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Standard Test Method for Measuring Optical Distortion in Transparent Parts Using Grid Line Slope[1]

This standard is issued under the fixed designation F2156; 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 When an observer looks through an aerospace transparency, relative optical distortion results, specifically in thick, highly angled, multilayered plastic parts. Distortion occurs in all transparencies but is especially critical to aerospace applications such as combat and commercial aircraft windscreens, canopies, or cabin windows. This is especially true during operations such as takeoff, landing, and aerial refueling. It is critical to be able to quantify optical distortion for procurement activities.

1.2 This test method covers the apparatus and procedures that are suitable for measuring the grid line slope (GLS) of transparent parts, including those that are small or large, thin or thick, flat or curved, or already installed. This test method is not recommended for raw material.

~~1.3The values stated in SI units shall be regarded as the standard. The values given in parentheses are for information only.~~

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

1.3.1 *Exception*—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.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

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

F801 Test Method for Measuring Optical Angular Deviation of Transparent Parts

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *design eye*, *n*—the reference point in aircraft design from which all anthropometrical design considerations are taken.

3.1.2 *distortion*, *n*—the rate of change of deviation resulting from an irregularity in a transparent part.

3.1.2.1 *Discussion*—Distortion shall be expressed as the slope of the angle of localized grid line bending, for example, 1 in 5 (see Fig. 1).

3.1.3 *grid board*, *n*—an optical evaluation tool used to detect the presence of distortion in transparent parts.

3.1.3.1 *Discussion*—The grid board 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 *grid line slope*, *n*—an optical distortion evaluation parameter that compares the slope of a deviated grid line to that of a nondeviated grid line.

3.1.4.1 *Discussion*—The degree of deviation shall be indicated by a ratio, for example, 1 in 2, 1 in 8, or 1 in 20 (the visual optical quality improves as the second number gets larger.)

3.1.5 *installed angle*, *n*—the transparency 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. 2).

3.1.6 *repeatability limit (rL)*, *n*—from Practice E177, 27.3.2, "approximately 95 % of individual test results from laboratories

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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.

