Designation: F 1863 – 98

Standard Test Method for Measuring the Night Vision Goggle-Weighted Transmissivity of Transparent Parts[1]

INTRODUCTION

Test Methods D 1003 and F 1316 apply to the transmissivity measurement of transparent materials, the former being for small flat samples, and the latter for larger, curved pieces such as aircraft transparencies. Additionally, in D 1003, the transmissivity is measured perpendicular to the surface of test sample and both test methods measure only in the visible light spectral region. Night vision goggles (NVGs) are being used in aircraft and other applications (for example, marine navigation, driving) with increasing frequency. These devices amplify both visible and near-infrared (NIR) spectral energy. Overall visual performance can be degraded if the observer uses the NVGs while looking through a transparency that has poor transmissivity in the visible and NIR spectral regions. This test method describes both direct and analytical measurement techniques that determine the NVG-weighted transmissivity of transparent pieces including ones that are large, curved, or held at the installed position.

1. Scope

1.1 This test method covers apparatuses and procedures that are suitable for measuring the NVG-weighted transmissivity of transparent parts including those that are large, thick, curved, or already installed. This test method is sensitive to transparencies that vary in transmissivity as a function of wavelength.

1.2 Since the transmissivity (or transmission coefficient) is a ratio of two radiance values, it has no units. The units of radiance recorded in the intermediate steps of this test method are not critical; any recognized units of radiance (for example, watts/m^2-str) may be used, as long as it is consistent.[2]

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[3]

E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods[4]

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method[4]

F 1316 Test Method for Measuring the Transmissivity of Transparent Parts[5]

3. Terminology

3.1 *Definitions:*

3.1.1 *analytical test method*, *n*—the test method that uses spectral transmissivity data of a transparent part collected by the use of either spectraphotometric or spectraradiometric instrumentation. The data are then examined using analytic methods to determine the NVG-weighted transmissivity of the part.

3.1.2 *direct test method*, *n*—the test method that uses the actual luminous output, as measured by a photometer, properly coupled to the eyepiece of the test NVG. The NVG-weighted transmissivity of the part is then determined by forming the ratio of the NVG output luminance with the transparent part in place to the luminance output without the part.

3.1.3 *NVG-weighted spectral transmissivity*, *n*—the spectral transmissivity of a transparent part multiplied by the spectral sensitivity of a given NVG (see Fig. 1).

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[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.

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[2] *RCA Electro-Optics Handbook*, RCA/Solid State Division/Electro Optics and Devices. Technical Series EOH-11. Lancaster, PA; 1974.

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

[4] *Annual Book of ASTM Standards*, Vol 14.02.

[5] *Annual Book of ASTM Standards*, Vol 15.03.

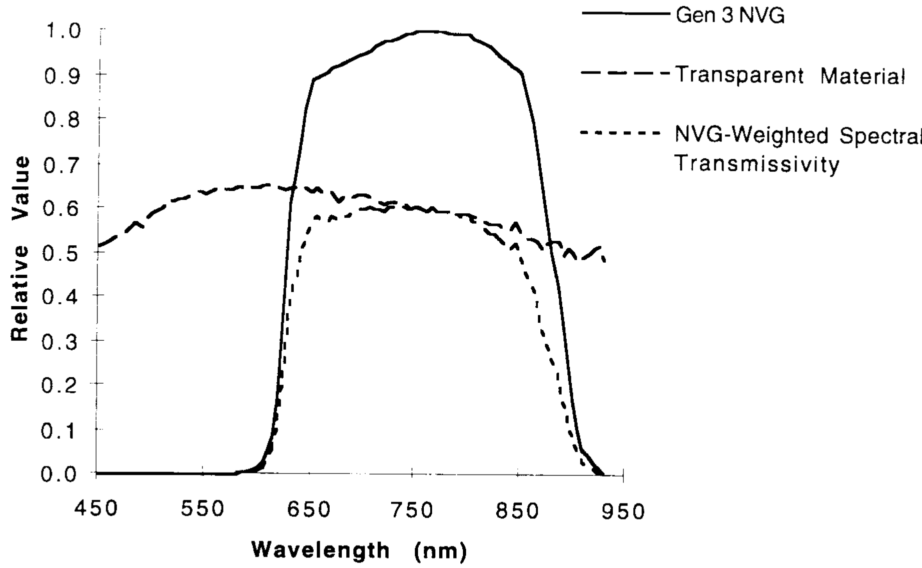

FIG. 1 An Example of How the Spectral Sensitivity of a Generation 3 NVG Multiplied by the Spectral Transmissivity of a Transparent Part Equals the NVG-Weighted Spectral Transmissivity of That Part. Integrating the Curve with Respect to Wavelength Yields the Part's NVG-Weighted Transmissivity (T_{NVG}) Value

3.1.4 *NVG-weighted transmissivity (T_{NVG}), n*—the spectral transmissivity of a transparent part multiplied by the spectral sensitivity of a given NVG integrated with respect to wavelength (see Fig. 1, Eq 1 and Eq 2).

