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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~~ 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 ~~*design eye*—the reference point in aircraft design from which all visual or optical anthropometrical design considerations are taken.~~

~~3.1.3~~*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.

~~3.1.4*installed angle*—the transparency (windscreen, canopy, or cabin window) orientation as installed in the aircraft, defined by the angle between a horizontal line (line-of-sight) and a plane tangent to the surface of the transparency (see Fig. 1).~~

4. Summary of Test Method

4.1 The flat transparent part is ~~mounted, preferably~~ mounted at ~~the installed angle,~~ 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 ~~the design eye or other~~ a specified viewing ~~position specified by~~ distance from the ~~procuring agency.~~ 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 ~~compared to a reference part (if required), which is referred~~ when viewing through it perpendicular to ~~as a compensator plate. If the~~ its surface. The part to be measured ~~is~~ must be essentially flat and mounted such that its surface is perpendicular to the camera ~~axis then no~~

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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.

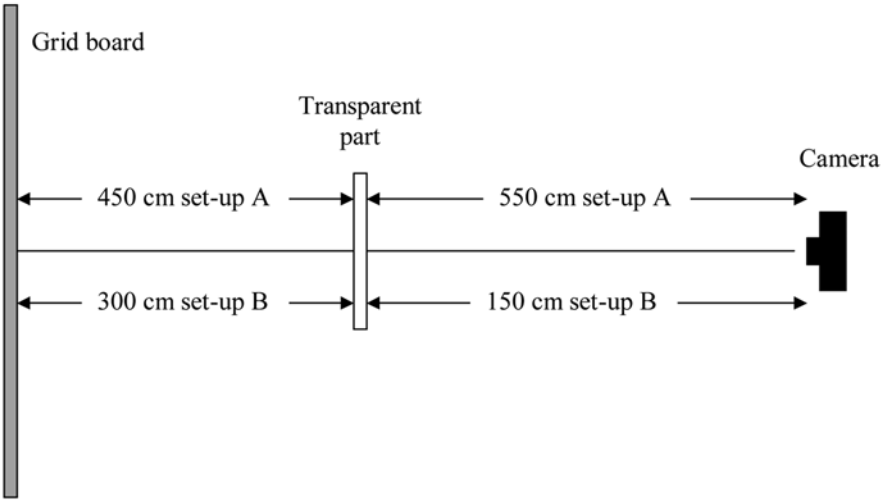

FIG. 2 Suggested Distances for Measurements.

~~compensator/reference part is required.~~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.

6.2 *Grid Board*—The grid board provides a defined pattern against which the transparent part is examined (see ~~Fig. 2~~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 digital camera is acceptable. The camera shall be firmly mounted at design eye (or position specified by the procuring agency) to prevent any movement during the photographic exposure.~~

6.4~~*Compensator Plate*—This is a transparent reference that possesses the same basic characteristics of the transparency that will be measured, that is, thickness, shape, index of refraction. If the measurement area is small, a flat plate of glass may be used. The purpose of the compensator plate is to compensate for lateral displacement of the reference image of the double-exposure images. If the part to be measured is essentially flat and it is mounted so that its surface is perpendicular to the optical axis of the camera, then a compensator plate may not be required.~~ —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.

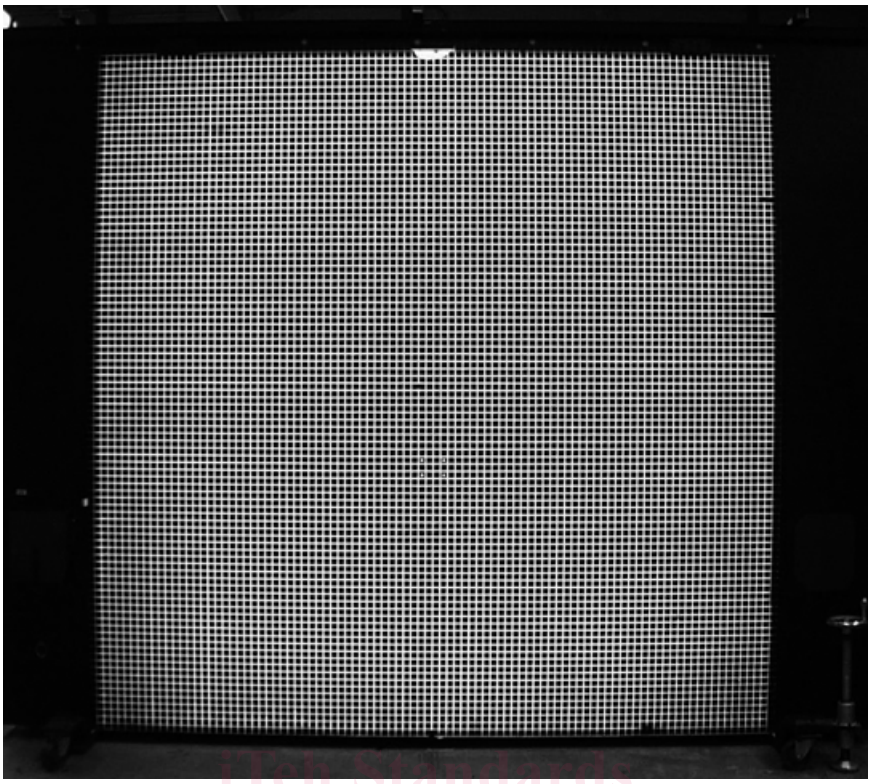

FIG. ~~2~~ 1 Grid Board Pattern

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

~~8.1Optical angular deviation in a transparent part can be measured by one of the following methods:~~

~~8.1.1*Photographic Double-Exposure Method*:~~

~~8.1.1.1Firmly mount the transparent part to be examined to prevent movement during photographing. Mount the part at the installed angle, or the angle specified by the procuring agency. Record the mounted angle, and report it with the results.~~

~~8.1.1.2Mount the camera at design eye position or other position specified by the procuring agency. 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. For photographic camera measurement use high resolution black and white film.~~

~~8.1.1.3Place the grid board a specified distance from the camera as dictated by the procuring agency (see Fig. 1 for some suggested distances) and insure that the grid board pattern is in good focus at the focal plane of the camera.~~

~~8.1.1.4Prepare 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 the second exposure of the grid board alone.~~

~~NOTE1—The second exposure is taken with no transparency in the path only if the part is essentially flat and the part is mounted so that its surface is essentially perpendicular to the camera axis. If this is not the case, then the second exposure must be taken through a reference part and all angular deviation assessments are made with respect to the angular deviation of the reference part. The reference part should have approximately the same thickness, shape, and index of refraction as the parts to be tested.~~

~~8.1.1.5Develop the film and produce 8 by 10 in. matte finish prints (minimum size). The matte finish will reduce reflection problems during measurement.~~

~~8.1.1.6Measure optical deviation as follows:~~

~~8.1.1.7The double-exposure photograph is examined to locate the area of maximum grid line shift in either the horizontal or vertical direction (see~~

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 should 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