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THE TRANSMISSION, ABSORPTION COEFFICIENT, AND INDEX OF REFRACTION OF THE B-1 AND FB-111 WINDSCREENS

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Spectral characteristics have been measured on the B-1, and two types of FB-111 windscreens in the spectral region of 0.3 - 2.0 μm. The total transmission, index of refraction, dispersion and Lambert absorption coefficients were determined to quantitate the effective protection offered by these windscreens to high-intensity radiation.
Total windscreen transmission measurements were performed spectrophotometrically with each sample in normal incidence and adjacent

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20. ABSTRACT (Continued)

to the detection aperture, allowing both the direct transmission and the forward scatter to be measured.

The index of refraction for each windscreen was measured using a laser spectrometer system. The index of refraction at eight wavelengths in the visible spectrum was accurately determined with this system.

The Lambertian absorption coefficients were calculated from the information obtained in total transmission and reflection measurements; they were expressed in the units of cm^{-1} and calculated at 5 nanometer intervals throughout the spectral region of 0.3 - 2.0μm.

Finally, a method is presented to calculate the light attenuation offered by the three windscreens to this region of spectral radiation at various angles of incidence.

THE TRANSMISSION, ABSORPTION COEFFICIENT, AND INDEX OF REFRACTION OF THE B-1 AND FB-111 WINDSCREENS

INTRODUCTION

The hazards of flashblindness and ocular burns from intense light sources have been under investigation by the Air Force for many years. Since the first nuclear detonation in 1942, the potential for both has increased manyfold.

Flashblindness is best defined as a temporary loss of vision due to a brief exposure to high-intensity light. Flashblindness does not cause permanent damage to the eye, and the vision recovery time associated with it is dependent on the brightness of the source, location of the exposure on the retina, and the brightness of the target. Although flashblindness is a temporary phenomenon, the inability to read instrument panels and the effect on dark adaptation at night is a serious problem to the pilot.

Ocular burns are caused by a light source of such high intensity that eye tissue is destroyed causing a permanent loss of vision or scotoma. Burns can occur in any component of the ocular media depending on the wavelength content of the source. For instance, retinal burns are predominantly produced by sources containing wavelengths in the near-ultraviolet (UV), visible, and near-infrared (IR) spectra, while corneal damage occurs from wavelengths in the far-UV and IR regions. Lenticular damage has been observed for selected wavelengths at the near-UV and IR spectra.

Another recent source of high-intensity radiation has evolved--the laser, now used in aircraft weapon delivery systems. Laser light, unlike the thermal emission of a nuclear detonation, emits energy in very narrow bandwidths.

The recognition of ocular effects due to high-intensity light sources has brought about the need for protective eyewear. Consequently, numerous types of goggles and visors have been designed and fabricated to reduce eye hazards to aircrew and nonaircrew personnel.

Other sources of eye protection are the aircraft windscreen and canopy which are constructed of various glasses and plastics. Although the windscreen alone may not afford adequate protection against high-intensity radiation, the protection they do provide should be considered in the estimation of safe separation distances and in the design of protective eyewear.

Previous windscreen testing has been concerned with two main areas of interest--structural and optical quality (2). Structural testing has dealt with heat, impact, and crack resistance of the windscreen. Optical quality testing has measured the formation of multiple images, distortion at various viewing angles, magnification effects, and luminous transmission (1, 2).

Studies of windscreens and canopies as possible sources of protection against high-intensity radiation have been minimal and were primarily in the areas of radar reflective properties, radiation protection from onboard electronic systems, and solar radiation protection (3, 5).

This study was made to determine the spectral characteristics for three types of windscreen enclosures--the B-1 and two types of FB-111 windscreens. The transmission, absorption, and index of refraction were measured as a function of wavelength in the UV, visible, and near-IR spectrum. With this information, an accurate determination of the protective qualities of these windscreens can be assessed for laser and nonionizing nuclear radiation.

THEORY

Theoretically, the light incident on a sample can be accounted for by the following relation:

$$I_i = I_r + I_s + I_a + I_t \qquad (1)$$

where the subscripts designate the incident, reflected, scattered, absorbed, and transmitted intensities, respectively. I_i and the sum $I_t + I_s$ can be measured directly and I_r can be calculated from the index of refraction for the sample. I_a and the related Lambertian absorption coefficients can then be determined from equation 1.

Reflection Losses and the Index of Refraction

Reflection losses, I_r, arise at the interface of mediums having unequal indices of refraction. The fraction of light reflected, R, from one surface is a function of the indices of refraction, N_1, N_2, of the two mediums comprising the interface, and calculated according to the Fresnel reflection law as:

$$R = \frac{(N_1-N_2)^2}{(N_1+N_2)^2} \tag{2}$$

For the case of a sample measured in air, we can assume the value of N_1 or N_2 as 1.0 and constant, such that the reflection is rewritten as:

$$R = \frac{(1-N_2)^2}{(1+N_2)^2} \tag{3}$$

where N_2 is the index of refraction of the sample.

The index of refraction for any sample is a function of wavelength and can be determined according to Snell's Law if the angle of incidence and refraction are known. Snell's Law for the index of refraction, N_2, is

$$N_2 = \frac{\text{Sin } \theta_i}{\text{Sin } \theta_r} \tag{4}$$

where θ_i and θ_r are the angles of incidence and refraction, respectively.

The index of refraction for a sample can be measured at each wavelength of interest and tabulated for later use in the calculation of reflection losses. However, since the index of refraction is a function of wavelength, it would be more advantageous to an investigator if an analytical expression could be found which could approximate the index of refraction as a function of wavelength, $N(\lambda)$. The advantage of expressing $N(\lambda)$ analytically is that the index of refraction at each wavelength could be calculated rather than measured. This is particularly useful in computer calculations such as this study employed.

The analytical expression of $N(\lambda)$ for a particular substance, the dispersion equation, is unique and depends upon the atomic structure of that substance. Many forms of the dispersion equation have been proposed, depending on how accurate a representation of $N(\lambda)$ is required. In this study, the Sellmeier approximation to the dispersion equation was used. It is of the form: (4)

$$N^2 = 1 + \sum_{i=1}^{n} \frac{A_i \lambda^2}{\lambda^2 - \lambda_{mi}^2} \tag{5}$$

Where: N = the index of refraction
A_i = the "i"th experimentally determined coefficient
λ = wavelength (microns)
λ_{mi} = center wavelength of the "i"th absorption band.

The summation is taken over the n absorption bands in the spectral range of interest.

If a Sellmeier dispersion equation is plotted for a transparent sample with two absorption bands (as was found with the windscreens under study), one obtains the curve in Figure 1.

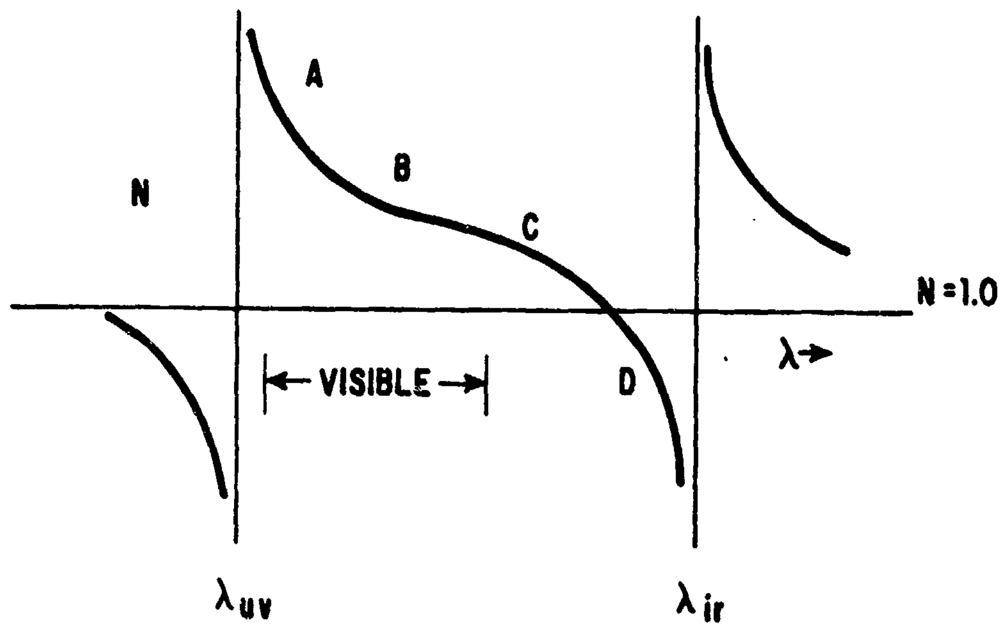

Figure 1. Typical dispersion curve for a transparent sample with two absorption bands λ_{uv} and λ_{ir}.

In the region AB, the index of refraction decreases after having been extremely large at the UV absorption maxima, λ_{uv}. The index of refraction decreases with increasing wavelength as shown in the portion of the curve ABC. In this region, the curve ABC is called normal dispersion and is observed in the near-UV, visible, and near-IR spectra of the sample.

The portion CD is observed in the near infrared and is caused by approaching an IR absorption maximum λ_{ir}. The index of refraction drops off rapidly in this region and theoretically to $-\infty$ at the absorption maxima due to the discontinuity in the denominator of equation 5. As we pass through the absorption band λ_{ir}, the analytical expression for $N(\lambda)$ jumps from $-\infty$ to $+\infty$ and then decreases in value.

In practice, the index of refraction cannot become negative or go to +∞ as the Sellmeier formula suggests. The equation represents the refractive index of an absorbing medium quite well, until applied to wavelengths near the absorption bands, where we obtain $n = \infty$. Near the absorption bands the dispersion losses, often called the damping factor or frictional losses of the absorbing atoms or molecules, do not allow the index of refraction to become infinite. Because of these losses, the index of refraction on the short wavelength side reaches a minimum and joins the maximum value of the index of refraction on the long wavelength side at $\lambda = \lambda m$ where the index of refraction equals 1.0, as shown in Figure 2 (5).

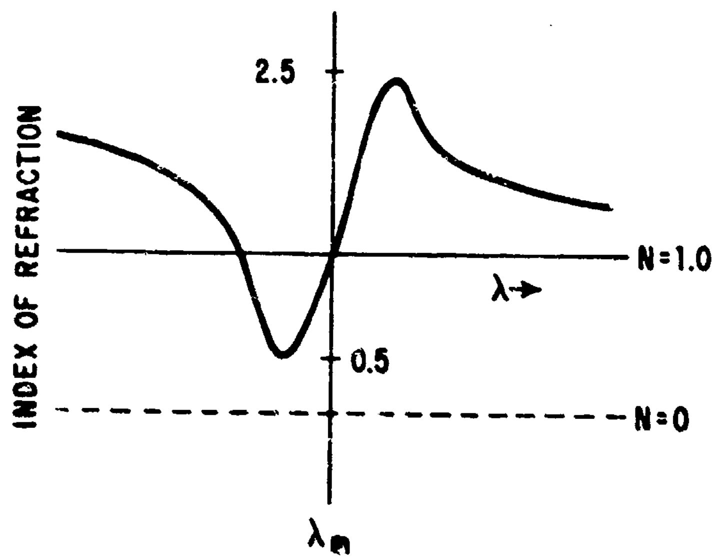

Figure 2. Dispersion losses.

In this investigation we arbitrarily assumed an index of refraction maximum of 2.5 and a minimum of 0.5 for regions where Sellmeier's equation would predict a smaller or larger index of refraction.