3.1.5 *NVG spectral sensitivity*, *n*—the sensitivity of an NVG as a function of input wavelength.

3.1.6 *photometer*, *n*—a device that measures luminous intensity or brightness by converting (weighting) the radiant intensity of an object using the relative sensitivity of the human visual system as defined by the photopic curve.[2,5]

3.1.7 *photopic curve*, *n*—the photopic curve is the spectral sensitivity of the human eye for daytime conditions as defined by the *Commission Internationale d'Eclairage* (CIE) 1931 standard observer.[2,6]

3.1.8 *transmission coefficient*, *n*—see *transmissivity*.

3.1.9 *transmissivity*, *n*—the transmissivity of a transparent medium is the ratio of the luminance of an object measured through the medium to the luminance of the same object measured directly.

4. Summary of Test Method

4.1 *General Test Conditions*—The test method can be performed in any light-controlled area (for example, light-tight room, darkened hangar, or outside at night away from strong light sources). The ambient illumination must be very low because of the extreme sensitivity of the NVGs. A fixture holds the NVG and its objective lens is aimed at and focused on a target. The target can be either an evenly illuminated white, diffusely reflecting surface or a transilluminated screen (lightbox). The illumination is provided by a white, incandescent light source. Handle the samples carefully as not to cause any damage. Do not clean them with any solvents. Use part-specific, prescribed cleaning materials and methods.

4.1.1 *Direct Test Method*—Attached directly to the eyepiece of the NVG is a photodetector. It has been found that the measured field of view (FOV) should be smaller than the uniformly illuminated portion of the target. The target illumination is adjusted so that the output of the NVGs is about 1.7 cd/m^2 (0.5 fL). This ensures that the NVG input is not saturated; the automatic gain control (AGC) is not active. The luminance output of the NVG is measured and then repeated with the transparent material in place. The transmissivity is equal to the NVG output luminance with the transparent material in place divided by the NVG output luminance without the material (see Eq 1). The result is the NVG-weighted transmissivity (T_{NVG}) of the transparent material.

4.1.2 *Analytical Test Method*—Without the sample in place, measure the light source's spectral energy distribution from 450 through 950 nm in 5-nm incremental steps. Place the sample into the spectrophotometer or spectraradiometer fixture. Perform spectral measurements, also from 450 through 950 nm in 5-nm incremental steps. Obtain from the NVG manufacturer the spectral sensitivity of the goggle that will be used in conjunction with the part. Perform the analytic method as defined in Eq 2 to derive the T_{NVG}.

5. Significance and Use

5.1 *Significance*—This test method provides a means to measure the compatibility of a given transparency through which NVGs are used at night to view outside, nighttime ambient illuminated natural scenes.

5.2 *Use*—This test method may be used on any transparent part, including sample coupons. 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*—This test method can be performed in any light-controlled area (for example, light-tight room, darkened hangar, or outside at night away from strong light

[6] Wyszecki, Gunter, and Stiles, WS, *Color Science: Concepts and Methods, Quantitative Data and Formulae,* 2nd ed., New York, John Wiley and Sons, 1982.

sources) since the NVGs are extremely sensitive to both visible and near infrared light. Extraneous light sources (for example, exit signs, telephone pole lights, status indicator lights on equipment, and so forth) can also interfere with the measurement.

6.2 *White Diffuse Target*—The white target can be any uniformly diffusely reflecting or translucent material (for example, cloth, flat white painted surface, plastic). The target area should be either smaller (see Fig. 2) or larger (see Fig. 3) than the NVG FOV (35 to 60° typical) to minimize potential alignment errors.

6.3 *Light Source*—The light source should be regulated to ensure that it does not change luminance during the reading period. It should be a low output, 2856K incandescent light since this type emits sufficient energy in both visible and infrared without any sharp emission peaks or voids.[2] Its output must be uniformly distributed over the measurement area of the white diffuse target. Use of neutral density filters or varying the lamp distance may be needed to achieve sufficiently low luminance levels to be obtained for test, since varying the radiator's output would shift its color temperature.

