Designation: F733 – 09 (Reapproved 2014)

Standard Practice for Optical Distortion and Deviation of Transparent Parts Using the Double-Exposure Method[1]

This standard is issued under the fixed designation F733; 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 photographic practice determines the optical distortion and deviation of a line of sight through a simple transparent part, such as a commercial aircraft windshield or a cabin window. This practice applies to essentially flat or nearly flat parts and may not be suitable for highly curved materials.

1.2 Test Method F801 addresses optical deviation (angluar deviation) and Test Method F2156 addresses optical distortion using grid line slope. These test methods should be used instead of Practice F733 whenever practical.

1.3 *This standard does not purport to address the safety concerns 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:*

F801 Test Method for Measuring Optical Angular Deviation of Transparent Parts

F2156 Test Method for Measuring Optical Distortion in Transparent Parts Using Grid Line Slope

3. Terminology

3.1 *Definitions:*

3.1.1 *deviation*—the displacement of a line or object when viewed through the transparent part. Expressed as the angular measurement of the displaced line, for example, milliradians of angle.

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

3.1.3 Expressed as the angular bending of the light ray per unit of length of the part, for example, milliradians per centimetre.

3.1.4 May also be expressed as the slope of the angle of localized grid line bending, for example, 1 in 5 (see Fig. 1).

3.1.5 *installed angle*—the part attitude as installed in the aircraft. Defined by the angle between a horizontal line and the plane of the part, and the angle of sweep back from a horizontal line normal to the center line of the aircraft. See Fig. 2 for an example.

4. Summary of Practice

4.1 The transparent part is placed a given distance from a grid line pattern. A camera is placed so as to photograph the grid pattern as viewed through the part. The photograph is then examined and optical distortion or deviation is measured.

5. Significance and Use

5.1 Transparent parts, such as aircraft windshields and windows, can be inspected using this practice, and the amount of optical distortion or deviation can be measured. The measurement can be checked for acceptability against the specification for the part. The photograph (digital file, print or negative) can be maintained as a permanent record of the optical quality of the part.

6. Apparatus

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

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

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

6.1.3 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. 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.

[1] This practice 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.

Current edition approved Dec. 1, 2014. Published December 2014. Originally approved in 1981. Last previous edition approved in 2009 as F733 – 09. DOI: 10.1520/F0733-09R14.

