Designation: F1252 – 21

Standard Test Method for Measuring Optical Reflectivity of Transparent Materials[1]

This standard is issued under the fixed designation F1252; 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 a procedure for measuring the reflectivity of transparent materials, hereafter known as specimens. The results are repeatable without specifying a particular brand name of instrumentation.

1.2 This test method applies to substantially flat parts. Errors in measurement can occur if the parts being measured are not substantially flat.

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

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Terminology

2.1 *Definitions:*

2.1.1 *angle of incidence* (Θ_i), *n*—in the plane of the light source, specimen, and photometer, the angle of incidence is the angle between the incident light ray and the normal to the surface (see Fig. 1).

2.1.2 *angle of reflection* (Θ_r), *n*—in the plane of the light source, specimen, and photometer, the angle of reflection is the angle between the reflected light ray and the normal to the surface (see Fig. 1).

2.1.3 *light source, n*—unless otherwise specified, the National Institute of Standards and Technology (NIST) diffused nonpolarized Standard Illuminance A or C light source shall be used. The light source size shall be such that there shall be sufficient overlap of the front and rear images on the specimen to overfill the measurement field size of the photometer. This measurement field size, and front and back reflected image overlap, are illustrated in Fig. 2. (As angle of incidence and specimen thickness increase, the two images will diverge.) The light source used shall be specified and reported as part of the test results.

2.1.4 *measurement field size, n*—the angular extent, in degrees or arc minutes, of the measurement aperture of the photometer.

2.1.5 *photometer, n*—any commercial photometer or photopic filtered radiometer with a suitable measurement field size (1° or smaller is recommended). A model with a viewfinder is recommended.

2.1.6 *pivot point, n*—the point in space at which the incident light ray and reflected light ray are to intersect (see Fig. 1).

2.1.7 *reflectivity, adj*—the reflectivity of a transparent specimen is defined as the ratio of the luminance of the reflected image of a light source to the luminance of the light source. The reflectivity will depend upon several factors: the angle at which the reflected light is measured, the thickness, surface quality, and type of material of the specimen, whether the specimen is coated, the spectral distribution of the light source, and the spectral sensitivity of the measurement device. The reflectivity, as defined here, includes the small amount of scattered light that contributes to the luminance of the reflected image.

3. Summary of Test Method

3.1 The luminance of the standard source is determined by measuring it directly with the photometer. The luminance of the reflection of the source, from both the front and back surfaces of the specimen, is then measured off the specimen at a specified geometry. The luminance of the reflection is divided by the luminance of the source to obtain the reflectivity of the specimen.

[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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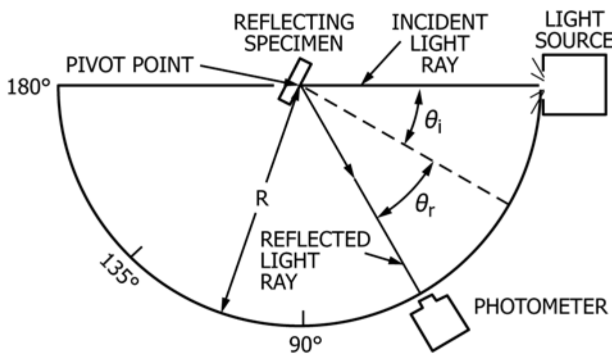

FIG. 1 Apparatus Set-Up

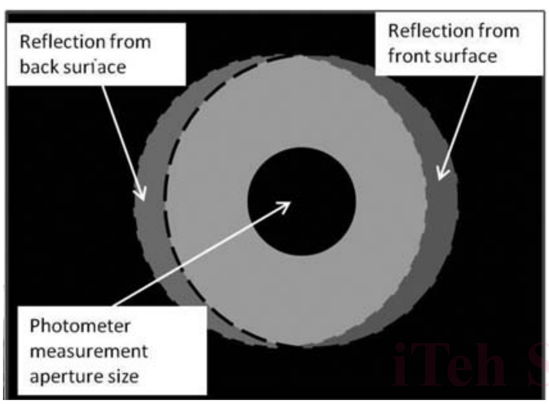

FIG. 2 Photometer Measurement Field Size (Aperture) Compared to Specimen Front and Back Surface Reflections

4. Significance and Use

4.1 Reflections from aircraft transparencies of instrument lights and other cockpit objects have been a concern to many pilots. Attempts to reduce these reflections have been hampered by the lack of a repeatable measurement method and variances in reflection measuring instrumentation.