6.4 *Night Vision Goggles*—A family of passive image intensifying devices that use visible and near-infrared light and enable the user to see objects that are illuminated by full moonlight through starlight-only conditions. The goggle that is used for test should be the same as that used with the given transparent material.

6.5 *Photometer*—Any calibrated photometer may be used for this measurement. However, the detector must be properly coupled to the NVG eyepiece, and the FOV over which the light is integrated must be known.

7. Test Specimen

7.1 If necessary, clean the part to be measured using the procedure prescribed for the specific material. Use of non-standard cleaning methods can irrevocably damage the part. No special conditions other than cleaning are required.

8. Calibration and Standardization

8.1 It is not necessary that the photometer be calibrated in absolute luminance units since the measurement involves the division of two measured quantities yielding a dimensionless value. A generic photodetector can be substituted for the photometer if its FOV is known.

9. Procedure

9.1 *General Procedures*—Perform all measurements in a darkened, light-controlled area. To control the effects of reflection, verify that there are no extraneous light sources that can produce reflections within the measurement area of the transparent material. To control the effects of haze, verify that no light other than the measurement light falls on the area being tested.

9.2 *Direct Test Method*—This test method allows analysis of large or small transparent parts placed at either normal (perpendicular to the optical axis) or installed orientations, such as an aircraft windscreen. Fig. 2 illustrates the use of a small, transilluminated lightbox. Fig. 3 depicts the use of a large, front-illuminated, white, diffusely reflective target, illuminated as uniformly as possible using a regulated white incandescent light source. The size of the target is dependent upon the test location, the obtainable luminance uniformity, and the FOV of the photodetector assembly. In the field, a transilluminated lightbox is probably the easiest to set up and use, as it offers the advantage of compact, self-contained portability. Maintain the same target-to-NVG distance during the measurements. In a light-tight room, a white, diffusely reflecting, front-illuminated surface may be used. In the field, the NVG can be held by hand and under laboratory conditions, can be mounted in a sturdy fixture. Aim and focus the NVG on the white target. Attach the photodetector to the NVG eyepiece. With the transparent material removed from the measurement path, adjust the variable white light to produce an NVG output luminance of about 1.7 cd/m^2 (0.5 fL). This insures that the NVG's input is not saturated; the AGC is not activated. As a result of the extreme sensitivity of NVGs, neutral density filters may need to be placed in front of the light source to obtain low enough target luminance. After recording the NVG's output luminance, place the transparent material in the measurement path. If the material is a sample, its orientation relative to the

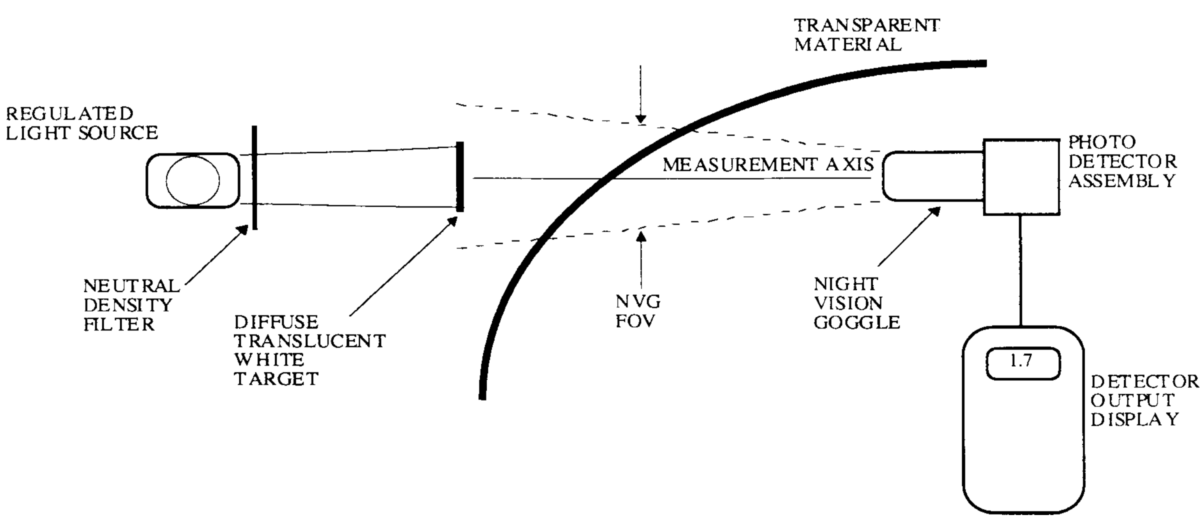

FIG. 2 Direct Test Method Equipment Set Up to Measure the Night Vision Goggle-Weighted Transmissivity of a Transparent Part Using a Transilluminated Lightbox That Underfills the NVG FOV