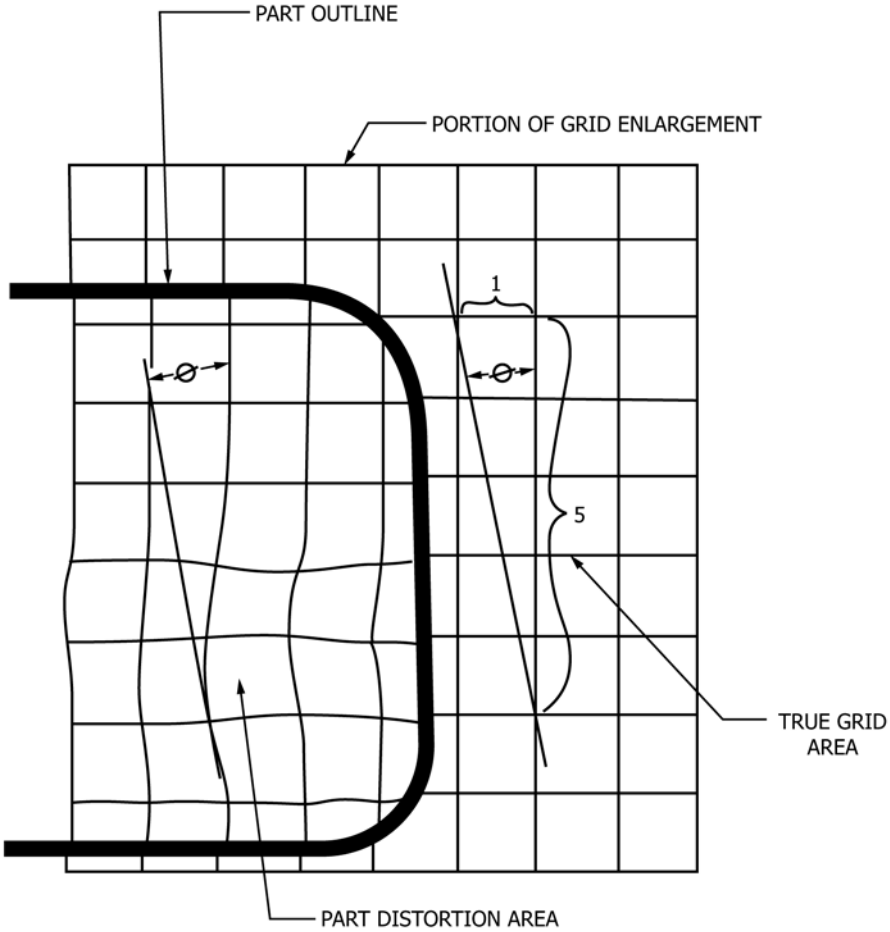


FIG. 1 Optical Distortion Represented by Tangent

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 are left transparent, and when lighted from behind with fluorescent lights, provide a bright grid pattern with excellent photographic characteristics.

TABLE 1 Optical Inspection Distances

Method A	
Camera-to-grid-board distance	1000 cm (32 ft 10 in.)
Camera-to-part distance	550 cm (18 ft 1 in.)
Part-to-grid board distance	450 cm (14 ft 9 in.)
Method 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.)

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 The grid board shall have a width and height large enough so that the area of the part to be photographed can be superimposed within the perimeter of the grid board. Details of the grid square size shall be as specified by the procuring activity, but grids shall not have a line spacing less than 1.27 cm (½ in.), or more than 2.54 cm (1 in.).

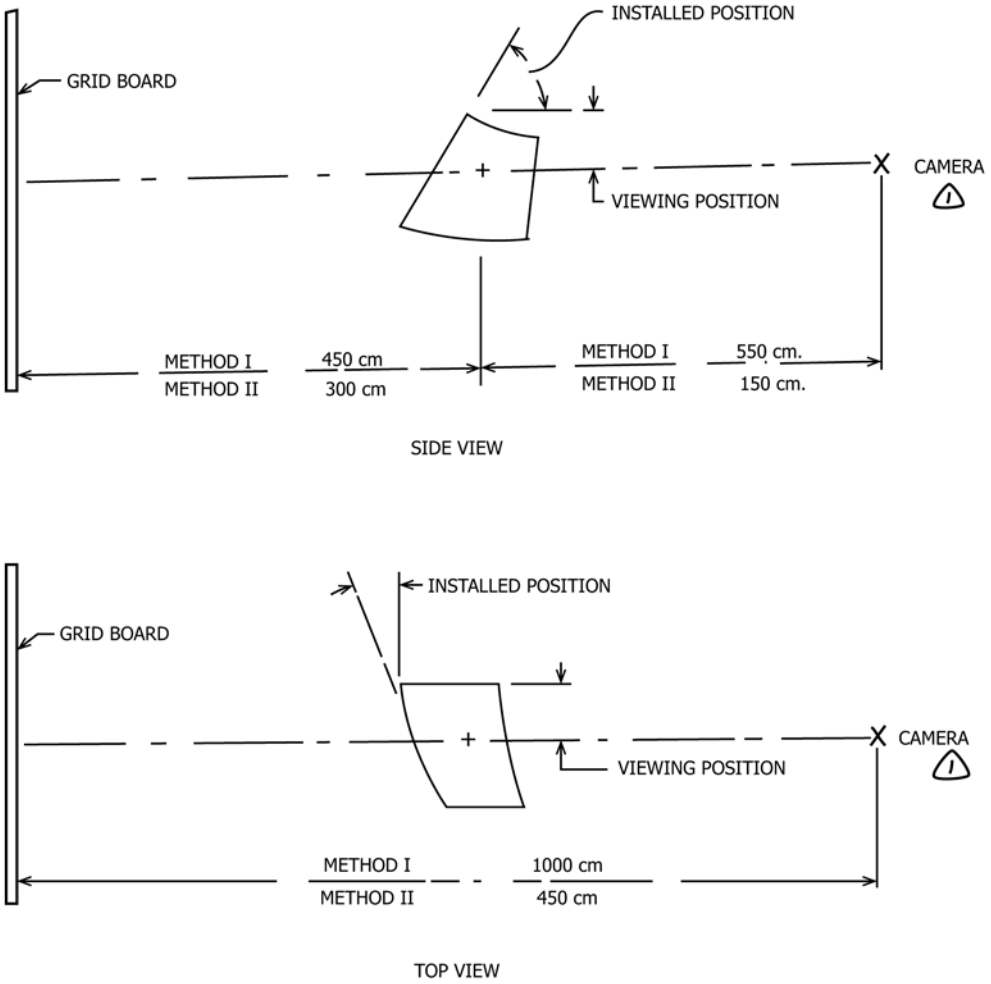
6.3 *Camera*—Unless otherwise specified, the camera shall utilize a 4 by 5-in. film size. The lens opening used shall be f 8 or smaller. The camera shall be firmly mounted to prevent any movement during the photographic exposure. Digital cameras are acceptable if they have sufficient resolution (pixel count) for the size of part to be measured.

