Designation: F 1316 – 90 (Reapproved 1996)

Standard Test Method for Measuring the Transmissivity of Transparent Parts[1]

This standard is issued under the fixed designation F 1316; 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.

INTRODUCTION

Test Method D 1003 has received wide acceptance as a test method to measure luminous transmissivity in transparent materials. However, because Test Method D 1003 requires critical alignment of equipment on both sides of the transparency, it is not suited to measuring the transmissivity of large, curved parts or parts that are installed. In addition, Test Method D 1003 measures the luminous transmissivity of the material in a direction perpendicular to the surface of the material. For the majority of aircraft windscreens, the pilot is not viewing through the transparency perpendicular to the surface. Since the transmissivity varies as a function of viewing angle the values of transmissivity measured perpendicular to the surface do not indicate what the pilot will see when viewing through the windscreen.

For the above reasons this test method has been developed to allow the measurement of transmissivity of a transparent part at any angle. Since the relative alignment of the equipment items on either side of the transparency is not critical, this test method can also be used on large, thick, or curved parts and parts that are already installed.

1. Scope

1.1 This test method describes an apparatus and procedure that is suitable for measuring the transmissivity of large, thick, or curved transparent parts including parts already installed. This test method is limited to transparencies that are relatively neutral with respect to wavelength (not highly colored).

1.2 Since the transmissivity (transmission coefficient) is a ratio of two luminance values, it has no units. The units of luminance recorded in the intermediate steps of this test method are not critical; any recognized units of luminance (for example, foot-lamberts or candelas per square metre) may be used, as long as use is consistent.

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:*

D 1003 Test Method for Haze and Luminous Transmittance of Transparent Plastics[2]

3. Terminology

3.1 *Definitions:*

3.1.1 *black reference*—a light-absorbing, black material, such as black velvet flocking.

3.1.2 *photometer*—a device that measures luminance as defined by the spectral sensitivity of the photopic curve.

3.1.3 *Photopic curve*—the photopic curve is the spectral sensitivity of the eye for daytime conditions as ***Committee Internationale d'Elairage (CIE) 1931 standard observer***.

3.1.4 *regulated light source*—a light source with electronic feedback to ensure that its illuminance remains constant over time.

3.1.5 *transmission coefficient*—same as *transmissivity*.

3.1.6 *transmissivity*—the transmissivity of a transparent medium is the ratio of the luminance of an object measured through the medium to the luminance of the object measured directly.

4. Summary of Test Method

4.1 A regulated light source with a relatively large, diffusely radiating surface area is placed on one side of a transparent part to be measured. A black, light-absorbing reference surface is placed next to the light source. A photometer is used to measure the luminance of the light source and black reference directly and through the transparency. The light source reading measured through the transparency minus the black reference reading through the transparency is divided by the light source measured directly minus the black reference measured directly

---

[1] This test method is under the jurisdiction of ASTM Committee F-7 on Aerospace and Aircraft and is the direct responsibility of Subcommittee F07.08 on Transparent Enclosures and Materials.

Current edition approved Nov. 15, 1990. Published March 1991.

[2] *Annual Book of ASTM Standards*, Vol 08.01.

(see Eq 1). This ratio is the transmission coefficient of the transparency. The black reference surface is used to correct the measurement from the effects of light scatter due to haze and from reflections.[3]

5. Significance and Use

5.1 *Significance*—This test method provides a means to measure the transmissivity of parts in the field (already installed on aircraft) and of large, thick or curved parts that may not lend themselves to measurement using Test Method D 1003.

5.2 *Use*—This test method may be used on any transparent part. It is primarily intended for use on large, curved, or thick parts that may already be installed (for example, windscreens on aircraft).

6. Apparatus

6.1 *Test Environment*—It is preferable to carry out this test method in a light controlled environment although this is not absolutely necessary. The transparency should be shaded from direct sunlight falling on the surface and a light absorbing black cloth should be placed in the appropriate reflection geometry with respect to the transparency to reduce reflections.

6.2 *Photometer*—Any properly calibrated photometer may be used for this measurement. It should have a measurement field that is smaller than the regulated light source to ensure accurate readings. It is recommended that a small, portable photometer with a 1° measurement field (or less) be used.

6.3 *Light Source*—The light source should be regulated to ensure that it does not change luminance during the reading period. It should have a relatively large, diffusely emitting surface area to permit easy measurement when using the photometer. The spectral distribution of the light source is not critical unless the transparency under test has significant spectral peaks or voids. For daylight measurements it is possible to use a white reflecting surface illuminated by sunlight instead of a powered light source. Care must be taken that the luminance of the reflective surface does not change during the reading.