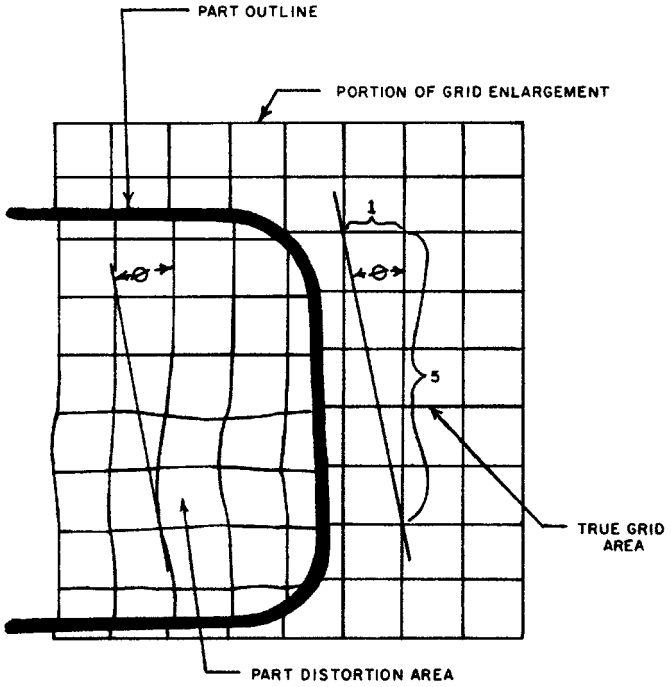

FIG. 1 Optical Distortion Represented By Tangent

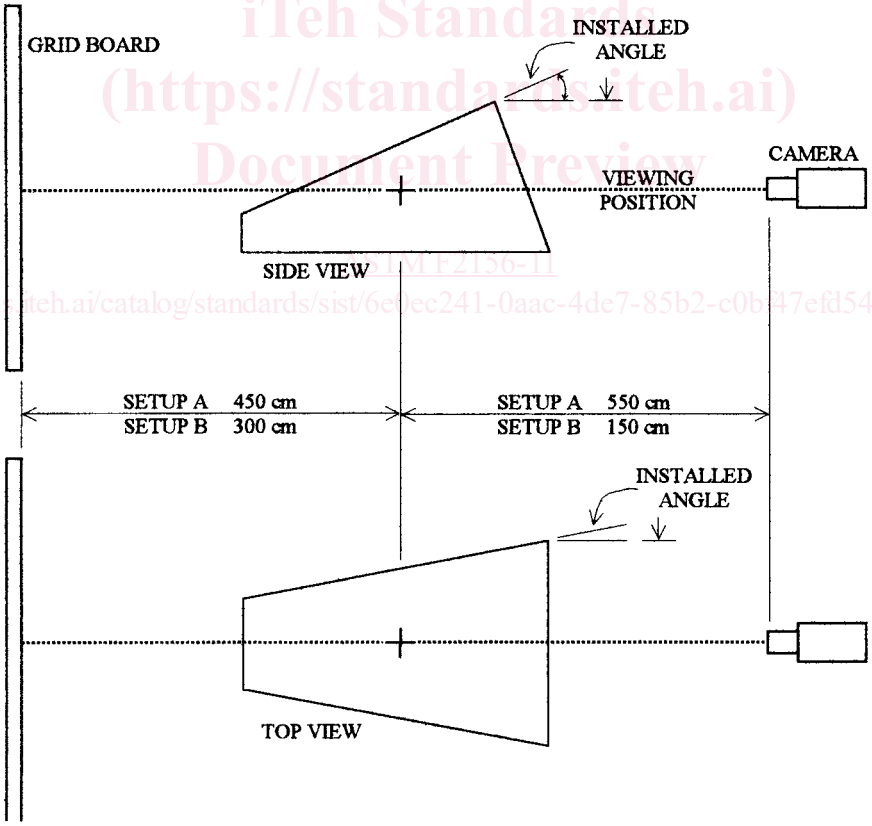

FIG. 2 Schematic Diagrams of GLS Photographic Recording Distances

similar to those in an Inter-laboratory Study (ILS) can be expected to differ in absolute value from their average value by less than 1.96*s* (about 2*s*).”

3.1.6.1 *Discussion*—in terms of this test method, approximately 95 % of all pairs of replications from the same evaluator and the same photo differ in absolute value by less than the *rL*.

3.1.7 *reproducibility limit (RL), n*—from Practice E177, 27.3.3, "approximately 95 % of all pairs of test results from laboratories similar to those in the study can be expected to differ in absolute value by less than $1.960\sqrt{2}s$ (about $2.0\sqrt{2}s$) = $2.77s$ (or about $2.8s$). This index is also known as the 95 % limit on the difference between two test results."

3.1.7.1 *Discussion*—in terms of this test method, approximately 95 % of all pairs of replications from different evaluators and the same photo differ in absolute value by less than the *RL*.

4. Summary of Test Method

4.1 The transparent part shall be mounted, preferably at the installed angle, at a specified distance from a grid board test pattern. A photographic camera shall be placed so as to record the grid pattern as viewed through the part from the design eye (or other specified) viewing position. If the viewing position is not defined, the values in Table 1 may be used as photographic test geometry. The image is then analyzed to assess the level of optical distortion as measured by grid line slope.

4.2 Distortion shall be recorded using either a single-exposure photograph or a double-exposure photograph. The photographed grid shall then be measured using either a drafting machine procedure or a manual procedure. Each procedure has its own level of precision.

5. Significance and Use

5.1 Transparent parts, such as aircraft windshields, canopies, cabin windows, and visors, shall be measured for compliance with optical distortion specifications using this test method. This test method is suitable for assessing optical distortion of transparent parts as it relates to the visual perception of distortion. It is not suitable for assessing distortion as it relates to pure angular deviation of light as it passes through the part. Either Test Method F801 or Practice F733 is appropriate and shall be used for this latter application. This test method is not recommended for raw material.

6. Apparatus

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

6.1.1 Setup A requires a room approximately 12 m (40 ft) long.

6.1.2 Setup B requires a room approximately 7 m (23 ft) long.

6.1.3 Setup C: other distances shall be used if desired. GLS results will vary with different distances, which means that measurements of different parts taken at different distances cannot be compared.

6.1.4 The walls, ceiling, and floor shall have low reflectance. A flat black paint or coating is preferred though not required.

6.2 *Grid Board*—The grid board shall provide a defined pattern against which the transparent part is examined. Grid boards shall be one of the following types:

6.2.1 *Type 1*—The grid board shall be 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 or evenly distributed natural sunlight conditions provide illumination of the strings.

6.2.2 *Type 2*—The grid board shall be 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 shall be a rigid sheet of material that 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 The grid board shall have a width and height large enough so that the area of the part to be imaged is superimposed within the perimeter of the grid board. Details of the grid square size shall be as specified by the procuring activity. The recommended grid line spacing shall be not less than 1.27 cm (½ in.) or more than 2.54 cm (1 in.).

6.3 *Camera*—The camera shall be used to photograph distortion for the evaluation of grid line slope. For highest resolution, it is recommended that a large format camera be used, although a 35-mm camera is also acceptable. Black-and-white film shall

TABLE 1 GLS Photographic Recording Distances

Setup A	
Camera-to-grid-board distance	1000 cm (32 ft 10 in.)[A]
Camera-to-part distance	550 cm (18 ft 1 in.)
Part-to-grid-board distance	450 cm (14 ft 9 in.)
Setup B	
Camera-to-grid-board distance	450 cm (14 ft 9 in.)
Camera-to-part distance	150 cm (4 ft 11 in.)
Part-to-grid-board distance	300 cm (9 ft 10 in.)
Setup C	
Camera-to-grid-board distance	User defined
Camera-to-part distance	User defined[B]
Part-to-grid-board distance	User defined

[A] All measurements shall be ±3 cm or ±3 %, whichever is smaller.

[B] It is recommended that the camera-to-part distance be the design eye distance.