7. Test Specimen

7.1 The part to be checked 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 The procuring activity shall specify whether Method A or Method B (see Table 1) or some other set of distances shall be used to measure optical distortion and deviation. If Method A or Method B are not used, the actual distances used shall be reported. When the part is flat and mounted nearly vertical, Method A is a more stringent test than Method B. Certain parts may show substantial optical deviation by Method B simply due to refraction of the light rays. If the part is a windscreen the procuring activity may require the camera to be positioned at the pilot's eye position.



NOTE 1—The camera viewing position line of sight shall be through the center of the pilot's eye position for the part as specified by the procuring activity.

FIG. 2 Example of Installed Angle

8.2 Measure optical distortion through the part by the following procedure:

8.2.1 Mount the transparent part to be examined firmly to prevent movement during photographing. The mounted angle of the part shall be as specified by the procuring activity. It is recommended that the part be mounted at the installed angle. Record the mounted angle, and report with the results.

8.2.2 The distances for positioning of camera, part, and grid board shall be in accordance with Method A or Method B as shown in Table 1 or as determined by the procuring activity. A depiction of the set up is shown in Fig. 2.

8.2.3 Prepare a single exposure photograph of the grid board viewed through the part. The camera shall be focused on the grid board.

8.3 Photograph optical deviation through the part by the following procedure.

8.3.1 Prepare a double exposure photograph. Photograph the grid board through the part as in 8.2. Then, without allowing any movement of the camera, remove the part and make the second exposure of the grid board alone. If a digital camera is used the two exposures can be digitally superimposed with the aid of a computer and appropriate software.

8.4 Evaluate optical distortion or deviation for the transparent part by projecting or printing the negative suitably enlarged, and measuring the distortion or deviation. The projection or print shall be a minimum of one fifth the linear dimensions of the part photographed. See Fig. 1 for one method of optical distortion evaluation, and Fig. 3 for an example of optical deviation. Alternatively, analysis of the image can be accomplished on a computer (if a digital camera is used) using appropriate image analysis software.

9. Calculation

9.1 *General Information*—The following information is given to aid in the explanation of optical distortion and deviation measurements:

$$S = \frac{D \times 1000}{P} \tag{1}$$

where:

S = grid square signfiicance in milliradians,
D = grid dimension, cm, and,
P = part-to-grid-board distance, cm.