6.4 *Black Reference*—A shaded, light-absorbing black material such as velvet may be used to increase the accuracy of the measurement. This reference must have about the same area as the light source or reflective material used for the light reading since the photometer must also measure the apparent luminance of the black reference.

7. Test Specimen

7.1 Clean the part to be measured, using any acceptable procedure, to remove any surface contaminants that may contribute to the loss of transmissivity. No special conditioning other than cleaning is required.

8. Calibration and Standardization

8.1 The photometer should have the same spectral sensitivity as the eye but since the measurement involves the division of two quantities measured by the photometer it is not necessary that the photometer be calibrated in absolute luminance units.

9. Procedure

9.1 Place the light source (or white reflective surface) on one side of the transparency such that is can be viewed from the other side of the transparency. The transparency should be at the desired angle for measurement. The distance from the light source to the transparency is not critical but must be greater than 30 cm (11.8 in.) to prevent erroneous readings due to light scatter and reflections. The distance from the light source to the photometer is also not critical but should be short enough so that the photometer measurement field easily falls within the emitting area of the light source. The distance from the transparency to the photometer is not critical and may be as small as 0 cm. The black reference should be placed adjacent to the light source so that it may also be viewed through the transparency. The light absorbing cloth should be placed next to the transparency on the opposite side from the light source (see Fig. 1).

9.2 If the transparency is subject to direct sunlight, a solar shield should be used to shade the area of the transparency (see Fig. 1).

9.3 The photometer is then used to measure the luminance of the light source and the black reference. These readings are designated L_s and L_b respectively. The light source and black reference are then measured again but this time viewing through the transparency. These readings are L_{s_t} and L_{b_t} respectively. Both the direct measurements and the measurements through the transparency should be made at about the same distance and angle from the light source.

10. Calculation

10.1 The transmissivity of the transparency is calculated

FIG. 1 Geometry of the Transmissivity Measurement

[3] Turk, H. L. and Merkel, H. S., *A New Method for Measuring the Transmissivity of Aircraft Transparencies*. Technical Report AAMRL-TR-89-044, Armstrong Aerospace Medical Research Laboratory, 1989.

using the following equation:

$$t = \frac{L_{s_t} - L_{b_t}}{L_s - L_b} \quad (1)$$

where:
t = the transmission coefficient of the transparency,
L_s = the luminance of the light source (white surface),
L_{s_t} = the luminance of light source measured through the transparency,
L_b = the luminance of the black reference, and
L_{b_t} = the luminance of black reference measured through the transparency.

The transmission coefficient, t, can be converted to percent transmission, T, by multiplying by 100. In equation form:

$$T = 100 \times t \quad (2)$$

10.2 The second term in the numerator in Eq 1 removes effects due to light scatter or reflections from the measurement. Similarly, the second term in the denominator removes errors that arise from the black reference pattern not being completely black. See the appendix Appendix X1for the derivation of this equation.

11. Precision and Bias

11.1 Four tests were done on a set of nine samples to obtain information on precision and bias. The first test was done using Test Method D 1003 for comparison purposes; the other three tests were done using the current procedure. These tests were reproducibility test (using Test Method D 1003) at four laboratories with a total of six devices, repeatability test using one photometer and one operator for twelve trials, reproducibility test using one operator in one laboratory with seven different photometers, and reproducibility using one photometer and six operators at four different laboratories.

11.2 The nine transparent samples included one laminated sample (2.22 cm (⅞ in.) total thickness), three thick (1.59 cm (⅝ in.)) monolithic samples, and five thin (0.32 cm (⅛ in.)) monolithic samples. The samples ranged from about 90 % transmissive to about 15 % transmissive, that includes most of the transmissivities that would be encountered in aircraft transparencies and helmet visors. There is no reason to expect that thickness of the sample or number of layers would have an effect on the measurement of transmissivity.

11.3 To provide a reference for comparison, the nine samples were measured following Test Method D 1003 at four laboratories using a total of six devices, yielding 54 measurements. The variance and coefficient of variation (standard deviation divided by the mean transmissivity times 100 %) were calculated for the six measurements made on each sample. The variance σ^2 was 0.214 and the mean coefficient of variation was 0.97 %, resulting in a 95 % confidence interval of ± 1.9 % of the transmissivity reading. It should be noted that the coefficient of variation was not uniform with respect to transmissivity but tended to be higher for lower transmissivities.

