Designation: F1181 – 09 (Reapproved 2014)

Standard Test Method for Measuring Binocular Disparity in Transparent Parts[1]

This standard is issued under the fixed designation F1181; 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 amount of binocular disparity that is induced by transparent parts such as aircraft windscreens, canopies, HUD combining glasses, visors, or goggles. This test method may be applied to parts of any size, shape, or thickness, individually or in combination, so as to determine the contribution of each transparent part to the overall binocular disparity present in the total "viewing system" being used by a human operator.

1.2 This test method represents one of several techniques that are available for measuring binocular disparity, but is the only technique that yields a quantitative figure of merit that can be related to operator visual performance.

1.3 This test method employs apparatus currently being used in the measurement of optical angular deviation under Method F801.

1.4 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.5 *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

3. Terminology

3.1 *Definitions:*

3.1.1 *angular deviation*—the angular displacement of a light ray as it passes through a transparent part, expressed as an angular measurement, for example, degree, minutes of arc, milliradians. Since it is an angular measurement, the amount of linear displacement increases with distance.

3.1.2 *binocular disparity*—the difference between the two images on the retina resulting from the lateral separation between the two eyes when viewing an object at a fixation point or due to the fact that an object is either nearer or farther than the fixation point. A certain amount of disparity is beneficial and natural, leading to the perception of depth. However, when the disparity exceeds the limits for binocular fusion, doubling of vision, eye fatigue, and headaches occur as the eyes strain to merge the disparate images.

3.1.3 *diplopia*—the doubling of images of an object due to the fact that the object is either nearer or farther than the point of fixation or due to the fact that the lines of regard of the eyes do not intersect at the point of fixation.

3.1.4 *Panum's area*—the area on the retina in which the eyes are able to fuse disparate images so that single vision occurs.

4. Summary of Test Method

4.1 Using an optoelectronic system (consisting of a transmitter and a receiver, described in Test Method F801) and with the part held in its installed angle, two sets of angular deviation measurements are made at several intervals (for example, 2°) in both azimuth and elevation. The extent of the area to be measured is dependent on the type of part being measured, for example, windscreen, visor, and so forth. The first set of measures is taken from the left eye position, the second from the right eye position. The separation between the two eye positions is 2.5 in. (6.35 cm), a distance equivalent to the interpupillary distance between the human eyes. The measurements taken from the left eye position are subtracted from that taken from the right eye position to determine binocular disparity.

5. Significance of Use

5.1 Diplopia or doubling of vision occurs when there is sufficient binocular disparity present so that the bounds of Panum's area (the area of single vision) is exceeded. This condition arises whenever one object is significantly closer (or

[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.

Current edition approved Dec. 1, 2014. Published December 2014. Originally approved in 1988. Last previous edition approved in 2009 as F1181 – 09. DOI: 10.1520/F1181-09R14.

[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.

farther) than another so that looking at one will cause the image of the other to appear double. This can be easily demonstrated: Close one eye and look at a clock (or other object) on a distant wall. Now place your thumb to one side of the image of the clock. Now open both eyes. If you look at the clock, you should see two thumbs. If you look at your thumb, you should see two clocks.

5.2 Complaints from pilots flying aircraft equipped with wide field of view head up displays (HUDs) such as the LANTIRN HUD indicated that they were experiencing discomfort (eye fatigue, headaches, and so forth.) or seeing either two targets or two pippers (aiming symbols on the HUD) when using the HUD. Subsequent investigations revealed that the problem arose from the fact that the aircraft transparency and the HUD significantly changed the optical distances of the target and the HUD imagery so that binocular disparity, which exceeded Panum's area was induced. Use of this test method provides a procedure by which the amount of binocular disparity being experienced by a human operator due to the presence of a transparent part in his field of view may be easily and precisely measured.

6. Apparatus

6.1 *Transmitter* capable of projecting collimated light rays from a suitable target. The transmitter should be firmly fixed to the floor or other stationary fixture.

6.2 *Receiver* firmly affixed to the floor or a stable platform consisting of the following components:

6.2.1 *Displacement Compensation and Imaging Lens* with a focal length of 10 in. (254 mm).

6.2.2 *Optical Beam Splitter* to separate the incoming light into two orthogonal elements (elevation and azimuth). The beam splitter should be positioned to keep both optical path lengths equal.

6.2.3 *Two Linear Charge Coupled Devices (CCD or diode) Arrays,* each located at the focal plane of the displacement compensating lens. One array is oriented horizontally (for the measurement of azimuthal changes) and the other oriented vertically (for the measurement of elevation changes). An appropriate element spacing of the arrays is 0.001 in. (0.0254 mm). Using this element spacing and the 10-in. (254-mm) lens, each diode will represent the equivalent of 0.1 mrad angular deviation.

6.2.4 *Electronic System* that determines the center diode of the band of illuminated diodes on each CCD array.

6.2.5 *Electronic System* that converts the number to be displayed on the digital readout.

6.3 *Transmitter and Receiver Lenses* should be of achromatic construction to reduce the effect of aberrations on the measurement.