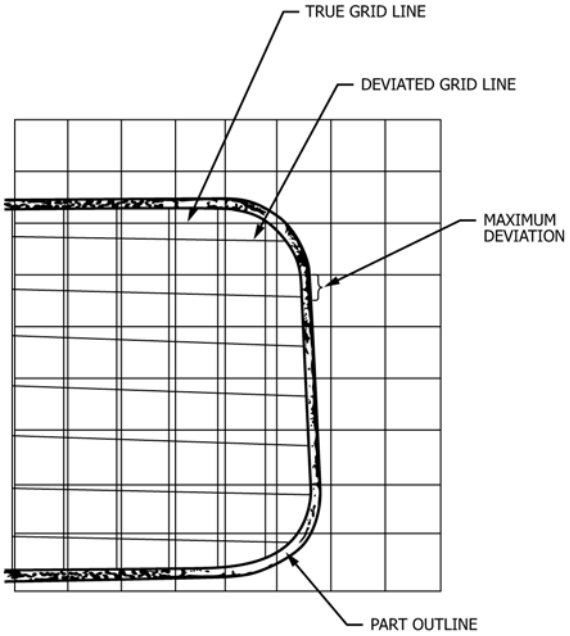


FIG. 3 Optical Deviation—Double Exposure

$$M = \frac{C_g}{C_p \times G} \quad (2)$$

where:

M = number of grid lines subtended by the view through one-linear centimetre of the transparent parts,
C_g = camera-to-grid-board distance, cm,
C_p = camera-to-part distance, cm, and
G = grid size, cm.

9.2 *Optical Distortion*—Optical distortion in a transparent part can be measured by the following methods:

9.2.1 The projected or printed photograph negative or digital image is examined to locate the area of maximum grid line distortion in either the horizontal or vertical direction. The slope of the distorted grid line is described in terms of grid squares of run for one grid square of slope. The example shown in Fig. 1 has a slope of one to five.

9.2.2 This method expresses optical distortion as milliradians per centimetre of part. The photograph negative or digital image is examined as described in 9.2.1 but the angle of slope, θ (see Fig. 1), is converted to the natural tangent, that is, 0.200.

$$\text{Optical Distortion} = S \times M \times \text{Tangent } \theta \quad (3)$$

9.2.3 This method of measuring optical distortion is possible when a precision grid is used (all grid squares are of identical size ±0.15 mm). The distortion is expressed in milliradians per centimetre of part. The projected or printed photograph is examined as described in 9.2.1 to locate the area of maximum distortion. The height, width, or diagonal of the most severely distorted grid square or consecutive squares is accurately measured to ±3 % of the grid size as projected or printed. The identical dimension is measured on a true grid square or squares (the grid portion outside the area of the part, see Fig. 1). The decimal ratio of the stretch or compression (length change) of the distorted grid section to an identical true grid section is calculated [for example, R = (6.30 mm – 5.25 mm) ÷ 5.25 mm = 0.200].

$$\text{Optical Distortion} = S \times M \times R \quad (4)$$

where:

R = decimal ratio of the *length change* distorted grid section to the true grid section.

9.3 *Optical Deviation*—It should be noted that neither Method A nor Method B measures the exact optical deviation (angular deviation, see Test Method F801 for alternative procedures) of the part. This is due to refraction of certain of the light rays dependent on mounting angle, part contour and thickness, or other factors. This inherent deviation should be taken into account when evaluating the part. Optical deviation in the part is measured as follows. (Note that this procedure only works if the part is essentially flat and mounted such that the plane of the surface is perpendicular to the optical axis of the camera and parallel with the grid board surface.)

9.3.1 The projected or printed double exposure photograph is examined to locate the area of maximum grid line shift in either the horizontal or vertical direction. Each grid square as photographed represents a specific angular significance, therefore the angular deviation, in milliradians is given by:

$$\text{Deviation} = S \times \frac{G}{T} \quad (5)$$

where:

S = grid significance in milliradians,
G = maximum grid shift, cm, and
T = true grid dimension, cm.

See Fig. 3 for an example of optical deviation.

10. Precision and Bias

10.1 Since this ASTM document is written as a practice, no Precision and Bias section is required. However, Test Methods F801 (optical deviation or angluar deviation) and Test Method F2156 (optical distortion using grid line slope) address essentially the same parameters as this practice does, but, since they are test methods, they contain Precision and Bias information.

11. Keywords

11.1 distortion; grid-line slope; optical deviation; optical distortion; transparency quality