4.2 This test method reduces the instrument variations by standardizing the light source, calculation method, and area of specimen surface being measured; a brand of instrumentation is not specified. Since the reflectivity is defined as the ratio of two luminance measurements and does not depend on an absolute measurement, dependence upon the accuracy of the calibration of the measuring instrument is reduced.

4.3 The test method may be used to objectively compare the reflection characteristics of various transparent materials. Furthermore, the test method may be used to evaluate reflections of a specified spectral distribution light source (for example, a monochromatic light-emitting diode) by using that source in place of the standard light source.

4.4 Provisions are made to check for polarization effects of the sample and to record the reflectivity of a standard specimen. These provisions are offered as an option to the tester; it is up to the user or the requiring agency to determine the significance and use of these data.

4.5 Since the reflections are measured photopically, the results are representative of what the pilot would visually perceive.

5. Apparatus and Setup

5.1 The apparatus shall be set up as shown in Fig. 1.

5.2 The angle of incidence Θ_i shall be determined by the user or requiring agency. Since $\Theta_i = \Theta_r$, the total angle of reflection $\Theta = 2\Theta_i = 2\Theta_r$. Θ_i and Θ_r shall be accurate to within ±0.5°, hence Θ shall be accurate to within ±1°.

5.3 The distance from the light source to the specimen and from the specimen to the photometer is not critical. However, it is desirable to position the light source relatively far from the sample (for example, 50 cm or more) to minimize the effects of scattered light from the specimen contaminating the reflectivity measurement. The light source to specimen distance must be such that the reflected image viewed through the photometer is sufficiently large to overfill the photometer measurement field (see 2.1.3 and Fig. 2). The distance from the specimen to the photometer must be short enough to ensure the reflected images overfill the measurement aperture but long enough to ensure the photometer can focus on the image.

5.4 The testing shall be done in a room with controlled lighting such that the photometer reading with the reference light off is less than 0.1 % of the reflection reading measured with the reference light on. This will ensure ambient room light contamination of the results is less than 0.1 %.

5.5 A flat black surface (such as black velvet) may be positioned behind (but not touching) the specimen during measurement to reduce possible ambient light contamination effects.

5.6 The photometer measurement aperture size (for example, 1°), the reference light source emitting surface size (for example 5 cm circular), the distance from the reference light source to the specimen, the distance from the photometer to the specimen and the angle of incidence shall all be included in the report.

6. Procedure

6.1 Allow the light source and photometer to warm up in accordance with the manufacturer's specification.

6.2 The pivot point is the point in space at which the front surface of the specimen shall be placed (6.5) such that the reflection occurs at the desired geometry. Establish the pivot point by marking the point with a small object, such as a piece of cardboard. Position the light source at a proper distance from the pivot point (5.3).

6.3 Locate the photometer such that the light source, pivot point, and photometer are in line (see Fig. 3). Direct the photometer such that its measurement field is centered on the

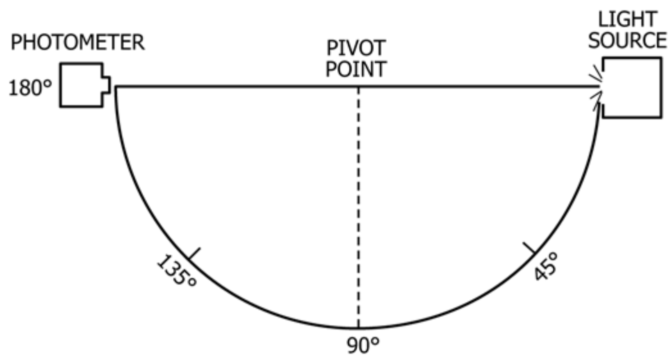

FIG. 3 Apparatus Set-Up for Source Measurement

light source. Focus the photometer on the light source and record the luminance *L*.

6.4 Locate the photometer at a position equidistant from the pivot point such that the angle between the source, pivot point, and photometer is twice the desired angle of incidence[2] (see Fig. 1). Direct the photometer such that the pivot point is centered in the FOV.