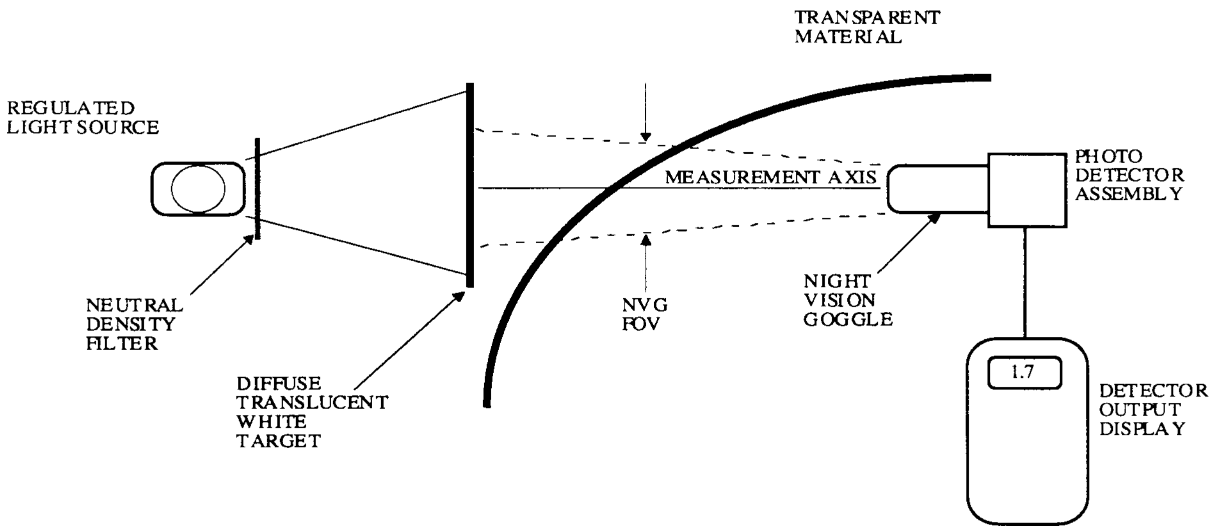

FIG. 3 Direct Test Method Equipment Set Up to Measure the Night Vision Goggle-Weighted Transmissivity of a Transparent Part Using a Transilluminated Lightbox That Overfills the NVG FOV

measurement path can be simply perpendicular or at the installed angle. If an aircraft transparency is being tested, the NVG should be located at the design eye position relative to the transparency which is mounted in its installed position. Measuring at the installed angle is critical since many materials exhibit variations in transmissivity as a function of angle. Record the NVG's output with the test piece in place. To prevent damage to the NVGs, verify that they are turned off before the test area lights are turned on.

9.2.1 There are numerous classes of NVGs (Generations 2, 3; Types A, B) that vary in their spectral sensitivity, intensified FOV, resolution, and so forth. It is important to select the proper NVG type that will be used in a given application. The NVG must also be in good working condition and meet minimum user performance specifications.

9.2.2 The target illumination source can be an incandescent operating at 2856K, which is the standard color temperature that is used for many NVG test procedures. The illumination from this source can be varied using neutral density filters, since varying the light's voltage would cause a corresponding color temperature shift. If the NVG is to be used to view an area through a specific transparent material that is illuminated by a different kind of light source (for example, mercury vapor, sodium), then that source must be properly noted in the test report.

9.2.3 The luminance output of the NVG is measured and then repeated with the transparent material in place. The transmissivity is equal to the NVG output luminance with the transparent material in place divided by the NVG output luminance without the material (see Eq 1). The result is the NVG-weighted transmissivity (T_{NVG}) of the transparent material.

9.3 *Analytical Test Method*—When using a spectrophotometer, the sample is usually limited to about 2- by 2-in. sample coupons held in a normal position. In general (but depending on the model), a spectraradiometer can be used to measure large or small parts at normal or installed positions. With the sample removed, measure the light source's spectral energy distribution from 450 through 950 nm in 5-nm incremental steps. Place the sample into the spectrophotometer or spectraradiometer fixture. Perform spectral measurements, also from 450 through 950 nm in 5-nm incremental steps. Obtain from the NVG manufacturer the spectral sensitivity of the goggle type (in 5-nm increments) that will be used in conjunction with the transparent part. Perform analytic method as defined by Eq 2 to derive the T_{NVG}.