Absorption Coefficients

The absorbed intensity, I_a, can be calculated using equation 1, measured values for I_i, $(I_t + I_s)$, and calculated values for I_r. I_r can be computed using the Sellmeier equation for the index of refraction and equation 3. Consider the light incident on a sample as shown in Figure 3:

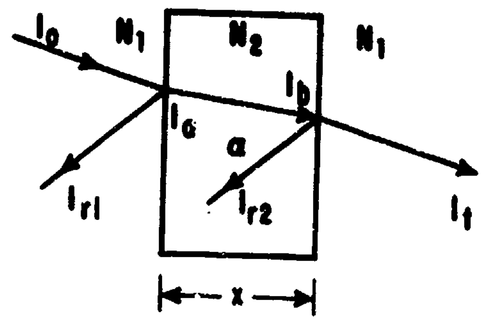

Figure 3. Sample with incident light, I_o.

where: I_o = incident intensity

I_{r1}, I_{r2} = reflected intensities

N_1, N_2 = indices of refraction

α = Lambert absorption coefficient (1/cm)

I_a, I_b = intensities just beneath the front and rear surfaces of the sample, respectively

I_t = transmitted intensity, including all forward scatter intensity

X = thickness of sample (cm)

The Lambert absorption coefficient, α, is defined as

$$\alpha = \frac{1}{X} \ln (1/T) \qquad (6)$$

where: $T = \frac{I_b}{I_a} = \frac{\text{Intensity just leaving sample}}{\text{Intensity just entering sample}}$

I_a is equal to the difference between I_o and I_{r1}, where I_{r1} is the first reflection as calculated by Fresnel's reflection law (assuming $N_1 = 1$, for air):

$$I_{r1} = I_o \frac{(1-N_2)^2}{(1+N_2)^2}$$

$$\text{Hence, } I_a = I_o - I_o \left(\frac{1-N_2}{1+N_2}\right)^2 = I_o \left[1-\left(\frac{1-N_2}{1+N_2}\right)^2\right] \tag{7}$$

Similarly for I_b: $I_b - I_{r2} = I_t$

or

$$I_t = I_b \left[1-\left(\frac{1-N_2}{1+N_2}\right)^2\right]$$

and

$$I_b = I_t \left[1-\left(\frac{1-N_2}{1+N_2}\right)^2\right]^{-1} \tag{8}$$

Therefore:

$$T = \frac{I_b}{I_a} = \frac{I_t}{I_o}\left[1-\left(\frac{1-N_2}{1+N_2}\right)^2\right]^{-2} \tag{9}$$

Now the Lambert absorption coefficient is calculated as:

$$\alpha = \frac{1}{X}\, Ln\left(\frac{1}{T}\right) = \frac{1}{X}\, Ln\left(\frac{I_o}{I_t}\left[1-\left(\frac{1-N_2}{1+N_2}\right)^2\right]^2\right) \tag{10}$$

METHODS AND MATERIALS

Transmission Measurements

Instrumentation and Calibration--Total transmission measurements were made in the spectral range of 0.3 to 2.0 μm for the B-1 and the FB-111 gold-coated and uncoated windscreens; a Cary model 14 UV-visible-near-IR spectrophotometer was used with the beam at normal incidence and the samples adjacent to the detector aperture. This assured that all the light transmitted by the sample including the forward scatter and reflection, fell within the detector aperture of the spectrophotometer. The orientation of the sample was maintained normal to the beam by a sample holder which allowed adjustment of the angle of incidence up to 45°.

Before the spectrophotometer measurements were made the instrument was calibrated. The electronics of the Cary 14 spectrophotometer was stabilized at the beginning of each recording session by allowing a 4-hr warmup period. A spectral scan, without a sample in place, was made to determine the stability and to balance the reference and sample light intensities. In addition, spectral scans were made with a 1.0 optical density (OD) screen filter in the sample beam, establishing a 0 to 1.0 OD range and the recording amplifier stability which was always ± 0.01 absorption units. In addition to the 0 to 1.0 OD calibration, various other screen filters (0.5, 1.5, and 2.0 OD) were periodically measured. When these filters were scanned, the stability of the recording pen amplifier had a variance of less than ± 0.02 absorption units.

The wavelength accuracy and bandwidth were calibrated by repetitively scanning the strong emission line spectra of a mercury/cadmium (Hg/Cd) lamp. (The tungsten lamp normally used in the Cary spectrophotometer was replaced by a Hg/Cd lamp.) Wavelength accuracy was within the instrument specifications of 4.0Å. The maximum wavelength error was 3.05Å; most errors were considerably less. Table 1 lists the measured bandwidth at the normal programmed slit width for selected lines in the ultraviolet and visible.

TABLE 1. BANDWIDTH MEASUREMENTS FOR THE CARY 14 SPECTROPHOTOMETER

λ (Å)	Programmed slit width (mm)	Δλ bandwidth (Å)
3650.15	0.120	7.4
4046.56	0.050	3.0
4678.16	0.017	1.6
5085.82	0.011	1.6
5769.59	0.011	1.7
6438.47	0.024	2.3

Spectral Scanning Procedures--To obtain high resolution and wavelength accuracy, all scans were performed at a speed of 5.0Å/sec; windscreen samples were initially scanned in the 1.0 OD range. When the optical density of the samples exceeded the 1.0 OD range, they were rescanned in the 1.0 to 2.0 OD range. With a 2.0 OD screen filter placed in the reference beam, two additional optical density ranges could be obtained: 2.0 to 3.0 and 3.0 to 4.0. When required, all samples were measured to an optical density of 4.0 throughout the wavelength range of 300 to 2000 nm. In a high absorption region, where optical density is changing at a rapid rate, the samples were scanned at the slowest rate available, 0.5Å/sec. This insured that the recording pen response time was not exceeded by the rate of optical density change. Each sample cut from a windscreen was mounted in the sample holder and aligned so the beam passed through the center of the sample.

The spectrophotometric scan of each sample was repeated 7 times in this position.

Data Analysis--The optical density data were digitized manually on forms listing wavelength and optical density. A sampling rate of 5Å per sample was taken in most cases. In regions where the optical density was changing rapidly, the sample rate was doubled to 2.5Å per sample. Sample points were tabulated for 7 different spectrophotometric scans.

To manage the large amounts of spectrophotometric data, a computer program was written for the Hewlett-Packard model 9820 programmable calculator.

Measurement of the Index of Refraction

Instrumentation--To measure the index of refraction, a laser spectrometer system was designed and constructed consisting of two sections: (a) laser and optics, and (b) sample holder and manipulator.

A Coherent Radiation krypton gas laser, model 523, was used as the monochromatic light source in the system and was capable of delivering 8 visible wavelengths shown in Table 2.

TABLE 2. KRYPTON LASER OUTPUT LINES

λ (nm)	Spectrum color	Average power (mW)
647.1	Red	150
568.2	Yellow	60
530.3	Green	60
520.8	Green	60
482.5	Blue	20
476.2	Blue	30
463.0	Blue	5
461.9	Blue	5

The laser beam was collimated and redirected through a lens, a 50-μm aperture and a beam splitter to the sample holder, where the index of refraction was measured (Fig. 4).

The sample holder and manipulator consisted of 7 components: the mount, tilt control, elevator control, rotator control, horizontal adjustment, base, and refraction grid. The mount and base sections were used to hold the sample in place and provided a sturdy mounting rail which allowed front-to-back movement, towards or away from the laser beam.

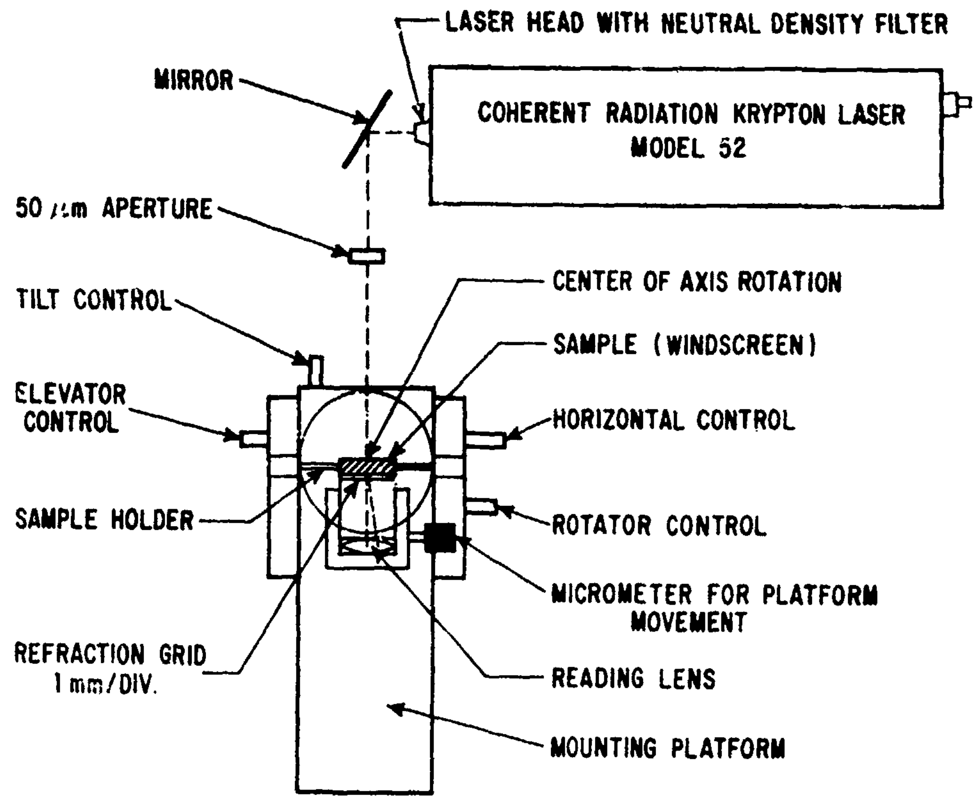

Figure 4. Measurement system for the index of refraction.

The rotator section of the system allowed the operator to change the angle of incidence of the laser beam. The rotator revolved around the sample's vertical axis and permitted a direct reading of the angle of incidence in degrees. The tilt, elevator, and horizontal controls were used to position the windscreen so that the laser beam passed through the vertical and horizontal center of each sample. The refraction grid was mounted on a bed which was moved in a perpendicular motion to the laser beam by means of a micrometer adjustment. The grid lines were separated by 1 mm. This unit was used as a coordinate system to measure the position of the unrefracted and refracted laser beam after passing above or through the windscreen sample. The difference in coordinate position between the unrefracted and refracted beam was a measure of the index of refraction of the sample.

Measurement Procedures--The index of refraction was calculated by measuring the thickness of the windscreen, the angle of incidence, and the difference in the coordinate position for the refracted and unrefracted beam, as shown in Figure 5.

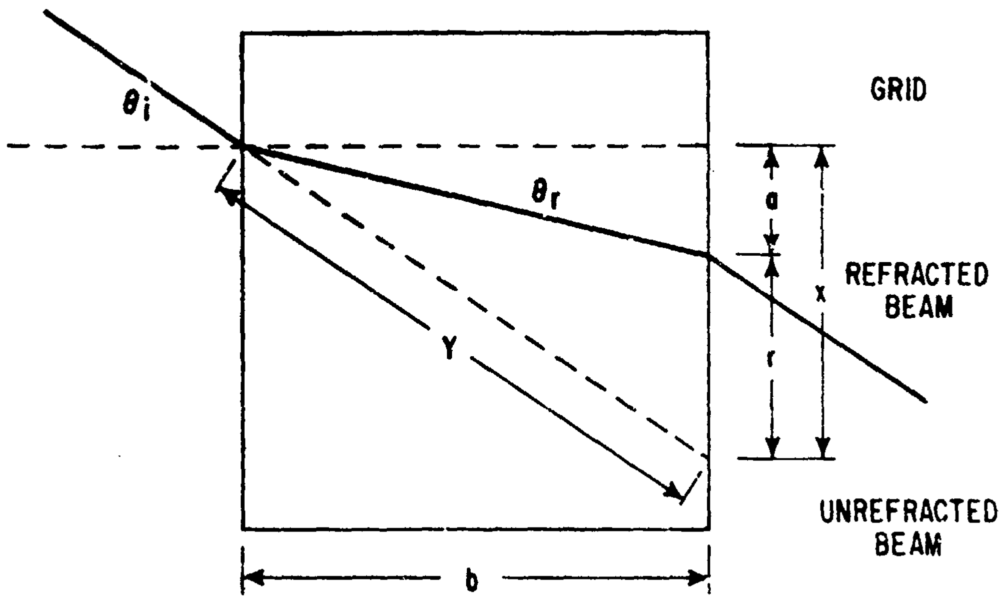

Figure 5. Calculation of index of refraction.

A computer program was written to accept these three measured parameters and to calculate the subsequent index of refraction. From Figure 5:

$$b/\cos\theta_i = Y$$

and: $Y \sin\theta_i = x$

Therefore: $a = x - r$

where: r = difference in centimeters between refracted and unrefracted beams' position
b = sample thickness
θ_i = angle of incidence
θ_r = angle of refraction

Now the angle of refraction is calculated as:

$$\theta_r = \mathrm{Tan}^{-1}\ (a/b) = \mathrm{Tan}^{-1}[(x-r)/b] \qquad (11)$$

The index of refraction can be calculated using Snell's Law as:

$$N = \frac{\mathrm{Sin}\theta_i}{\mathrm{Sin}\theta_r} \qquad (12)$$

Data Analysis--Twenty measurements were taken per sample at each of the laser wavelengths listed in Table 2. From these measurements a frequency histogram was plotted by the calculator; the mean and variance for the 20 measurements were also determined. A sample histogram plot is presented in Figure 6. A minimum acceptable value for the variance was 0.0001. If the variance did not meet this specification, an additional 20 measurements were taken and statistically analyzed until the 0.0001 variance was met. In most cases, the variance was far below the 0.0001 level.

