Comparative study of methods for measuring window film UV and luminous transmittance

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Abstract. This work presents a comparison of window film ultraviolet transmission calculated according ISO 13837 methods A and B and window film luminous transmission calculated for illuminates A and D65. The results show a difference from 350% to 800% in ultraviolet transmission between ISO 13837 methods A and B for the evaluated window films. On the other hand, the difference in luminous transmission results for the evaluated window films is less than 1%.

1. Introduction
Based on a market research conducted by ABRAWF (Brazilian Association of Users of Window Film), 70 % of respondents wish to have solar control films installed in their vehicles [1], among the reasons that support the decision of consumers the most important are the protection against UV radiation and its damage. In solar control film data sheet [2-3], for automotive or building construction use, there is a wide range of information whose magnitudes are not in a didactic way, to reach the consumer. Example of this can be the "UV rejection rate". As shown in data sheets without a normative reference or calculation method, it is difficult to make the comparison between products and preclude a choice based on technical criteria by the consumer. Although there is no Brazilian standard headed the issue, the legislation dealing with the use of automotive films [4], Resolution 254 CONTRAN (Brazilian National Transit Department), deals only with the values of light transmittance for the illuminant A. Internationally there is a set of standards that addresses the issue with different methods of calculation. The DIN EN 410 [5] deals with the evaluation of films for building which determines the visible transmittance using illuminant D65 [6] and UV transmittance in the range 280-380 nm for the spectrum of the sun with an air mass equal to one. The ISO 13837 [7] defines methodology for evaluation of automotive films considering two methods for UV transmittance: the spectral range 300-400 nm with a solar spectrum air mass of 1.5 and the other in the spectral range 300-380 nm with a solar spectrum air mass of 1. For visible transmittance ISO 13837 does not mention a calculation method. The SAE J1796 standard [8] deals with automotive film application, in turn, it determines the visible transmittance using illuminant A [6] and the UV transmittance in the range of 300 to 400 nm with a solar spectrum air mass equal to 1.5, the same as the first method of ISO 13837.

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The difference between air masses can impact the result of UV transmittance, taking into account the differences between their spectra are proportional to solar intensities, as the lower air mass, makes greater the intensity of the sun. The spectral range used to calculate the UV transmittance indicates that the window film may consider the effects of blue light radiation in the 400 nm [9-10], which is not measured when this portion of the spectrum is not accounted in the spectral calculation.

The difference of illuminants in the calculation of visible light transmittance allows the evaluation of luminous transmission for different types of lamps spectral power distribution. The illuminant D_65 resembles the sun and the illuminant A the conventional vehicles headlights. Considering these two conditions of use, the most critical situation can be compared to the minimum value of 75% for light transmittance requested by CONTRAN [4].

The objective of this study is to compare the results of calculations for 2 types of commercial window films applying the different methods of determining the luminous transmittance for illuminants A and D_65 and the two methodologies of UV transmittance for the different spectral bands and air masses. The results will support the consumer and technical community regarding the specification criteria of choose solar control films.

2. Methodology
To develop this work, two samples of commercial sunscreen window film, designated as P1 and P2, were used. The properties of light transmittance and UV transmittance of the samples were evaluated as described in items 2.1 and 2.2. The measurements of the spectral transmittance of solar control films were performed using a double beam spectrophotometer with an integrating sphere, for a measurement spectral step and band width of 5 nm.

2.1. Evaluation of light transmittance
The light transmittance of the window films was calculated according to the procedure of SAE J1796, considering the illuminant A and a modification of this procedure considering the illuminant D_65 as defined in DIN EN 410.

2.2. Evaluation of UV transmittance
The UV transmittance of window films was calculated according to ISO 13837 using the two methods described. The methodology A that corresponds to the spectral range from 300 to 400 nm solar spectrum for air mass 1.5 and the methodology B in the spectral range from 300 to 380 nm solar spectrum for air mass 1.

3. Results
Two window films, P1 and P2 were measured, based on the methodology described. The measurement results of the spectral transmittance of UV to visible are shown in Figure 1. Based on the results of spectral transmittance calculations for determining the values of UV transmittance and light transmittance were performed.

