured shall be cleaned using any acceptable procedure, to remove any foreign material that might cause localized optical distortion. No special conditioning, other than cleaning, is required. The part shall be at ambient temperature.

8. Procedure

8.1 Firmly mount the flat transparent part parallel to the surface of the grid board target pattern at a distance of 450 cm (Setup A, see Fig. 2) or 300 cm (Setup B, see Fig. 2) or at distance specified by procuring agency.

8.2 Mount the camera a specified distance from the flat transparent part as shown in Fig. 2. This distance is to be 550 cm (Setup A) or 450 cm (Setup B) or some other distance specified by the procuring agency (see Fig. 2). Make sure that the optical axis of the camera is perpendicular to the grid board surface and is aimed at the center of the target panel.

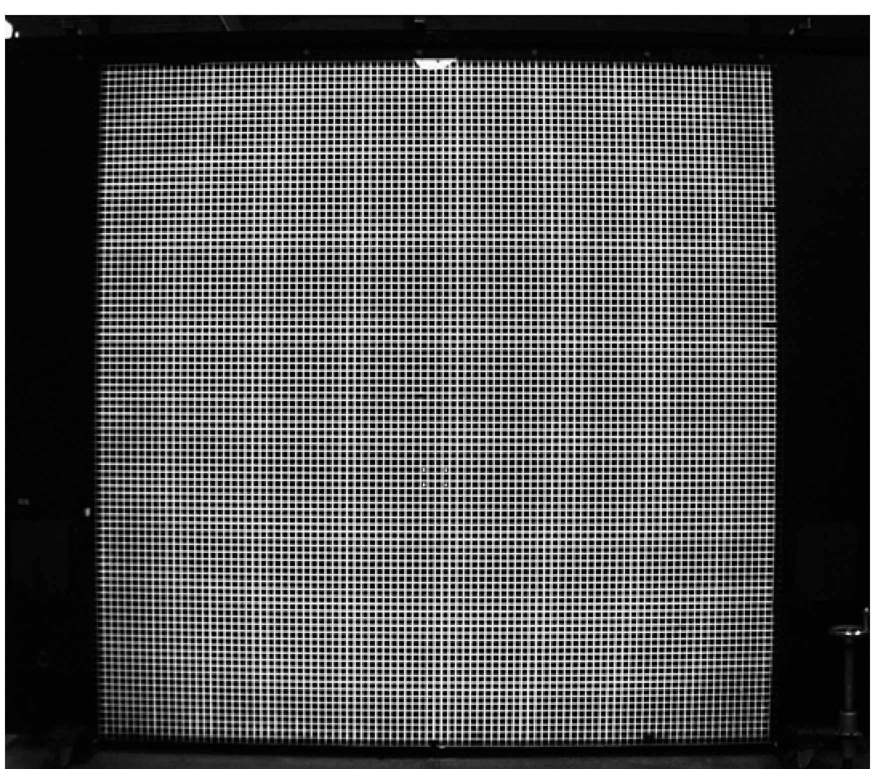

FIG. 1 Grid Board Pattern

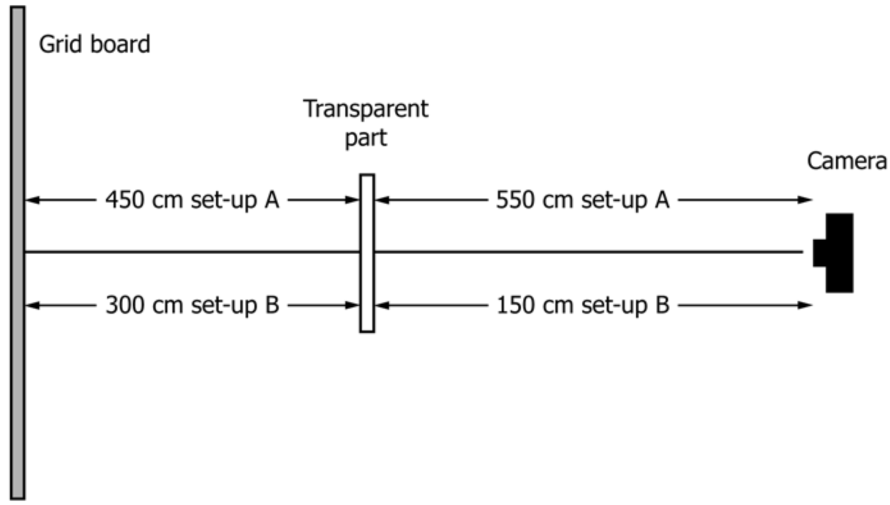

FIG. 2 Suggested Distances for Measurements.