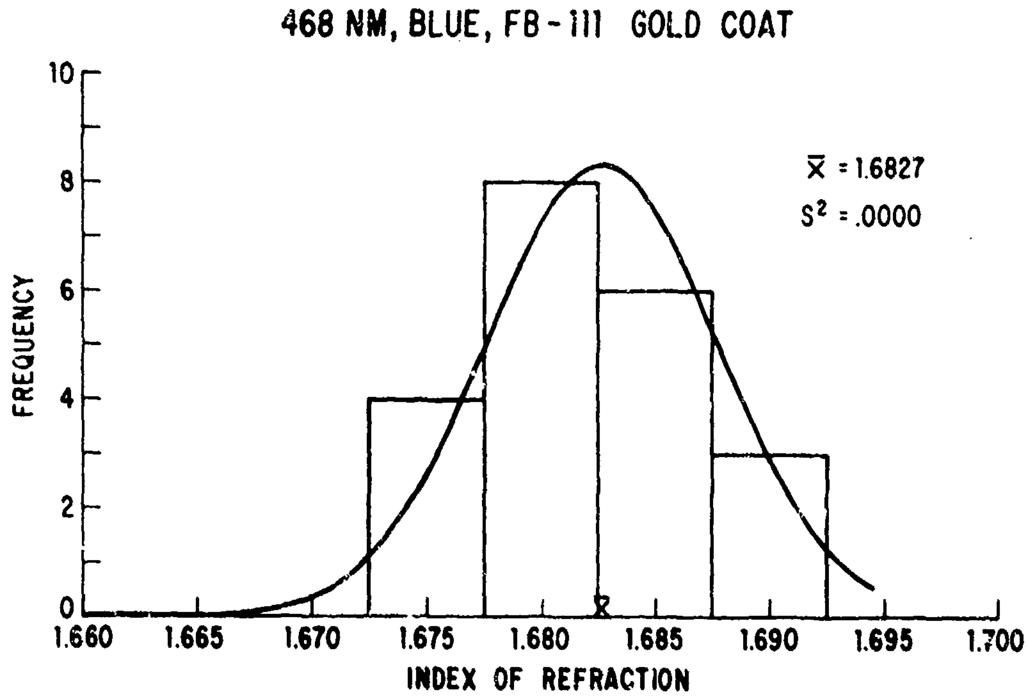

Figure 6. Sample histogram analysis for index of refraction measurements.

Dispersion Curve Construction--The eight laser wavelengths and corresponding indices of refraction were plotted on linear graph paper. From these eight points, a "best fit" hand-drawn curve was constructed. Two widely separated points on the curve were selected to calculate the Sellmeier dispersion equation coefficients (4).

The Sellmeier dispersion equation has the form (as reported before in equation 5):

$$N^2 = 1 + \sum_{i=1}^{n} \frac{A_i \lambda^2}{\lambda^2 - \lambda_{mi}^2}$$

in which λ_{mi} = absorption band location in microns.

The summation was taken as many times as maximum absorption bands were present in the spectral range of interest. In the measurement of FB-111 and B-1 windscreens, two strong absorption bands were present in the range of 0.3 to 2.0 μm. These two absorption bands, which vary with windscreen type, were measured in each windscreen. One absorption maximum was found in the UV and the other was found in the near-IR. Therefore, the Sellmeier equation takes the form:

$$N^2 = 1 + \frac{A\lambda^2}{\lambda^2 - \lambda_{uv}^2} + \frac{B\lambda^2}{\lambda^2 - \lambda_{ir}^2} \qquad (13)$$

After measurement of the two maximum absorption wavelengths, λ_{uv} and λ_{ir}, the coefficients A and B could be determined by using the two widely separated index of refraction measurements. A second determination for the A and B coefficients was derived and an average was determined. At the wavelength designated as the UV and IR absorption maxima, the Sellmeier equation predicted an infinite index of refraction, as found in theory. Consequently, because of dispersion losses, it is impossible to expect an infinite index of refraction. For each sample a nominal index of refraction of 2.5 maximum and 0.5 minimum was arbitrarily assumed near and at λ_{uv} and λ_{ir}.

Calculation of the Absorption Coefficients

With the index of refraction characterized by an equation and the transmission curves determined previously, the absorption curves could be calculated according to equation 10. A computer program was written which accepted transmission points stored on cassette tapes, performed the reflection corrections, and finally calculated and plotted the absorption coefficients as a function of wavelength. At each wavelength, the index of refraction was calculated from the Sellmeier dispersion equation. Reflection losses were then calculated from the index of refraction.

RESULTS

Transmission Measurements

Figures 7 to 9 show the results of the transmission measurements and depict the average transmission for seven trials in the wavelength interval of 0.3 to 2.0 μm for the B-1, FB-111 gold-coated, and FB-111 uncoated windscreens.

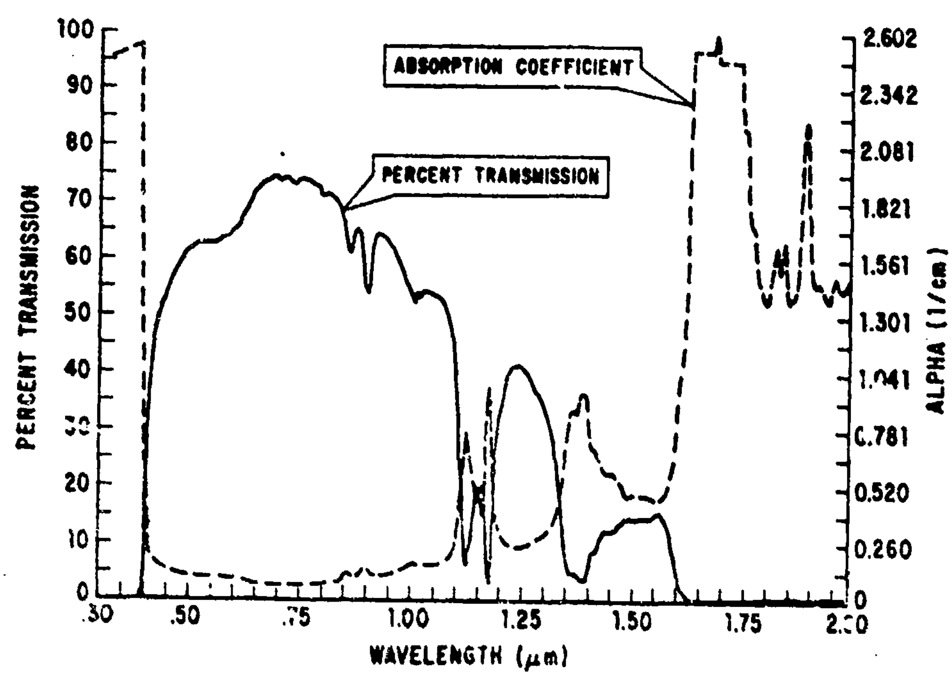

Figure 7. Transmission and absorption coefficient curves for the B-1 windscreen.

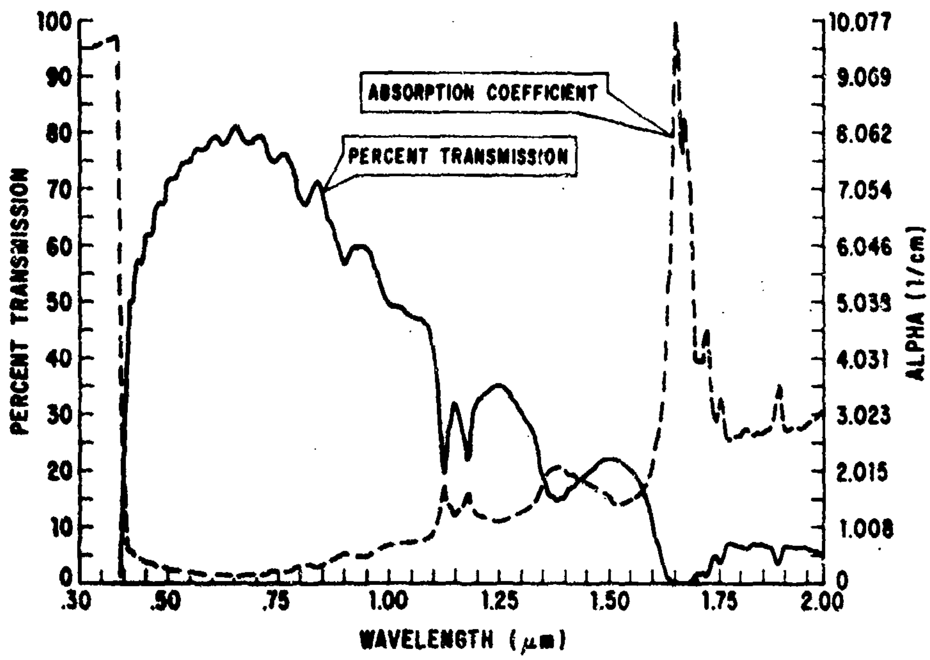

Figure 8. Transmission and absorption coefficient curves for the FB-111 gold-coated windscreen.

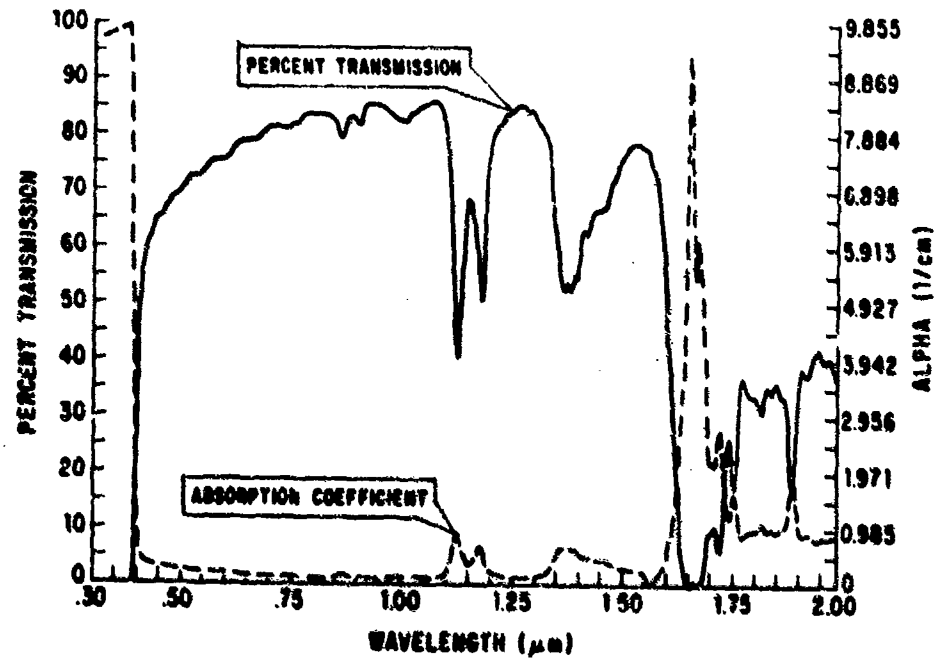

Figure 9. Transmission and absorption coefficient curves for the FB-111 uncoated windscreen.