3.1. Measurements of the spectral transmittance
The measurement results of the spectral transmittance are shown in Figure 1. An attention shall be draw to the UV range of solar film transmittance which impacts the UV transmittance calculation.
3.2. Measurement of UV transmittance

The UV transmittance ($T_{UV}$) was obtained from the spectral transmittance according to the methodologies of calculation (air mass equals to 1) and B (air mass equals to 1.5) of ISO 13837, and their values are presented in Table 1.

**Table 1.** UV transmittance with different air masses

| Sample | Method A   | Method B     |
|--------|------------|--------------|
|        | $T_{UV}$ (%) | $T_{UV}$ (%) |
|        | $M_{air}=1.5$ | $M_{air}=1.0$ |
| P1     | 9.02       | 2.03         |
| P2     | 9.18       | 0.96         |

3.3. Measurement of light transmittance

The values for light transmittance (LT) as SAE 1796 were evaluated for illuminant A and also using the same calculation methodology for the illuminant D65. The results are shown in Table 2.

**Table 2.** Luminous transmittance for different illuminant.

| Sample | $L_{TA}$ (%) | $L_{TD65}$ (%) |
|--------|--------------|---------------|
| P1     | 33.38        | 33.82         |
| P2     | 51.05        | 51.31         |
4. Discussion
The results showed different numerical values for the same sample when measured by different methods. The main reasons for it are discussed for each measured quantity.

4.1. Analysis UV transmittance
In the analysis of the values obtained from measurements of UV transmittance, it is clear that the method choice can determine significant differences in these. The data in Table 1 show that depending on the method, the tested samples had different values for $T_{UV}$, which presented impressive differences ranging from 350% for the sample P1 and 800% for the sample P2. The slightly greater spectral range from 300 to 400 nm in method A, compared with 300 at 380 nm in method B is a reason for the $T_{UV}$ difference which was emphasised by window films’ transmittance, despite the greater air mass method to reduce the intensity of the solar spectral power distribution [9], as seen in Figure 2.

![Figure 2. Change in spectral irradiance with the air mass from [9].](image)

4.2. Analysis of luminous transmittance
The comparison of the values of luminous transmittance showed no significant differences, when the evaluated films were subjected to various illuminant sources. Which in other words means, the use of films submitted to illuminant $D_{65}$ (daylight) or to illuminant A (automotive headlights) does not alter significantly the vision.

The methodological difference in calculation depends on the application made. For automotive use the Resolution 254 CONTRAN establishes the illuminant A. The application of film in building construction use illuminant $D_{65}$ as a reference to the daylight that enters the building. Although the daylight can be applied to automotive field, the use of illuminant A as a reference consider the critical condition for transmittance which lead to lower transmittance values as shown in Table 2.

5. Conclusion
Concerning the results of the UV transmittance of the solar films evaluated by two standard methods, differences from 350% to 800% were obtained for measured samples. Thus, the commercial presentation of the product shall inform the results of the UV transmittance and the standardized method used in its calculation. A better solution would be a law regulation by the responsible public
agency of a specific standard method for presented the UV transmittance of the solar films in the Brazilian market.

Regarding the measurements in the visible range, the use of different illuminants (A and D<sub>65</sub>), showed no significant differences, but in the case of application in the building construction environment using illuminant D<sub>65</sub> is more appropriate.

6. References
[1] ABRAWF - Projeto Window Film- Relatório Final Falcão Bauer. Acessed 23th April 2013 <http://www.abrawf.com.br/new/pdf/REL-WINDOW_FILM.pdf>.
[2] Catalogo Solargard. Acessed 23th April 2013. <http://www.solargard.com.br/Comercial/Especificações_de_desempenho>_2>.
[3] Catalogo 3M. Acessed 23th April 2013. <http://www.3m.com/intl/br/windowfilm/linksc0e8.html?link=boletim>.
[4] CONTRAN, Conselho Nacional de Transito, Resolução nº. 254 de 26 de outubro de 2007.
[5] DIN EN 410: 2011-04. Determination of luminous and solar characteristics of glazing. English translation.
[6] CIE 15.2. Colorimetry. 2nd Edition, 1986.
[7] ISO 13837-2008 Road Vehicles – Safety glazing materials – Method for the determination of solar transmittance.
[8] SAE J1796: 2005. Spectral transmission test.
[9] CIE 85: Solar Spectral Irradiance, 1st Edition 1989.
[10] ICNIRP. Guidelines on limits of exposure to ultraviolet radiation of wavelengths between 180 nm and 400nm (incoherent optical radiation). Health Phys. 87:171-186; 2004.