11.4 All nine samples were measured using the procedure described herein by a single operator at one laboratory using a single photometer. The procedure was repeated twelve times, yielding 108 measurements. The variance and coefficient of variation were calculated for each sample as noted above. The estimate of the variance σ_e^2 was 0.0115 and the mean coefficient of variation was 0.18 %. The coefficient of variation was fairly uniform independent of the transmissivity of the sample.

11.5 All nine samples were measured with this procedure by a single operator at one laboratory using seven different photometers, yielding 63 measurements. The estimate of the variance σ_p^2 was 0.0564 and the mean coefficient of variation was 0.49 %.

11.6 All nine samples were measured with this procedure by a total of six operators at four laboratories using a single photometer, yielding 54 measurements. The estimate of the variance σ_o^2 was 0.0467 and the mean coefficient of variation was 0.35 %.

11.7 Considering a typical application of the new procedure to involve different operators in different laboratories using different photometers, the confidence interval may be estimated from the acquired data. The variance of the transmissivity measurement, σ^2, may be modeled as:

$$\sigma^2 = \sigma_o^2 + \sigma_p^2 + \sigma_e^2 \quad (3)$$

where:
σ_o^2 = the variance of the operator,
σ_p^2 = the variance of the photometer, and
σ_e^2 = the variance of the repeatability error.

It is assumed there is no operator-photometer interaction. Substituting the appropriate values into Eq 3 yields.

$$\sigma^2 = 0.115 \quad (4)$$

The corresponding 95 % confidence interval is then:

$$\pm 1.96 \times \frac{\sigma}{\bar{x}} \times 100\,\% = \pm 1.12\,\% \quad (5)$$

where:
$\bar{x}$ = the mean transmissivity of the samples (0.595).

11.8 The preceding information indicates this new procedure is slightly more precise than Test Method D 1003 since it results in a tighter confidence interval. The confidence interval of the new procedure is 1.12 %, versus 1.90 % for Test Method D 1003. Thus if the transmissivity were measured to be 0.50 (0 %) the 95 % confidence interval would be 0.494 to 0.506 (49.4 % to 50.6 %).

11.9 This test method has no known inherent bias. However, it is likely slightly different results will be obtained using this test method than Test Method D 1003. When light is incident on a nominally transparent part the transmitted light is composed of both scattered and unscattered components. The scattered light is measured as haze using Test Method D 1003. The unscattered light is the only useful transmitted light for image formation and visibility. This test method measures almost exclusively the unscattered transmitted light whereas Test Method D 1003 measures a combination of both the scattered and unscattered transmitted light. It is for this reason that Test Method D 1003 will tend to result in higher transmissivity values than this test method for parts that exhibit measurable haze.

11.9.1 The degree of difference depends on the amount of haze in the transparent material. Four of the nine samples tested had haze readings in the region of 1 to 2 %. These samples had transmissivity values of 84 to 90 % using this method but registered an average of 1.6 % higher using the Test Method D 1003. The other five samples had very low haze readings (less than 0.1 %) and showed a random relationship with the Test Method D 1003.

11.10 This test method is the appropriate one to use if the transparency under test is to be used for visual or sensor image transmission such as an aircraft windscreen or sensor protective cover.

APPENDIX

(Nonmandatory Information)

X1. DERIVATION OF THE TRANSMISSIVITY EQUATION

X1.1 This appendix provides a brief derivation of the equation that is used to calculate transmissivity. It is necessary to devise a means to remove the effects of light scatter and reflections from the measurement of transmissivity. It is assumed that the unwanted light, *S*, is sufficiently uniform that it does not change appreciably during the time of the test nor does it vary over the area of the transparency required to measure both the light source target and the black reference target.

X1.2 The light level measured through the transparency will be reduced by a factor equal to the transmissivity, *t*, and will be enhanced by a term equal to the scattered/reflected light, *S*. In equation form:

$$L_{s_t} = (t \times L_s) + S \text{ for measuring the light source, and}$$

$$L_{b_t} = (t \times L_b) + S \text{ for measuring the black reference}$$

where:

t = the transmission coefficient of the transparency,
L_s = the luminance of the light source (white surface),
L_{s_t} = the luminance of light source measured through the transparency,
L_b = the luminance of black reference,
L_{b_t} = the luminance of the black reference measured through the transparency, and S is the unknown scattered/reflected light.

Solving these two equations for *S* and setting them equal yields:

$$S = L_{s_t} - (t \times L_s) = L_{b_t} - (t \times L_b)$$

Solving for *t* yields:

$$t = \frac{L_{s_t} - L_{b_t}}{L_s - L_b}$$

that is the desired equation.