Index of Refraction

The dispersion curves for the three windscreens are shown in Figure 10. Absorption maxima measurements in the

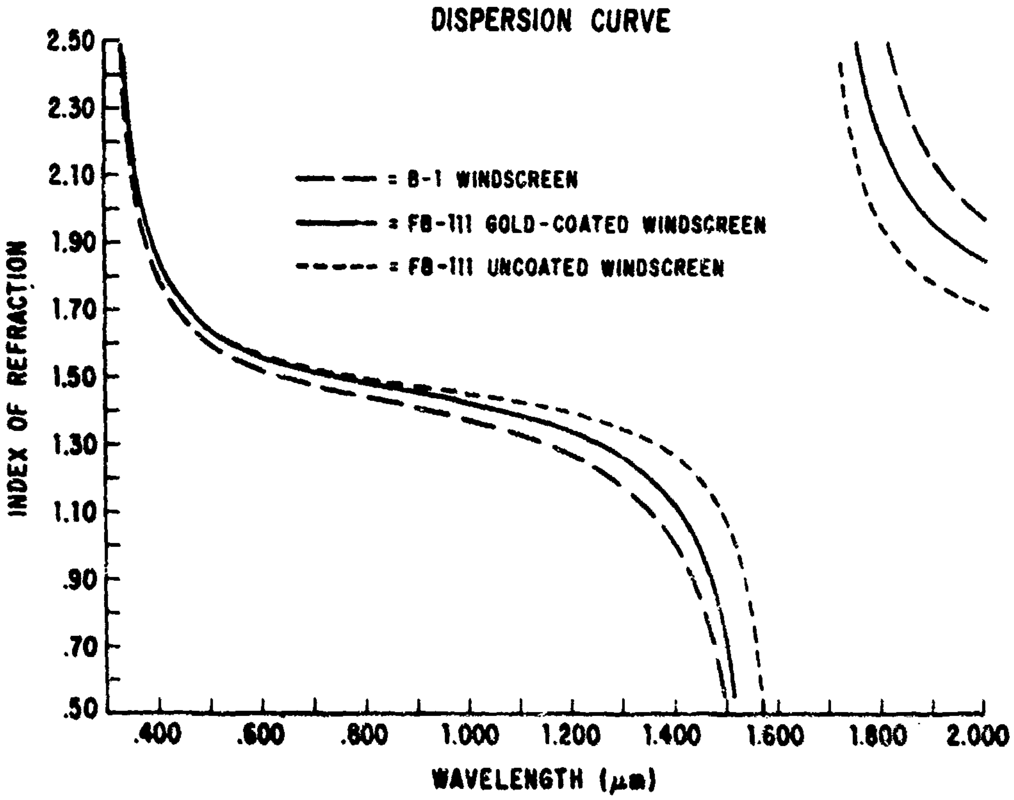

Figure 10. Sellmeier dispersion curves for the B-1, FB-111 gold-coated, and FB-111 uncoated windscreens.

UV and IR, as well as calculations for the coefficients A and B, are listed in Table 3. These values were used to formulate the Sellmeier dispersion equation and to generate the dispersion curves and index of refraction for each windscreen.

TABLE 3. DISPERSION EQUATION COEFFICIENTS

Windscreen	λ_{uv}	λ_{ir} (μm)	A	B
FB-111 gold coated	0.295	1.665	1.1230	0.386
FB-111 uncoated	0.295	1.665	1.1130	0.237
B-1	0.295	1.695	1.0445	0.510

Calculation of the Absorption Coefficient Curves

Figures 7 to 9 show the absorption coefficients plotted vs wavelength for the FB-111 uncoated, FB-111 gold-coated, and B-1 windscreens. A tabulation of results for Figures 7 to 10 is located in Appendix A. The tables list the mean total transmission (T_{mean}), mean optical density (OD_{mean}), index of refraction (N), and Lambert absorption coefficient (ALPHA) vs wavelength for the three windscreens under investigation.

DISCUSSION AND CONCLUSIONS

Transmission Measurements

B-1 Windscreen--The five-layer B-1 windscreen, which has a total thickness of 3.54 cm, transmitted less than 0.01% throughout the interval of 0.3 to 0.39 μm. As the wavelength increased above 0.39 μm, the transmission increased quite rapidly until about 0.45 μm and then leveled off to a maximum transmission of 78% at about 0.685 μm. The transmission remained about 78% until 0.825 μm where a steady but slow decrease in transmission was observed to 1.200 μm, where the transmission became less than 5%. A broad transmission peak was observed in the interval 1.200 to 1.375 μm with a maximum transmission of 37% at 1.275 μm. The transmission remained low (about 10%) at approximately 1.625 μm where it dropped off to less than 1.5% throughout the remaining spectra to 2.0 μm. At various intervals in this region the transmission dipped to less than 0.01%, as was the case for the interval of 1.640 to 1.750 μm, indicating an absorption maxima.

FB-111 Gold-Coated Windscreen--The FB-111 windscreen was a polycarbonate sample, 0.914-cm thick, with a thin gold-film layer on the inside surface. The UV and near-visible transmission was similar to that of the B-1. Virtually no light was transmitted up to 0.4 μm, where the transmission increased rapidly in the interval of 0.40 to 0.45 μm. Throughout the remainder of the visible spectra, the transmission showed a steady rise to a maximum transmission of 80% at 0.675 μm. The total transmission remained high until 0.825 μm where, as was found in the B-1, a gradual decrease was observed until a minimum of 17% transmission was reached at 1.18 μm. The remainder of the spectra from 1.18 to 2.00 μm is similar to that of the B-1. A broad peak occurred in the interval of 1.2 to 1.375 μm with a 42% transmission peak at about 1.28 μm. From 1.28 μm to 1.6 μm, the transmission was greater than 10%, with a 25% transmission peak at about 1.5 μm. A rapid decrease in transmission was observed from 1.50 μm to 1.625 μm, where the transmission was less than 1%. After this point, the transmission remained less than 10% out to 2.0 μm. From 1.655 to 1.675 μm a strong absorption band of less than 0.01% transmission was observed.

Figure 8 shows transmission oscillations starting at 0.425 μm and continuing throughout the spectra to 1.125 μm. The oscillations were caused by thin film interference effects of the gold layer. Upon removal of the gold film, the interference oscillations decreased or disappeared. Using the spectrophotometric equation for film thickness, the gold layer was found to be 4.23 μm thick.

$$b = \frac{N(\lambda_1 \times \lambda_2)}{2(\lambda_1 - \lambda_2)} \qquad (14)$$

where: b = thickness in microns
N = number of complete interference cycles
λ_1 = first wavelength of measurement in microns
λ_2 = endpoint wavelength of measurement in microns

<u>FB-111 Uncoated Windscreen</u>--The transmission of the uncoated windscreen was approximately the same in the visible as the coated sample, with the exception of the interference pattern which disappeared with the removal of the gold film. Small differences in transmission can be noted in Figures 8 and 9.

The major differences between the gold-coated and uncoated windscreens were found in the near-IR spectra. Besides the lack of interference patterns in the uncoated windscreen, consistently higher transmission values were measured. In one particular region, starting at 1.20 μm and ending at 1.375 μm, the transmission of the uncoated windscreen was approximately 45% greater than in the gold-coated sample. Therefore, we can assume that the thin gold film absorbs the majority of the near-IR spectra. In both samples (gold-coated and uncoated) the characteristic polycarbonate absorption was found in the wavelength interval of 1.125 to 1.200 µm, except for a general attenuation level change due to the gold film. In the interval starting at 1.400 µm and continuing to 2.0 µm (Figs. 8-9), the gold-coated film continued to provide the major difference in transmission between the two samples. For instance, the gold film provided in general a decrease of 30% to 50% in total transmission from the uncoated windscreen. Sharp absorption fluctuations were again found in the uncoated sample at about 1.655 to 1.70 µm, but the transmittance was a factor of 10 greater than the gold-coated sample.

All three windscreens were found to be excellent UV absorbers below 0.4 µm. The FB-111 gold-coated windscreen was found to offer the maximum attenuation in the near-IR and consequently would afford better protection in that region of the spectrum compared to the uncoated FB-111 windscreen. For example, at the neodymium laser wavelength (1.06 µm), the FB-111 gold-coated windscreen transmitted 47.2% of the light; while the FB-111 uncoated and B-1 windscreens transmitted 85.9% and 53.5%, respectively. The FB-111 uncoated windscreen had the highest peak transmission in the visible spectra, passing a maximum of 83% of the light at 0.700 µm. The effect of the gold layer on the FB-111 windscreen was to provide more near-IR attenuation without compromising the transmission "window" in the visible.

Index of Refraction and Dispersion Curve

All the windscreens were found to have two absorption bands--one in the UV and one in the near-IR. The UV absorption band was common to all and was centered at 0.295 µm. The two FB-111 windscreens contained the same IR absorption band at 1.665 µm. The gold layer on the coated FB-111 windscreen did not alter the center of the absorption band. The B-1 windscreen has a different IR absorption band than the FB-111; it was wider, attenuating over a larger wavelength region, and was centered at 1.695 µm. The index of refraction of the FB-111 gold-coated windscreen changed with wavelength more rapidly than the uncoated FB-111 windscreen. The B-1, however, demonstrated the most change in index of refraction with wavelength. The laminated B-1 windscreen was treated as being homogeneous in the measurement of the index of refraction. The value of the index of refraction for the B-1 windscreen was an average or composite measurement from all of the laminates. Similarly, the FB-111 gold-coated windscreen was also treated in this fashion.

Absorption Coefficient Calculations

The total transmission results were corrected for reflection and scatter losses prior to calculation of the absorption coefficients. In this manner only "true" absorption is found, and losses other than by absorption are excluded. The value of the absorption coefficient is such that it characterizes the sample's spectral absorption per unit thickness; thus only the sample's light pathlength need be known. From this information the percent transmission can be calculated.

In the B-1 and FB-111 gold-coated windscreens, each windscreen was treated as if it were homogeneous in the calculation of the absorption coefficient. Therefore, all laminates and coatings within a windscreen were assumed to have the same absorption coefficient. Effectively, the composite absorption was calculated for these two windscreens. Since the goal of this investigation was to measure the absorption of the windscreen as it appears in the aircraft, an absorption coefficient measurement for each laminate was deemed necessary.

Of the windscreens studied, the FB-111 gold-coated windscreen had the largest absorption coefficients throughout the spectrum studied. In comparing the two FB-111 windscreens, the gold layer provided the major portion of the absorption in the near-IR and very little in the UV and visible spectra. The B-1 windscreen had the smallest absorption coefficients but did not have good transmission characteristics, since it was approximately 3 1/2 times as thick as the FB-111 windscreens. The B-1 also exhibited the greatest reflection losses of any of the windscreens due to its laminated construction, which creates multiple internal reflections.

SUMMARY

This study reports the transmission, absorption, and index of refraction of three Air Force windscreens. Its objective was to determine the effective protection offered by these enclosures from UV, visible, and near-IR radiation. Excellent protection (>4.0 OD) was found in the UV spectrum for all three windscreens measured. The amount of near-IR attenuation varied with each windscreen type. Two factors that enhanced the near-IR attenuation properties of windscreens were multiple laminations and gold film coatings. Thin gold film coating seems to be most advantageous because visible light transmission was not decreased. Laminated windscreens, which inherently contain multiple internal reflections, attenuate in the visible to some degree as well as the near-IR.

The results of this investigation permit the calculation of the transmission and reflection losses of the three aircraft windscreens.

By measuring the angles of incidence of the radiation and the thickness of the windscreen, transmission can be calculated using absorption coefficients measured in this study. Transmission can be computed as shown below:

$$\%T = 100 \times e^{-\alpha(\lambda)(x/\cos \theta_i)} \qquad (15)$$

where: $\%T$ = % transmission of windscreen
$\alpha(\lambda)$ = absorption coefficient at wavelength of interest
x = thickness of windscreen
θ_i = angle of incidence to windscreen

Reflection losses from windscreen/air interfaces can be computed by utilizing the dispersion curve (Fig. 10) for the particular windscreen and equation 3, Fresnel's reflection law. For unpolarized light, the reflection law is valid for angles of incidence less than 50°. Angles of incidence greater than 50° will cause reflections greater than predicted by equation 3 and, consequently, the effective protection of the windscreens will be greater.

The results reported in this study can also be applied to nuclear nonionizing electromagnetic radiation. If the wavelength content and distribution are known for a particular nuclear detonation, an average windscreen transmission and reflection value can be computed.