6.5 Position the specimen such that the center of the front surface is at the pivot point. Remove any object that may have been used to mark the pivot point. Keeping the photometer and source fixed, adjust the attitude of the specimen until the image of the source completely covers the photometer's measurement field. Depending on the specimen, the image of the source may be separated into two images due to reflections from the front and back surfaces of the specimen (Fig. 2). In this case, position the source such that the overlapping region of the images is centered over the measurement field. Focus the photometer on the image of the source and measure the luminance of the source reflection using the specimen. Record this value as L_s.

6.6 (Optional) Repeat the measurement as in 6.5 and with the transparent specimen rotated 90° around an axis normal to the surface. Record this reading as L_p (see Fig. 4).

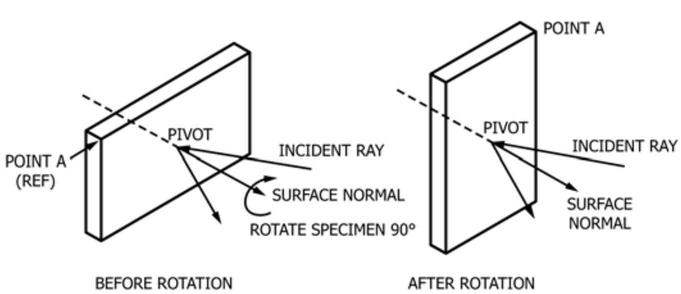

FIG. 4 Rotation of Sample for Polarization Check

6.7 Steps 6.3 – 6.6 shall be repeated a minimum of three times for each specimen (varying the location of the reflection upon the surface of the specimen each time) to account for localized variances in reflectivity and to establish repeatability.

6.8 As an option to the user or requiring agency, a standard specimen may be identified. If so, perform steps 6.3 – 6.6 using the standard specimen. Record the luminance value as L_{st}.

6.9 Fill out Fig. 5 to calculate the reflection.

7. Precision and Bias[3]

7.1 *Precision*—This precision section is based on a simulated interlaboratory study that was accomplished at a single laboratory. Repeatability was achieved by having a single operator make repeated measurements with a single photometer without changing the measurement set-up. Reproducibility between laboratories was simulated by having the same operator completely disassemble the measurement configuration and make another set of measurements after reassembling the measurement configuration at least two hours later. While not ideal, it is expected that this procedure should capture most of the variance expected from between laboratory measurements. This is possible because the measurement procedure itself involves the ratio of two measurements made with the same light measuring instrument; therefore, even if the instrument is horribly miscalibrated, the fact that the calculated value is the ratio of two measurements eliminates calibration errors as a source of variance. Nevertheless, the following precision values should be considered optimistic (perhaps somewhat low) but they are more realistic than the previously published values and should serve until a proper, multi-laboratory, ILS is achieved.

7.1.1 Table 1 summarizes the results of an Internal Laboratory Study conducted using Test Method F1252 – 08. To be conservative, the repeatability and reproducibility values in the following sections are based on the largest (worst) percent values (Columns 5 and 7) found in Table 1.

7.1.2 *Repeatability*—The difference between successive results obtained by the same operator with the same apparatus under constant operating conditions, would, in the long run, in the normal and correct operation of the test method exceed the following values only in one case in twenty:

Repeatability = 0.15 % of coefficient value. For example, if a measurement of a sample results in a reflection coefficient value of 0.08000, then only one time in twenty should a repeat measurement be different by more than 0.15 % of this value (0.08000) or by more than 0.00012. Similarly, if the sample was measured to have a reflection coefficient of 0.50000, then the repeatability value would be 0.15 % of 0.50000 or 0.00075. In other words, the potential error is proportional to the value measured.

7.1.3 *Reproducibility*—The difference between two single and independent results obtained by different operators working in different laboratories on identical material would in the long run, exceed the following values only in one case in

[2] There exists a maximum angle of incidence for which measurements can be made. For the apparatus specified, this angle, Θ_{max}, depends only upon the size and thickness of the specimen, and the size of the light source. A thin specimen 4 in. wide will permit measurements for Θ up to 132°. Θ_{max} will decrease as the specimen thickness increases. For most measurements a four inch wide specimen will be adequate; a larger width may be required for very thick specimens and/or large values of Θ.

[3] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:F07-1009. Contact ASTM Customer Service at service@astm.org.