10. T_{NVG} Calculation

10.1 *Direct Test Method Calculation*—When using a photodetector attached to the NVG eyepiece, the calculation is described by Eq 1. The transmissivity is equal to the NVG output luminance with the transparent material in place (L_T) divided by the NVG output luminance without the material (L_B). The result is the NVG-weighted transmissivity (T_{NVG}) of the transparent material.

$$T_{NVG} = \frac{L_T}{L_B} \tag{1}$$

where:

T_{NVG} = NVG-weighted transmissivity,
L_T = NVG output luminance with the transparent material in place, and
L_B = NVG output luminance without the transparent material.

10.2 *Analytical Test Method*—Fig. 1 is an example of the elements of the T_{NVG} calculation. When substituting a spectraradiometer for the NVG and photodetector assemblies (see Figs. 2 and 3), the calculation is described by Eq 2. For Eq 2, T_{NVG} equals the integral with respect to wavelength of the transparent part's spectral transmissivity [P (λ)] times the spectral energy distribution of the light source [S (λ)] times the NVG spectral sensitivity [G (λ)] divided by the integral with respect to wavelength of the spectral energy distribution of the light source times the NVG spectral sensitivity.

$$T_{NVG} = \frac{\int_{450}^{950} P(\lambda)S(\lambda)G(\lambda)d\lambda}{\int_{450}^{950} S(\lambda)G(\lambda)d\lambda} \tag{2}$$

where:

T_{NVG} = NVG-weighted transmissivity,
$P(\lambda)$ = spectraradiometric scan through transparent part,
$S(\lambda)$ = spectral energy distribution of the light source, and
$G(\lambda)$ = spectral sensitivity of night vision goggle.

11. Precision and Bias

11.1 An interlaboratory study (ASTM RR F07-1004) was conducted to determine the precision of P94-02, Test Method for Measuring Night Vision Goggle-Weighted Transmissivity of Transparent Materials. Six labs (instruments) were used to measure four plastic samples, five times each. The statistical summaries are shown in Tables 1 and 2.

11.1.1 Since the accuracy of the measurements should not and did not depend upon the type of the transparent material, it is logical to calculate a mean T_{NVG} of the four sample sizes to derive the composite precision values indicative of this test method. In summary, the statistical analysis (Practices E 691 and E 177) revealed that the method's mean repeatability (S_r) was 0.009 T_{NVG} and the mean reproducibility (S_R) was 0.013 T_{NVG}. The mean 95 % limits for repeatability (r) was 0.025 T_{NVG} and the mean 95 % limits for reproducibility (R) was 0.035 T_{NVG}.

TABLE 1 Repeatability (S_r) and Reproducibility (S_R) Values in T_{NVG}

	Repeatability (S_r) Within Labs[A]	Reproducibility (S_R) Between Labs[B]
Sample 1	0.011	0.015
Sample 2	0.011	0.016
Sample 3	0.007	0.011
Sample 4	0.006	0.008
Mean	**0.009**	**0.013**

[A] S_r ranged from 0.006 to 0.011 T_{NVG}.
[B] S_R ranged from 0.008 to 0.016 T_{NVG}.

TABLE 2 95 % Repeatability (r) Limits and 95 % Reproducibility (R) Limits in T_{NVG}

	95 % r Limits Within Labs[A]	95 % R Limits Between Labs[B]
Sample 1	0.030	0.043
Sample 2	0.030	0.044
Sample 3	0.021	0.030
Sample 4	0.017	0.023
Mean	**0.025**	**0.035**

[A] r ranged from 0.017 to 0.030 T_{NVG}.
[B] R ranged from 0.023 to 0.044 T_{NVG}.

11.1.2 The 95 % limits were calculated using the formulae below. Since the 95 % limits are based on the difference between two test results, the − 2 factor was incorporated into the calculation (Practice E 177). For r = 95 % repeatability limit (within laboratories) and S_r = repeatability standard deviation.

$$r = 1.960 * \sqrt{2} * S_r \quad (3)$$

For R = 95 % reproducibility limit (between laboratories) and S_R = reproducibility standard deviation.

$$R = 1.960 * \sqrt{2} * S_R \quad (4)$$

11.2 The procedure in this test method has no bias because the NVG-weighted transmissivity is defined only in terms of the test method.

12. Keywords

12.1 canopy; night vision goggles; transmissivity; transparency; windscreen