6.4 *Dioptomer* to verify attainment of collimated light.

7. Test Specimen

7.1 Position the part to be tested in such a manner as to approximate its installed configuration. No special conditioning other than cleaning is required.

8. Procedure

8.1 Mount the transparent part on a fixture that allows accurate determination of the elevation and azimuth position of the part.

8.2 Locate and firmly mount the transmitter at a position corresponding to the design eye position (the cyclopean eye position). To obtain the position corresponding to the left (right) eye position, move the transparency 1.25 in. (31.7 mm) to the right (left) of the design eye position.

8.3 Locate and firmly mount the receiver external to the part to be measured and at a distance from the transmitter that is commensurate with the part being measured (sufficient to ensure the part being measured will not physically contact the receiver unit).

8.4 Establish a baseline or zero determination without a transparency in the optical path. Record the number as displayed on the digital readout under this condition.

8.5 Locate the transparency part between the transmitter and receiver. Take the readings from the left (right) eye position over area of interest as specified by using activity. Record readings for each point (azimuth, elevation) of the transparency that is measured. Determine differences between these readings and readings (8.4) made without the transparency in place.

8.6 Repeat 8.5, taking readings with the transmitter located and firmly mounted at right (left) eye position or as appropriate.

9. Calculation and Report

9.1 Determine the amount of horizontal and vertical binocular disparity present in the transparent part by completing the calculations set forth in paragraphs 9.1.1 – 9.1.4. Azimuth scores will yield horizontal disparity, elevation scores will yield vertical disparity.

9.1.1 Determine the amount of disparity present at each point (azimuth, elevation) on the transparent part by subtracting the readings from the left eye position from the readings taken from the right eye positions using the equations as follows:

$$D_x = X_L - X_R \text{ (disparity in azimuth)} \quad (1)$$

$$\text{or } D_y = Y_L - Y_R \text{ (disparity in elevation)} \quad (2)$$

9.1.2 Calculate the mean for these disparity readings using the Eq 3. This yields the average of the disparity readings found throughout the part.

$$\bar{D}_x = \sum D_x / N \text{ or } \bar{D}_y = \sum D_y / N \quad (3)$$

where:

$\bar{D}_x$ = mean for azimuth,
$\sum D_x$ = sum of azimuth readings,
N = number of readings,
$\bar{D}_y$ = mean for elevation, and
$\sum D_y$ = sum of elevation readings.

9.1.3 Calculate the standard deviation for these readings using the Eq 4 shown below. This yields a measure of the dispersion or variability of the readings obtained from a given part.

$$S_x = \sqrt{\frac{\sum D_x{}^2 - \left(\sum D_x\right)^2/N}{N-1}} \quad (4)$$

where:

S_x = standard deviation for azimuth,
$\sum D_x{}^2$ = sum of the squares for each reading,
$(\sum D_x)^2$ = sum of all readings squared,
N = number of readings, and
$N - 1$ = degrees of freedom.

9.1.4 Inspect the data to determine the largest absolute value for the readings obtained. This is the maximum error for the given readings.

9.2 Compare the scores obtained (mean, standard deviation, and max error) with scores given in appropriate specifications regarding the amount of disparity allowable in a given transparency. For current aircraft transparencies, this value is typically 10 min of arc (3 mrad).

NOTE 1—This value is composed of 2 components, for example, geometric errors due to shape, thickness, and so forth. of the windscreen and manufacturing errors due to the process materials tolerances, and so forth.

10. Precision and Bias

10.1 The data used to develop this section was obtained as the result of a round-robin test reported at the September 1990 F07.08 subcommittee meeting. The written report was entitled "Angular Deviation Revisited: Results of a Round Robin Test" and is available from ASTM headquarters. This round-robin test was done in support of Test Method F801 but is applicable here since the same basic device and procedure is used to obtain the data for calculating the binocular disparity.

10.2 There are two primary sources of error with this procedure: 1) those dealing with the measurement device itself, and 2) those dealing with the positioning of the part to be measured. Since this procedure only addresses the measurement device and not positioning equipment, this section will be confined to data relating to the precision of the measurement device itself.

10.3 The round-robin testing accomplished for F801 used a calibrated wedge to compare results between five measurement devices located at three laboratories. The overall repeatability was found to be ±0.1 milliradians for the 95 % confidence level. If the error sources are random then the calculated repeatability of a number that involves the subtraction of 2 measurements would be 1.414 times the repeatability of the single number. This implies the repeatability for the binocular disparity calculation is ±0.14 milliradians.

10.4 The overall 95 % confidence level reproducibility of the procedure for measuring angular deviation was found to be ±0.29 milliradians for a 5.07 milliradian calibrated wedge (or about 6 %). This implies the 95 % confidence level reproducibility of the binocular disparity calculation is 1.414 times 0.29 which is 0.41 milliradians or about 8 %.

10.5 There is no bias with this procedure since the calculation involves subtracting one reading from the other which removes any bias from the resulting relative number.

11. Keywords

11.1 angular deviation; binocular disparity; binocular vision; diplopia; double vision