8.3 Insure that the grid board pattern is in good focus at the focal plane of the camera. It is suggested that the F-number of the camera be set at F/8 or higher (smaller aperture) to improve focus.

8.4 Produce a double-exposure photograph by photographing the grid board through the transparency and then, without allowing any movement of the camera and without advancing the film, remove the part and take a second exposure of the grid board alone. Alternatively, if a digital camera is used, the two exposures (with and without the flat transparent part in the optical path) can be superimposed digitally using appropriate image processing software and all measurements can be made on the digitally "double-exposed" image.

8.5 Develop the film and produce 8 by 10 inch. matte finish prints (minimum size). The matte finish will reduce reflection problems during measurement. Alternatively, use the "double-exposed" digital image described above.

8.6 The double-exposure photograph (digital image) is examined to locate the area of maximum grid line shift (between exposures) in either the horizontal or vertical direction (see Fig. 3).

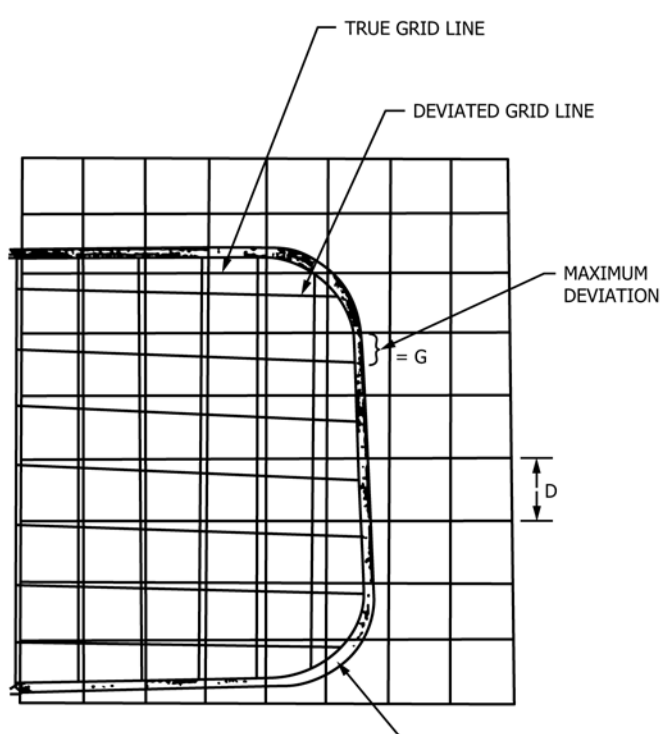

FIG. 3 Example of Double-Exposure Measurement of Optical Deviation

8.7 Measure the maximum grid shift from the true grid line in centimeters (or digital units if a digital image is used) and calculate deviation according to 9.1.

9. Calculations

9.1 Each grid square as photographed represents a specific angular significance, therefore:

$$\text{Angular deviation} = \alpha = S \times G/T \quad (1)$$

where:

α = angular deviation in milliradians,
S = grid significance in milliradians (the angular subtense of one grid square),
G = grid shift as measured on the photograph, cm (or digital units if digital camera is used) and
T = true (undistorted – not imaged through the transparency) grid dimension (i.e., the size of a side of one square of the grid pattern) as measured on the photograph (cm) or digital image (SAME digital units as used to measure G above).

The grid significance, *S*, is calculated using the following equation:

$$\text{Grid significance} = S = 1000 \times (D/P) \quad (2)$$

where:

S = grid significance,
D = actual grid dimension in cm (for example, 2.54 cm), and
P = part-to-grid-board distance in cm.

In order that angular deviation α be in units of milliradians, grid significance *S* must be in milliradians. Grid significance *S* is a nominally unitless parameter, insofar as actual grid dimension *D* and part-to-grid-board distance *P* must be in the same length units. A physical interpretation of the ratio *D/P* in Eq 2 is the tangent of the angle subtended at the part (of length *P* from the grid board) by the actual grid dimension (of length *D*). For angle sizes of 0.114 radians or less, angle size in radians is equivalent to the numerical value of the tangent of the angle (to three decimal places). So it is that the ratio *D/P* represents the subtended angle in radians for angles of 0.114 radians or less (an angle range which fully covers the scope of this standard). The multiplier of 1000 in Eq 2 converts radians to milliradians, thereby placing grid significance *S* in milliradians, as required for angular deviation α to be in units of milliradians.

10. Precision and Bias

10.1 Precision and bias has not yet been determined for this test method. The subcommittee is in process of planning an Interlaboratory Study to collect data for this section.

11. Keywords

11.1 angular deviation; canopy; grid board; optical deviation; transparency