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APPENDIX A
WINDSCREEN RESULTS
TABLE A-1. B-1 WINDSCREEN

LAMBDA(UM)	Tmean	ODmean	N	ALPHA
.3200	< .010	> 4.000	2.500	> 2.487
.3925	< .010	> 4.000	1.836	> 2.550
.3950	.016	3.809	1.826	2.427
.3975	.101	2.997	1.815	1.900
.4000	.732	2.136	1.806	1.341
.4025	3.480	1.458	1.796	.901
.4050	9.176	1.037	1.787	.628
.4075	17.413	.759	1.779	.448
.4100	25.411	.595	1.770	.342
.4125	32.808	.484	1.762	.270
.4150	36.696	.435	1.755	.239
.4175	40.094	.397	1.747	.215
.4200	42.667	.370	1.740	.198
.4225	44.852	.348	1.733	.184
.4250	46.423	.333	1.727	.175
.4300	48.141	.317	1.714	.166
.4300	48.141	.317	1.714	.166
.4325	48.991	.310	1.708	.162
.4350	49.804	.303	1.702	.157
.4375	50.262	.299	1.697	.155
.4400	50.981	.293	1.691	.152
.4425	51.830	.285	1.686	.148
.4450	52.516	.280	1.681	.144
.4475	52.865	.277	1.676	.143
.4500	53.092	.275	1.671	.142
.4525	54.024	.267	1.667	.137
.4550	54.650	.262	1.662	.135
.4600	55.554	.255	1.653	.131
.4650	56.731	.246	1.645	.125
.4700	57.532	.240	1.637	.122
.4750	58.289	.234	1.630	.119
.4800	59.256	.227	1.623	.115
.4850	59.902	.223	1.616	.113
.4900	60.518	.218	1.610	.110
.4950	61.216	.213	1.604	.107
.5000	61.667	.210	1.598	.106
.5050	61.872	.209	1.592	.105
.5100	62.284	.206	1.587	.104
.5150	62.595	.203	1.582	.103
.5200	62.802	.202	1.577	.102
.5250	62.988	.201	1.572	.102
.5300	63.073	.200	1.568	.102
.5350	63.052	.200	1.563	.102
.5400	63.111	.200	1.559	.102
.5450	63.065	.200	1.555	.103

TABLE A-1 (continued)

LAMBDA(UM)	Tmean	ODmean	N	ALPHA
.5500	63.001	.201	1.551	.104
.5550	62.867	.202	1.547	.104
.5600	62.944	.201	1.544	.104
.5650	63.194	.199	1.540	.104
.5700	63.359	.198	1.537	.103
.5750	63.605	.197	1.533	.102
.5800	63.919	.194	1.530	.101
.5850	64.239	.192	1.527	.100
.5900	64.389	.191	1.524	.099
.5950	64.686	.189	1.521	.098
.6000	65.026	.187	1.518	.097
.6050	65.291	.185	1.515	.096
.6100	65.787	.182	1.512	.094
.6150	66.314	.178	1.510	.092
.6200	67.079	.173	1.507	.089
.6250	67.903	.168	1.505	.086
.6300	68.631	.163	1.502	.083
.6350	69.292	.159	1.500	.081
.6400	70.279	.153	1.497	.077
.6450	71.175	.148	1.495	.073
.6500	71.966	.143	1.492	.070
.6550	72.371	.140	1.490	.069
.6600	72.683	.139	1.488	.068
.6650	73.278	.135	1.486	.066
.6700	73.657	.133	1.484	.065
.6750	73.949	.131	1.482	.064
.6800	74.123	.130	1.479	.063
.6850	74.340	.129	1.477	.062
.6900	74.624	.127	1.475	.061
.6950	74.789	.126	1.473	.061
.7000	74.661	.127	1.471	.062
.7050	74.175	.130	1.470	.064
.7100	73.860	.132	1.468	.065
.7150	74.445	.128	1.466	.063
.7200	74.638	.127	1.464	.062
.7250	74.584	.127	1.462	.063
.7300	74.387	.129	1.460	.063
.7350	74.000	.131	1.458	.065
.7400	73.372	.134	1.457	.068
.7450	73.228	.135	1.455	.068
.7500	74.120	.130	1.453	.065
.7550	74.339	.129	1.451	.064
.7600	74.390	.128	1.450	.064
.7650	74.317	.129	1.448	.065
.7700	74.004	.131	1.446	.066

TABLE A-1 (continued)

LAMBDA(UM)	Tmean	ODmean	N	ALPHA
.7750	73.767	.132	1.445	.067
.7800	73.458	.134	1.443	.068
.7850	73.165	.136	1.441	.070
.7900	73.118	.136	1.440	.070
.7950	72.923	.137	1.438	.071
.8000	72.735	.138	1.436	.072
.8000	72.735	.138	1.436	.072
.8000	72.735	.138	1.436	.072
.8000	72.735	.138	1.436	.072
.8000	72.735	.138	1.436	.072
.8000	71.533	.145	1.436	.076
.8050	71.351	.147	1.435	.077
.8100	71.449	.146	1.433	.077
.8150	71.642	.145	1.431	.076
.8200	71.642	.145	1.430	.076
.8250	71.475	.146	1.428	.077
.8300	71.238	.147	1.426	.078
.8350	70.750	.150	1.425	.080
.8400	70.359	.153	1.423	.082
.8450	69.792	.156	1.422	.084
.8500	68.846	.162	1.420	.088
.8550	67.486	.171	1.418	.094
.8600	65.212	.186	1.417	.104
.8650	61.991	.208	1.415	.118
.8700	61.218	.213	1.413	.122
.8750	63.301	.199	1.412	.112
.8800	65.078	.187	1.410	.105
.8850	65.469	.184	1.409	.103
.8900	64.792	.188	1.407	.106
.8950	62.598	.203	1.405	.116
.9000	59.258	.227	1.404	.132
.9050	55.067	.259	1.402	.152
.9100	54.193	.266	1.400	.157
.9150	60.680	.217	1.399	.125
.9200	63.270	.199	1.397	.114
.9250	64.545	.190	1.395	.108
.9300	64.692	.189	1.393	.108
.9350	64.548	.190	1.392	.108
.9400	64.338	.192	1.390	.109
.9450	64.097	.193	1.388	.111
.9500	63.782	.195	1.387	.112
.9550	63.257	.199	1.385	.114
.9600	62.526	.204	1.383	.118
.9650	62.211	.206	1.381	.119
.9700	61.402	.212	1.379	.123

TABLE A-1 (continued)

LAMBDA(UM)	Tmean	ODmean	N	ALPHA
.9750	60.489	.218	1.378	.128
.9800	59.578	.225	1.376	.132
.9850	58.435	.233	1.374	.138
.9900	57.146	.243	1.372	.144
.9950	56.164	.251	1.370	.149
1.0000	55.451	.256	1.368	.153
1.0050	54.601	.263	1.366	.157
1.0100	53.588	.271	1.364	.163
1.0150	52.603	.279	1.362	.168
1.0200	54.351	.265	1.360	.159
1.0250	53.642	.270	1.358	.163
1.0300	54.294	.265	1.356	.159
1.0350	54.651	.262	1.354	.158
1.0400	54.488	.264	1.352	.159
1.0450	54.274	.265	1.350	.160
1.0500	54.115	.267	1.348	.161
1.0550	53.957	.268	1.346	.162
1.0600	53.766	.269	1.343	.163
1.0650	53.592	.271	1.341	.164
1.0700	53.524	.271	1.339	.165
1.0750	53.366	.273	1.337	.166
1.0800	52.670	.278	1.334	.169
1.0850	51.965	.284	1.332	.173
1.0900	50.693	.295	1.329	.181
1.0950	49.064	.309	1.327	.190
1.1000	47.195	.326	1.325	.201
1.1050	44.305	.354	1.322	.219
1.1100	39.292	.406	1.319	.253
1.1150	33.038	.481	1.317	.302
1.1250	14.559	.837	1.312	.534
1.1300	8.347	1.078	1.309	.691
1.1350	6.194	1.208	1.306	.776
1.1400	9.318	1.031	1.303	.661
1.1450	11.886	.925	1.300	.592
1.1500	15.325	.815	1.297	.520
1.1550	19.398	.712	1.294	.454
1.1600	19.670	.706	1.291	.450
1.1650	17.952	.746	1.288	.476
1.1700	14.[illegible]	.829	1.285	.530
1.1750	20.006	.699	1.282	.446
1.1800	5.729	1.242	1.278	.799
1.1850	3.102	1.508	1.275	.973
1.1900	4.385	1.358	1.272	.875
1.1950	14.398	.842	1.268	.540
1.2000	25.554	.593	1.265	.378

TABLE A-1 (continued)

LAMBDA(UM)	Tmean	ODmean	N	ALPHA
1.2050	30.606	.514	1.261	.327
1.2100	33.316	.477	1.257	.303
1.2150	34.335	.464	1.253	.295
1.2200	36.843	.434	1.249	.275
1.2250	39.154	.407	1.245	.258
1.2300	40.087	.397	1.241	.252
1.2350	40.745	.390	1.237	.247
1.2400	41.337	.384	1.233	.243
1.2450	41.541	.382	1.228	.242
1.2500	41.482	.382	1.224	.243
1.2550	41.381	.383	1.219	.244
1.2600	40.976	.387	1.215	.247
1.2650	40.539	.392	1.210	.250
1.2700	40.107	.397	1.205	.253
1.2750	39.537	.403	1.200	.257
1.2800	38.774	.411	1.194	.263
1.2850	37.745	.423	1.189	.271
1.2900	36.695	.435	1.183	.279
1.2950	36.349	.440	1.178	.282
1.3000	36.199	.441	1.172	.284
1.3050	35.233	.453	1.166	.291
1.3100	34.247	.465	1.159	.300
1.3150	32.934	.482	1.153	.311
1.3200	31.993	.495	1.146	.319
1.3250	30.947	.509	1.139	.329
1.3300	29.243	.534	1.132	.345
1.3350	27.764	.557	1.125	.360
1.3400	24.481	.611	1.117	.396
1.3450	20.821	.682	1.109	.442
1.3500	16.676	.778	1.101	.505
1.3500	16.676	.778	1.101	.505
1.3550	11.552	.937	1.092	.609
1.3600	9.263	1.033	1.084	.671
1.3650	6.443	1.191	1.075	.774
1.3700	4.762	1.322	1.065	.859
1.3750	4.594	1.338	1.055	.870
1.3800	4.671	1.331	1.045	.865
1.3850	4.871	1.312	1.034	.853
1.3900	4.103	1.387	1.023	.902
1.3950	3.428	1.465	1.011	.953
1.4000	3.610	1.442	.999	.938
1.4050	3.561	1.448	.986	.942
1.4100	4.772	1.321	.973	.859
1.4150	7.170	1.145	.959	.744
1.4200	8.423	1.075	.944	.698

TABLE A-1 (continued)

LAMBDA(UM)	Tmean	ODmean	N	ALPHA
1.4250	8.322	1.080	.928	.702
1.4300	8.925	1.049	.912	.681
1.4350	9.656	1.015	.894	.659
1.4400	10.878	.963	.876	.624
1.4450	11.672	.933	.856	.603
1.4500	12.259	.912	.835	.588
1.4550	12.398	.907	.813	.584
1.4600	12.184	.914	.789	.587
1.4650	12.171	.915	.763	.585
1.4700	12.280	.911	.735	.579
1.4750	12.639	.898	.705	.567
1.4800	13.235	.878	.672	.549
1.4850	13.608	.866	.635	.535
1.4900	13.789	.860	.594	.522
1.4950	14.487	.839	.548	.495
1.5000	14.568	.837	.500	.478
1.5050	14.486	.839	.500	.479
1.5100	14.130	.850	.500	.486
1.5150	14.174	.849	.500	.485
1.5200	14.238	.847	.500	.484
1.5250	14.381	.842	.500	.481
1.5300	14.576	.836	.500	.477
1.5350	14.617	.835	.500	.477
1.5400	14.552	.837	.500	.478
1.5450	14.536	.838	.500	.478
1.5500	14.486	.839	.500	.479
1.5550	14.552	.837	.500	.478
1.5600	14.877	.827	.500	.472
1.5650	15.274	.816	.500	.464
1.5700	15.538	.809	.500	.459
1.5750	15.357	.814	.500	.463
1.5800	14.658	.834	.500	.476
1.5850	14.175	.848	.500	.485
1.5900	13.242	.878	.500	.505
1.5950	11.794	.928	.500	.537
1.6000	10.054	.998	.500	.582
1.6050	8.341	1.079	.500	.635
1.6100	6.379	1.195	.500	.711
1.6150	3.535	1.452	.500	.878
1.6200	2.128	1.672	.500	1.021
1.6250	1.710	1.767	.500	1.083
1.6300	.998	2.001	.500	1.235
1.6350	.469	2.328	.500	1.448
1.6400	.040	3.403	.500	2.147
1.6450	< .010	> 4.000	.500	> 2.535

TABLE A-1 (continued)

LAMBDA(UM)	Tmean	ODmean	N	ALPHA
1.6500	< .010	> 4.000	.500	> 2.535
1.6550	< .010	> 4.000	.500	> 2.535
1.6600	< .010	> 4.000	.500	> 2.535
1.6650	< .010	> 4.000	.500	> 2.535
1.6700	< .010	> 4.000	.500	> 2.535
1.6750	< .010	> 4.000	.500	> 2.535
1.6800	< .010	> 4.000	.500	> 2.535
1.6850	< .010	> 4.000	.500	> 2.535
1.6900	< .010	> 4.000	.500	> 2.535
1.6950	< .010	> 4.000	1.000	> 2.602
1.7000	< .010	> 4.000	2.500	> 2.487
1.7050	< .010	> 4.000	2.500	> 2.487
1.7100	< .010	> 4.000	2.500	> 2.487
1.7150	< .010	> 4.000	2.500	> 2.487
1.7200	< .010	> 4.000	2.500	> 2.487
1.7250	< .010	> 4.000	2.500	> 2.487
1.7300	< .010	> 4.000	2.500	> 2.487
1.7350	< .010	> 4.000	2.500	> 2.487
1.7400	< .010	> 4.000	2.500	> 2.487
1.7450	< .010	> 4.000	2.500	> 2.487
1.7500	< .010	> 4.000	2.500	> 2.487
1.7550	.019	3.714	2.500	2.301
1.7600	.030	3.520	2.500	2.175
1.7650	.031	3.503	2.500	2.164
1.7700	.054	3.271	2.500	2.013
1.7750	.117	2.930	2.500	1.791
1.7800	.151	2.820	2.500	1.720
1.7850	.156	2.807	2.500	1.711
1.7900	.250	2.601	2.500	1.577
1.7950	.354	2.451	2.500	1.480
1.8000	.426	2.371	2.500	1.427
1.8050	.474	2.324	2.500	1.397
1.8100	.517	2.287	2.494	1.373
1.8150	.532	2.274	2.462	1.368
1.8200	.472	2.326	2.433	1.405
1.8250	.353	2.452	2.405	1.489
1.8300	.275	2.561	2.379	1.563
1.8350	.226	2.646	2.355	1.621
1.8400	.339	2.470	2.333	1.508
1.8450	.338	2.471	2.311	1.511
1.8500	.208	2.681	2.291	1.649
1.8550	.315	2.501	2.272	1.534
1.8600	.513	2.290	2.254	1.399
1.8650	.564	2.248	2.237	1.373
1.8700	.534	2.273	2.220	1.391

TABLE A-1 (continued)

LAMBDA(UM)	Tmean	ODmean	N	ALPHA
1.8750	.533	2.274	2.205	1.393
1.8800	.514	2.289	2.190	1.404
1.8850	.393	2.406	2.176	1.482
1.8900	.212	2.673	2.163	1.657
1.8950	.063	3.203	2.150	2.002
1.9000	.032	3.498	2.137	2.196
1.9050	.085	3.073	2.126	1.920
1.9100	.188	2.727	2.114	1.696
1.9150	.334	2.476	2.104	1.534
1.9200	.435	2.362	2.093	1.461
1.9250	.459	2.338	2.083	1.446
1.9300	.446	2.351	2.074	1.455
1.9350	.455	2.342	2.064	1.451
1.9400	.504	2.297	2.055	1.422
1.9450	.566	2.247	2.047	1.391
1.9500	.593	2.227	2.038	1.378
1.9550	.594	2.226	2.030	1.379
1.9600	.489	2.311	2.023	1.434
1.9650	.437	2.360	2.015	1.467
1.9700	.411	2.387	2.008	1.485
1.9750	.452	2.345	2.001	1.459
1.9800	.501	2.300	1.994	1.430
1.9850	.515	2.288	1.988	1.423
1.9900	.485	2.314	1.981	1.440
1.9950	.456	2.342	1.975	1.459
2.0000	.429	2.368	1.969	1.477

TABLE A-2. FB-111 UNCOATED WINDSCREEN

LAMBDA(UM)	Tmean	ODmean	N	ALPHA
.3200	< .010	> 4.000	2.500	> 9.633
.3825	< .010	> 4.000	1.932	> 9.844
.3850	.011	3.968	1.919	9.768
.3875	.014	3.869	1.906	9.522
.3900	.024	3.623	1.894	8.907
.3925	.094	3.025	1.883	7.405
.3950	.860	2.066	1.872	4.992
.3975	4.399	1.357	1.861	3.210
.4000	13.422	.872	1.851	1.993
.4025	23.956	.621	1.841	1.363
.4050	34.321	.464	1.832	.973
.4075	42.535	.371	1.823	.741
.4100	48.545	.314	1.814	.599
.4125	52.820	.277	1.806	.510
.4150	55.623	.255	1.798	.456
.4175	57.745	.238	1.791	.418
.4200	58.930	.230	1.783	.398
.4225	59.725	.224	1.776	.386
.4250	60.435	.219	1.770	.375
.4275	61.075	.214	1.763	.366
.4300	61.663	.210	1.757	.358
.4325	62.190	.206	1.750	.350
.4350	62.889	.201	1.745	.340
.4375	63.537	.197	1.739	.331
.4400	64.063	.193	1.733	.324
.4450	65.068	.187	1.723	.310
.4475	65.320	.185	1.718	.308
.4500	65.575	.183	1.713	.305
.4525	65.853	.181	1.708	.302
.4550	65.745	.182	1.703	.306
.4600	66.180	.179	1.694	.301
.4650	66.946	.174	1.686	.291
.4700	67.813	.169	1.678	.280
.4750	68.579	.164	1.671	.270
.4800	69.348	.159	1.663	.260
.4850	69.619	.157	1.657	.258
.4900	69.709	.157	1.650	.259
.4950	69.780	.156	1.644	.260
.5000	70.194	.154	1.638	.255
.5050	70.749	.150	1.633	.248
.5100	71.524	.146	1.627	.238
.5150	72.309	.141	1.622	.228
.5200	72.882	.137	1.617	.221
.5250	73.310	.135	1.613	.216
.5300	73.308	.135	1.608	.217

TABLE A-2 (continued)

LAMBDA(UM)	Tmean	ODmean	N	ALPHA
.5350	73.285	.135	1.604	.219
.5400	73.141	.136	1.600	.223
.5450	73.405	.134	1.596	.220
.5500	73.743	.132	1.592	.216
.5550	74.231	.129	1.588	.210
.5600	74.678	.127	1.584	.205
.5650	75.270	.123	1.581	.197
.5700	75.740	.121	1.578	.191
.5750	76.035	.119	1.574	.188
.5800	76.059	.119	1.571	.189
.5850	76.135	.118	1.568	.189
.5900	76.137	.118	1.565	.189
.5950	76.236	.118	1.562	.189
.6000	76.033	.119	1.560	.193
.6050	76.134	.118	1.557	.192
.6100	76.742	.115	1.554	.184
.6150	77.379	.111	1.552	.176
.6200	77.944	.108	1.549	.169
.6250	78.582	.105	1.547	.160
.6300	78.890	.103	1.545	.157
.6350	79.122	.102	1.542	.154
.6400	79.381	.100	1.540	.151
.6450	79.302	.101	1.538	.153
.6500	79.645	.099	1.536	.149
.6550	79.672	.099	1.534	.149
.6600	79.487	.100	1.532	.152
.6650	79.433	.100	1.530	.154
.6700	79.590	.099	1.528	.152
.6750	79.749	.098	1.526	.151
.6800	80.277	.095	1.524	.144
.6850	80.757	.093	1.523	.138
.6900	81.184	.091	1.521	.133
.6950	81.636	.088	1.519	.127
.7000	82.039	.086	1.517	.122
.7050	81.877	.087	1.516	.125
.7100	81.740	.088	1.514	.127
.7150	82.010	.086	1.513	.124
.7200	81.902	.087	1.511	.126
.7250	81.984	.086	1.509	.125
.7300	81.796	.087	1.508	.128
.7350	81.662	.088	1.506	.130
.7400	81.499	.089	1.505	.133
.7450	81.525	.089	1.504	.133
.7500	82.036	.086	1.502	.127
.7550	82.361	.084	1.501	.123

TABLE A-2 (continued)

LAMBDA(UM)	Tmean	ODmean	N	ALPHA
.7600	82.444	.084	1.499	.122
.7650	82.527	.083	1.498	.121
.7700	82.965	.081	1.497	.116
.7750	83.378	.079	1.495	.111
.7800	83.846	.077	1.494	.105
.7850	84.065	.075	1.493	.103
.7900	84.256	.074	1.491	.101
.7950	84.449	.073	1.490	.098
.8000	84.504	.073	1.489	.098
.7950	84.449	.073	1.490	.098
.8000	84.090	.075	1.489	.103
.8050	84.202	.075	1.488	.102
.8100	84.345	.074	1.487	.101
.8150	84.403	.074	1.485	.100
.8200	84.269	.074	1.484	.103
.8250	84.131	.075	1.483	.105
.8300	83.911	.076	1.482	.108
.8350	83.801	.077	1.481	.110
.8400	83.747	.077	1.479	.111
.8450	83.412	.079	1.478	.115
.8500	82.970	.081	1.477	.122
.8550	82.342	.084	1.476	.130
.8600	81.182	.091	1.475	.146
.8650	79.962	.097	1.474	.163
.8700	80.121	.096	1.473	.161
.8750	81.720	.088	1.471	.140
.8800	82.881	.082	1.470	.125
.8850	83.565	.078	1.469	.116
.8900	83.758	.077	1.468	.114
.8950	83.511	.078	1.467	.117
.9000	82.936	.081	1.466	.125
.9050	82.282	.085	1.465	.134
.9100	82.390	.084	1.464	.133
.9150	83.980	.076	1.463	.112
.9200	85.515	.068	1.462	.093
.9250	85.994	.066	1.461	.087
.9300	86.223	.064	1.459	.084
.9350	86.226	.064	1.458	.085
.9400	86.174	.065	1.457	.086
.9450	86.145	.065	1.456	.086
.9500	85.893	.066	1.455	.090
.9550	85.554	.068	1.454	.094
.9600	85.302	.069	1.453	.098
.9650	85.243	.069	1.452	.099
.9700	84.850	.071	1.451	.104

TABLE A-2 (continued)

LAMBDA(UM)	Tmean	ODmean	N	ALPHA
.9750	84.516	.073	1.450	.109
.9800	84.320	.074	1.449	.112
.9850	83.987	.076	1.447	.117
.9900	83.542	.078	1.446	.123
.9950	83.266	.080	1.445	.127
1.0000	83.101	.080	1.444	.129
1.0050	83.019	.081	1.443	.130
1.0100	82.771	.082	1.442	.134
1.0150	82.798	.082	1.441	.134
1.0200	83.456	.079	1.440	.126
1.0250	84.226	.075	1.438	.116
1.0300	84.365	.074	1.437	.114
1.0350	84.643	.072	1.436	.111
1.0400	85.061	.070	1.435	.106
1.0450	85.455	.068	1.434	.101
1.0500	85.510	.068	1.432	.101
1.0550	85.821	.066	1.431	.097
1.0600	85.934	.066	1.430	.096
1.0650	86.047	.065	1.429	.095
1.0700	86.273	.064	1.428	.093
1.0750	86.528	.063	1.426	.090
1.0800	86.585	.063	1.425	.089
1.0850	86.416	.063	1.424	.092
1.0900	85.905	.066	1.422	.099
1.0950	85.484	.068	1.421	.104
1.1000	84.284	.074	1.420	.120
1.1050	82.147	.085	1.418	.149
1.1100	78.942	.103	1.417	.193
1.1150	74.356	.129	1.416	.258
1.1200	66.974	.174	1.414	.373
1.1250	56.607	.247	1.413	.558
1.1300	45.353	.343	1.411	.800
1.1350	40.853	.389	1.410	.915
1.1400	47.648	.322	1.408	.747
1.1450	55.349	.257	1.407	.584
1.1500	62.266	.206	1.405	.455
1.1550	68.806	.162	1.404	.346
1.1600	68.966	.161	1.402	.344
1.1650	67.285	.172	1.401	.372
1.1700	65.042	.187	1.399	.409
1.1750	61.281	.213	1.397	.475
1.1800	57.816	.238	1.396	.539
1.1850	51.222	.291	1.394	.672
1.1900	52.974	.276	1.392	.636
1.1950	65.397	.184	1.390	.405

TABLE A-2 (continued)

LAMBDA(UM)	Tmean	ODmean	N	ALPHA
1.2000	74.874	.126	1.389	.258
1.2050	77.501	.111	1.387	.221
1.2100	79.776	.098	1.385	.189
1.2150	80.885	.092	1.383	.175
1.2200	81.392	.089	1.381	.168
1.2250	82.389	.084	1.379	.156
1.2300	82.552	.083	1.377	.154
1.2350	83.014	.081	1.375	.148
1.2400	83.867	.076	1.373	.138
1.2450	84.254	.074	1.371	.133
1.2500	84.531	.073	1.368	.130
1.2550	84.976	.071	1.366	.125
1.2600	85.117	.070	1.364	.124
1.2650	85.707	.067	1.361	.117
1.2700	85.933	.066	1.359	.115
1.2750	86.074	.065	1.356	.113
1.2800	86.018	.065	1.354	.115
1.2850	85.622	.067	1.351	.120
1.2900	84.837	.071	1.349	.131
1.2950	85.033	.070	1.346	.129
1.3000	85.116	.070	1.343	.129
1.3050	84.558	.073	1.340	.137
1.3100	83.700	.077	1.337	.149
1.3150	82.633	.083	1.334	.163
1.3200	82.253	.085	1.331	.169
1.3250	81.606	.088	1.327	.179
1.3300	80.938	.092	1.324	.188
1.3350	80.434	.095	1.320	.196
1.3400	79.226	.101	1.317	.213
1.3450	76.538	.116	1.313	.252
1.3500	71.289	.147	1.309	.331
1.3550	64.822	.188	1.305	.436
1.3600	62.155	.207	1.301	.482
1.3650	58.389	.234	1.297	.552
1.3700	54.993	.260	1.292	.618
1.3750	52.834	.277	1.288	.663
1.3800	52.936	.276	1.283	.662
1.3850	54.167	.266	1.278	.638
1.3900	52.767	.278	1.273	.668
1.3950	53.875	.269	1.268	.646
1.4000	55.485	.256	1.262	.615
1.4050	55.051	.259	1.256	.625
1.4100	57.859	.258	1.250	.571
1.4150	62.590	.203	1.244	.487
1.4200	63.456	.198	1.237	.473

TABLE A-2 (continued)

LAMBDA (UM)	Tmean	ODmean	N	ALPHA
1.4250	62.605	.203	1.230	.489
1.4300	63.041	.200	1.223	.483
1.4350	64.193	.193	1.216	.464
1.4400	66.035	.180	1.208	.435
1.4450	66.928	.174	1.199	.421
1.4500	66.994	.174	1.190	.422
1.4550	66.974	.174	1.181	.423
1.4600	67.192	.173	1.171	.421
1.4650	67.658	.170	1.161	.415
1.4700	67.793	.169	1.150	.415
1.4750	68.939	.162	1.138	.398
1.4800	70.427	.152	1.126	.376
1.4850	71.997	.143	1.112	.353
1.4900	72.496	.140	1.098	.347
1.4950	73.746	.132	1.083	.330
1.5000	75.291	.123	1.066	.308
1.5050	76.086	.119	1.048	.298
1.5100	76.765	.115	1.029	.289
1.5150	77.627	.110	1.008	.277
1.5200	78.217	.107	.985	.269
1.5250	78.759	.104	.960	.260
1.5300	79.095	.102	.933	.254
1.5350	79.069	.102	.902	.251
1.5400	79.043	.102	.867	.246
1.5450	79.043	.102	.829	.238
1.5500	78.862	.103	.784	.228
1.5550	7[illegible].294	.106	.733	.215
1.5600	7[illegible].294	.106	.672	.182
1.5650	78.011	.108	.597	.128
1.5700	77.473	.111	.503	.026
1.5750	76.462	.117	.500	.036
1.5800	74.574	.127	.500	.063
1.5850	73.454	.134	.500	.080
1.5900	71.593	.145	.500	.108
1.5950	68.687	.163	.500	.153
1.5950	68.687	.163	.500	.153
1.6000	65.401	.184	.500	.207
1.6050	60.856	.216	.500	.286
1.6100	55.556	.255	.500	.385
1.6150	45.149	.345	.500	.612
1.6200	37.157	.430	.500	.825
1.6250	33.954	.469	.500	.924
1.6300	25.204	.599	.500	1.250
1.6350	19.178	.717	.500	1.549
1.6400	10.773	.968	.500	2.180

TABLE A-2 (continued)

LAMBDA(UM)	Tmean	ODmean	N	ALPHA
1.6450	4.500	1.347	.500	3.135
1.6500	2.818	1.550	.500	3.647
1.6550	.798	2.098	.500	5.027
1.6600	.075	3.125	.500	7.614
1.6650	.020	3.700	1.000	9.322
1.6700	.030	3.517	2.500	8.416
1.6750	.295	2.531	2.500	5.931
1.6800	.486	2.314	2.500	5.385
1.6850	.260	2.584	2.500	6.066
1.6900	.424	2.373	2.500	5.533
1.6950	.622	2.206	2.500	5.114
1.7000	1.590	1.799	2.500	4.087
1.7050	5.087	1.294	2.500	2.815
1.7100	9.144	1.039	2.500	2.173
1.7150	9.410	1.026	2.500	2.142
1.7200	9.854	1.006	2.432	2.117
1.7250	10.377	.984	2.369	2.084
1.7300	7.041	1.152	2.315	2.528
1.7350	6.074	1.217	2.268	2.708
1.7400	10.028	.999	2.226	2.175
1.7450	17.767	.750	2.189	1.563
1.7500	25.008	.602	2.155	1.201
1.7550	26.183	.582	2.125	1.162
1.7600	21.587	.666	2.098	1.384
1.7650	17.772	.750	2.073	1.606
1.7700	21.080	.676	2.050	1.427
1.7750	28.711	.542	2.029	1.097
1.7800	35.757	.447	2.010	.864
1.7850	36.999	.432	1.992	.833
1.7900	35.730	.447	1.975	.877
1.7950	34.631	.461	1.960	.917
1.8000	34.055	.468	1.946	.941
1.8050	33.664	.473	1.932	.958
1.8150	33.742	.472	1.908	.964
1.8150	33.742	.472	1.908	.964
1.8300	30.806	.511	1.876	1.075
1.8300	30.806	.511	1.876	1.075
1.8350	33.632	.473	1.866	.983
1.8400	35.393	.451	1.858	.930
1.8450	35.217	.453	1.849	.938
1.8500	34.201	.466	1.841	.973
1.8550	35.185	.454	1.833	.945
1.8600	36.229	.441	1.826	.915
1.8650	35.321	.452	1.819	.946
1.8700	33.864	.470	1.812	.994

TABLE A-2 (continued)

LAMBDA(UM)	Tmean	ODmean	N	ALPHA
1.8750	33.877	.470	1.806	.996
1.8800	33.886	.470	1.800	.998
1.8850	31.823	.497	1.794	1.068
1.8900	26.776	.572	1.789	1.259
1.8900	26.776	.572	1.789	1.259
1.8950	18.932	.723	1.783	1.640
1.9000	16.496	.783	1.778	1.793
1.9100	31.694	.499	1.768	1.082
1.9150	37.049	.431	1.764	.913
1.9200	38.499	.415	1.759	.872
1.9250	38.046	.420	1.755	.886
1.9300	37.451	.427	1.751	.905
1.9350	37.660	.424	1.747	.900
1.9400	38.895	.410	1.743	.866
1.9450	40.836	.389	1.740	.814
1.9500	41.636	.381	1.736	.794
1.9550	42.116	.376	1.733	.783
1.9600	41.634	.381	1.729	.797
1.9650	40.380	.394	1.726	.831
1.9700	39.944	.399	1.723	.844
1.9750	40.220	.396	1.720	.838
1.9800	40.687	.391	1.717	.826
1.9850	40.446	.393	1.714	.833
1.9900	39.034	.409	1.711	.873
1.9950	37.759	.423	1.708	.911
2.0000	36.549	.437	1.706	.947

TABLE A-3. FB-111 GOLD-COATED WINDSCREEN

LAMBDA(UM)	Tmean	ODmean	N	ALPHA
.3200	< .010	> 4.000	2.500	> 9.633
.3850	< .010	> 4.000	1.923	> 9.847
.3875	.011	3.960	1.910	9.752
.3900	.020	3.698	1.898	9.096
.3925	.089	3.051	1.886	7.471
.3950	1.192	1.924	1.875	4.633
.3975	3.878	1.411	1.865	3.347
.4000	11.250	.949	1.854	2.185
.4025	19.483	.710	1.845	1.588
.4050	27.419	.562	1.835	1.217
.4075	34.343	.464	1.826	.974
.4100	40.478	.393	1.818	.797
.4125	45.635	.341	1.809	.669
.4150	48.978	.310	1.801	.594
.4175	50.391	.298	1.794	.566
.4200	50.352	.298	1.786	.569
.4225	50.351	.298	1.779	.572
.4250	51.106	.292	1.772	.558
.4275	52.934	.276	1.765	.522
.4300	54.961	.260	1.759	.483
.4325	56.953	.244	1.753	.446
.4350	57.780	.238	1.747	.432
.4375	57.851	.238	1.741	.433
.4400	57.433	.241	1.735	.443
.4425	57.040	.244	1.730	.452
.4450	57.388	.241	1.724	.447
.4475	58.725	.231	1.719	.424
.4500	60.103	.221	1.714	.400
.4525	61.539	.211	1.709	.376
.4550	62.487	.204	1.705	.361
.4600	62.525	.204	1.696	.363
.4650	62.217	.206	1.687	.371
.4700	63.681	.196	1.679	.348
.4750	66.574	.177	1.672	.302
.4800	68.002	.167	1.664	.281
.4850	67.941	.168	1.657	.285
.4900	67.677	.170	1.651	.291
.4950	68.493	.164	1.644	.280
.5000	70.646	.151	1.638	.248
.4950	68.493	.164	1.644	.280
.5000	70.646	.151	1.638	.248
.5050	72.115	.142	1.633	.227
.5100	72.495	.140	1.627	.224
.5150	72.308	.141	1.622	.228
.5200	72.376	.140	1.617	.229

TABLE A-3 (continued)

LAMBDA(UM)	Tmean	ODmean	N	ALPHA
.5250	73.188	.136	1.612	.218
.5300	74.181	.130	1.607	.205
.5350	75.089	.124	1.603	.193
.5400	75.387	.123	1.599	.190
.5450	75.188	.124	1.594	.194
.5500	75.165	.124	1.590	.196
.5550	75.616	.121	1.586	.190
.5600	76.641	.116	1.583	.177
.5650	77.447	.111	1.579	.166
.5700	77.833	.109	1.576	.162
.5750	77.735	.109	1.572	.164
.5800	77.637	.110	1.569	.167
.5850	77.656	.110	1.566	.168
.5900	77.805	.109	1.563	.166
.5950	78.460	.105	1.560	.158
.6000	78.965	.103	1.557	.152
.6050	79.357	.100	1.554	.148
.6100	79.630	.099	1.551	.145
.6150	79.775	.098	1.548	.143
.6200	79.385	.100	1.546	.150
.6250	78.645	.104	1.543	.161
.6300	78.491	.105	1.541	.164
.6350	78.740	.104	1.538	.161
.6400	79.097	.102	1.536	.157
.6450	79.841	.098	1.534	.147
.6500	80.757	.093	1.531	.135
.6550	81.317	.090	1.529	.128
.6600	81.758	.087	1.527	.123
.6650	81.100	.091	1.525	.133
.6700	80.329	.095	1.523	.144
.6750	79.626	.099	1.521	.154
.6800	78.747	.104	1.519	.167
.6900	78.553	.105	1.515	.170
.6950	78.926	.103	1.513	.166
.7000	79.652	.099	1.511	.156
.7050	79.816	.098	1.509	.155
.7100	80.058	.097	1.507	.152
.7150	80.067	.097	1.505	.152
.7200	79.649	.099	1.504	.159
.7250	78.278	.106	1.502	.178
.7300	77.311	.112	1.500	.192
.7300	77.311	.112	1.500	.192
.7350	76.200	.118	1.498	.209
.7400	75.446	.122	1.497	.220
.7450	75.130	.124	1.495	.225

TABLE A-3 (continued)

LAMBDA(UM)	Tmean	ODmean	N	ALPHA
.7500	75.675	.121	1.493	.218
.7550	76.221	.118	1.492	.210
.7650	76.815	.115	1.489	.203
.7650	76.815	.115	1.489	.203
.7700	76.727	.115	1.487	.204
.7750	76.311	.117	1.485	.211
.7800	75.342	.123	1.484	.225
.7850	74.682	.127	1.482	.235
.7900	73.697	.133	1.481	.250
.7950	72.757	.138	1.479	.265
.8000	70.151	.154	1.478	.305
.8050	68.718	.163	1.476	.328
.8100	67.861	.168	1.475	.342
.8150	67.513	.171	1.473	.348
.8200	67.719	.169	1.472	.345
.8250	68.474	.164	1.470	.334
.8300	69.406	.159	1.469	.319
.8350	70.306	.153	1.467	.305
.8400	70.997	.149	1.466	.295
.8450	71.754	.144	1.465	.284
.8500	71.030	.149	1.463	.295
.8550	70.421	.152	1.462	.305
.8600	68.703	.163	1.460	.333
.8650	66.321	.178	1.459	.372
.8700	64.776	.189	1.457	.398
.8750	64.344	.191	1.456	.406
.8750	64.344	.191	1.456	.406
.8800	63.372	.198	1.454	.423
.8850	61.905	.208	1.453	.449
.8900	60.481	.218	1.452	.475
.8950	59.308	.227	1.450	.496
.9050	57.028	.244	1.447	.540
.9100	57.015	.244	1.446	.541
.9150	58.466	.233	1.444	.514
.9200	59.415	.226	1.443	.496
.9250	59.889	.223	1.441	.488
.9300	60.299	.220	1.440	.481
.9350	60.382	.219	1.439	.480
.9350	59.922	.222	1.439	.488
.9400	60.299	.220	1.437	.482
.9450	60.292	.220	1.436	.482
.9500	60.321	.220	1.434	.482
.9550	59.880	.223	1.433	.491
.9600	59.349	.227	1.431	.501
.9650	58.945	.230	1.430	.509

TABLE A-3 (continued)

LAMBDA(UM)	Tmean	ODmean	N	ALPHA
.9700	57.786	.238	1.428	.531
.9800	55.379	.257	1.425	.578
.9850	54.014	.267	1.423	.606
.9900	52.754	.278	1.422	.632
.9950	51.705	.286	1.420	.655
1.0000	50.738	.295	1.419	.676
1.0000	50.738	.295	1.419	.676
1.0050	50.072	.300	1.417	.691
1.0100	49.491	.305	1.415	.704
1.0150	49.263	.307	1.414	.709
1.0250	49.326	.307	1.410	.709
1.0300	49.168	.308	1.409	.713
1.0350	48.982	.310	1.407	.717
1.0400	48.542	.314	1.405	.728
1.0450	48.161	.317	1.403	.737
1.0500	47.774	.321	1.402	.746
1.0550	47.558	.323	1.400	.752
1.0600	47.395	.324	1.398	.756
1.0650	47.272	.325	1.396	.759
1.0650	47.272	.325	1.396	.759
1.0700	47.166	.326	1.394	.762
1.0750	47.313	.325	1.392	.759
1.0800	47.365	.325	1.390	.758
1.0850	46.880	.329	1.388	.770
1.0900	45.904	.338	1.386	.794
1.0950	45.811	.339	1.384	.796
1.1000	44.618	.350	1.382	.826
1.1050	42.924	.367	1.380	.869
1.1100	40.543	.392	1.378	.932
1.1150	37.471	.426	1.376	1.018
1.1200	32.868	.483	1.374	1.162
1.1250	27.575	.559	1.372	1.355
1.1300	21.817	.661	1.369	1.612
1.1350	19.539	.709	1.367	1.733
1.1400	25.750	.589	1.365	1.432
1.1500	29.331	.533	1.360	1.290
1.1550	31.977	.495	1.358	1.196
1.1600	31.742	.498	1.355	1.205
1.1650	30.601	.514	1.353	1.246
1.1700	29.225	.534	1.350	1.297
1.1750	27.183	.566	1.347	1.377
1.1800	25.135	.600	1.345	1.463
1.1850	22.051	.657	1.342	1.607
1.1900	22.592	.646	1.339	1.581
1.1950	27.609	.559	1.336	1.362

TABLE A-3 (continued)

LAMBDA(UM)	Tmean	ODmean	N	ALPHA
1.2000	30.913	.510	1.333	1.239
1.2050	31.846	.497	1.330	1.207
1.2100	32.523	.488	1.327	1.185
1.2150	32.892	.483	1.324	1.174
1.2200	33.195	.479	1.321	1.164
1.2250	33.644	.473	1.318	1.150
1.2300	33.945	.469	1.314	1.141
1.2350	34.264	.465	1.311	1.132
1.2400	34.722	.459	1.308	1.118
1.2450	35.098	.455	1.304	1.107
1.2500	35.262	.453	1.300	1.103
1.2550	35.344	.452	1.296	1.101
1.2600	35.230	.453	1.293	1.106
1.2650	35.154	.454	1.289	1.109
1.2700	34.860	.458	1.285	1.119
1.2750	34.434	.463	1.280	1.133
1.2800	34.022	.468	1.276	1.147
1.2850	33.160	.479	1.272	1.176
1.2900	32.522	.488	1.267	1.198
1.2950	32.111	.493	1.262	1.213
1.3000	31.593	.500	1.257	1.232
1.3050	30.942	.509	1.252	1.256
1.3050	30.942	.509	1.252	1.256
1.3100	30.340	.518	1.247	1.278
1.3150	29.504	.530	1.242	1.310
1.3200	29.053	.537	1.237	1.328
1.3250	28.545	.544	1.231	1.348
1.3300	27.827	.556	1.225	1.377
1.3350	27.311	.564	1.219	1.399
1.3400	26.530	.576	1.213	1.431
1.3450	25.062	.601	1.206	1.495
1.3500	23.176	.635	1.199	1.582
1.3550	20.458	.689	1.192	1.719
1.3600	19.261	.715	1.185	1.786
1.3650	17.955	.746	1.178	1.864
1.3700	16.435	.784	1.170	1.962
1.3750	15.611	.807	1.162	2.020
1.3800	15.312	.815	1.153	2.042
1.3850	15.383	.813	1.144	2.038
1.3900	14.720	.832	1.135	2.087
1.4000	15.206	.818	1.115	2.054
1.4050	15.102	.821	1.105	2.063
1.4100	15.694	.804	1.093	2.022
1.4150	16.898	.772	1.082	1.942
1.4200	17.215	.764	1.070	1.922

TABLE A-3 (continued)

LAMBDA(UM)	Tmean	ODmean	N	ALPHA
1.4250	16.965	.770	1.057	1.939
1.4300	17.195	.765	1.043	1.925
1.4350	17.660	.753	1.028	1.897
1.4400	18.290	.738	1.013	1.859
1.4450	18.722	.728	.997	1.833
1.4500	18.875	.724	.980	1.824
1.4550	19.115	.719	.961	1.810
1.4600	19.407	.712	.942	1.792
1.4650	19.710	.705	.920	1.773
1.4750	20.361	.691	.873	1.731
1.4800	20.821	.682	.846	1.702
1.4850	21.300	.672	.817	1.670
1.4900	21.464	.668	.785	1.652
1.4950	21.833	.661	.750	1.620
1.5000	21.996	.658	.711	1.593
1.5000	21.996	.658	.711	1.593
1.5050	22.173	.654	.666	1.559
1.5100	22.150	.655	.616	1.522
1.5150	22.225	.653	.557	1.460
1.5200	22.132	.655	.500	1.392
1.5250	22.066	.656	.500	1.396
1.5300	21.884	.660	.500	1.405
1.5350	21.730	.663	.500	1.412
1.5400	21.439	.669	.500	1.427
1.5450	21.152	.675	.500	1.442
1.5500	20.853	.681	.500	1.457
1.5550	20.547	.687	.500	1.474
1.5600	20.170	.695	.500	1.494
1.5650	19.899	.701	.500	1.509
1.5700	19.440	.711	.500	1.534
1.5750	18.852	.725	.500	1.568
1.5800	18.132	.742	.500	1.610
1.5850	17.614	.754	.500	1.642
1.5900	16.841	.774	.500	1.691
1.5950	15.821	.801	.500	1.760
1.6000	14.685	.833	.500	1.841
1.6050	13.486	.870	.500	1.934
1.6100	12.010	.920	.500	2.061
1.6150	9.616	1.017	.500	2.304
1.6200	7.716	1.113	.500	2.545
1.6250	6.894	1.162	.500	2.668
1.6300	5.013	1.300	.500	3.017
1.6350	3.716	1.430	.500	3.344
1.6400	2.123	1.673	.500	3.957
1.6450	.751	2.124	.500	5.094

TABLE A-3 (continued)

LAMBDA(UM)	Tmean	ODmean	N	ALPHA
1.6500	.404	2.394	.500	5.773
1.6550	.131	2.882	.500	7.003
1.6600	.019	3.723	.500	9.121
1.6650	< .010	> 4.000	1.000	> 10.077
1.6700	< .010	> 4.000	2.500	> 9.633
1.6750	.037	3.430	2.500	8.196
1.6800	.057	3.244	2.500	7.729
1.6850	.032	3.488	2.500	8.344
1.6900	.051	3.291	2.500	7.846
1.6950	.073	3.138	2.500	7.461
1.7000	.216	2.665	2.500	6.269
1.7050	.772	2.113	2.500	4.878
1.7100	1.717	1.765	2.500	4.003
1.7150	1.748	1.758	2.500	3.984
1.7200	1.800	1.745	2.500	3.951
1.7250	1.747	1.758	2.500	3.984
1.7300	1.174	1.930	2.500	4.419
1.7350	1.060	1.975	2.500	4.530
1.7400	2.019	1.695	2.500	3.826
1.7450	3.271	1.485	2.500	3.298
1.7500	4.505	1.346	2.496	2.949
1.7550	4.798	1.319	2.453	2.896
1.7600	3.953	1.403	2.415	3.123
1.7650	3.370	1.472	2.379	3.311
1.7700	4.000	1.398	2.347	3.135
1.7750	5.430	1.265	2.317	2.812
1.7800	6.757	1.170	2.289	2.583
1.7850	7.050	1.152	2.264	2.546
1.7900	6.869	1.163	2.240	2.584
1.7950	6.709	1.173	2.218	2.618
1.8000	6.662	1.176	2.197	2.633
1.8050	6.608	1.180	2.178	2.649
1.8100	6.654	1.177	2.159	2.648
1.8150	6.616	1.179	2.142	2.661
1.8150	6.638	1.178	2.142	2.657
1.8250	5.961	1.225	2.111	2.787
1.8300	6.073	1.217	2.096	2.772
1.8350	6.544	1.184	2.083	2.695
1.8400	6.898	1.161	2.070	2.642
1.8450	6.864	1.163	2.057	2.652
1.8500	6.639	1.178	2.045	2.693
1.8550	6.743	1.171	2.034	2.680
1.8600	6.939	1.159	2.024	2.653
1.8650	6.656	1.177	2.013	2.702
1.8700	6.455	1.190	2.004	2.739

TABLE A-3 (continued)

LAMBDA(UM)	Tmean	ODmean	N	ALPHA
1.8750	6.353	1.197	1.994	2.760
1.8800	6.337	1.198	1.985	2.766
1.8850	5.889	1.230	1.977	2.849
1.8900	5.045	1.297	1.968	3.022
1.8950	3.580	1.446	1.961	3.400
1.9000	3.233	1.490	1.953	3.514
1.9050	4.350	1.361	1.946	3.192
1.9100	5.645	1.248	1.939	2.909
1.9150	6.491	1.188	1.932	2.759
1.9200	6.567	1.183	1.925	2.749
1.9250	6.449	1.190	1.919	2.771
1.9300	6.248	1.204	1.913	2.808
1.9350	6.204	1.207	1.907	2.817
1.9400	6.317	1.200	1.901	2.800
1.9450	6.442	1.191	1.896	2.780
1.9500	6.477	1.189	1.890	2.776
1.9550	6.476	1.189	1.885	2.778
1.9600	6.305	1.200	1.880	2.809
1.9650	6.040	1.219	1.876	2.858
1.9700	5.812	1.236	1.871	2.902
1.9750	5.744	1.241	1.866	2.916
1.9800	5.737	1.241	1.862	2.919
1.9850	5.537	1.257	1.858	2.960
1.9900	5.297	1.276	1.853	3.009
1.9950	5.041	1.297	1.849	3.065
2.0000	4.753	1.323	1.845	3.131