Alsynite NZ Ltd

Measurement and Calculation of TS20 Solar Optical Properties

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1. INTRODUCTION

Vipac was commissioned by *Alsynite NZ Ltd* to measure the solar optical properties, i.e. solar transmittance and reflectance in the wavelength bands of 300nm to 2500nm, of a sample configuration of Alsynite *Topglass* rooflighting fibreglass. These measurements were then used to calculate parameters that relate to the solar heat transfer properties of the materials such as Shading Coefficient (SC), Solar Heat Gain Coefficient (SGHC) and Solar Heat Gain.

As per ASTM E903-96, the measured solar transmittance and reflectance are diffused transmittance and reflectance for normal incidence of the light beam.

All testing was conducted by the *Optics and Radiometry Laboratory* at the University of New South Wales. All data analysis has been conducted by Vipac Engineers and Scientists Ltd.

2. MATERIALS UNDER TEST

A test sample marked "*Topglass Cool – TS20 Twin Skin Natural Rooflighting*" was supplied by *Alsynite NZ Ltd* along with an unmarked clear fibreglass which was tested separately by VIPAC in July 2007 (see Report No. 30B-07-0054-TRP-291176-0). The test sample is grey tinted fibreglasss sheeting.

The materials under test are samples of the components of Alsynite's Topglass twin skin roof cladding system. This is comprised of an Alsynite *Topglass Cool – TS20 Twin Skin Natural Rooflighting* fibreglass upper sheet and a clear fibreglass lower sheet.

3. METHODOLOGY

The properties of both the translucent and clear samples were measured as described in the following paragraphs and the results combined using the methods described in *ISO9050:2003* for spectral transmittance and reflectance for clear double glazing to give a result for the overall twin skin configuration sample.

The solar optical properties of the upper sheets have been determined by testing for the upper and lower surface of each sheet, as a proportion of the solar radiation transmitted by the upper sheet will be reflected by the upper surface of the lower sheet. A proportion of this reflected radiation in the air gap between the sheets will be transmitted and reflected by the lower surface of the upper sheet and so on for both configurations.

It is important to note at this point that the combination of the test results for the upper and lower sheets of the Twin Skin system was made analytically using methods prescribed in *ISO 9050:2003* and has been used in this case as a “best estimate” (accurate to within ±10%, i.e. ±0.1 multiplied by the percentage value presented) of the actual values, as the Standard is written specifically for the determination of the above properties in glass. However, the standard specifically states that materials with light scattering properties (such as the material tested in this report) require much more complex analysis. Such an analysis is beyond the scope of this report

A flat test piece was cut from the sample sheets provided by *Alsynite NZ Ltd*. The test piece was then placed in a Spectrophotometer. The absolute diffused transmittance of the sample was measured for wavelength bands of 300 nm to 2500 nm and likewise for absolute diffused reflectance using an Integrating Sphere attachment.

The solar transmittance for the solar spectrum was evaluated using the Air Mass 1 Spectrum (Figure 1). The visible solar light transmittance was calculated from the Air Mass 1 Spectrum and the CIE-Spectral Luminous Efficiency Curve for the Human Eye (Figure 2).

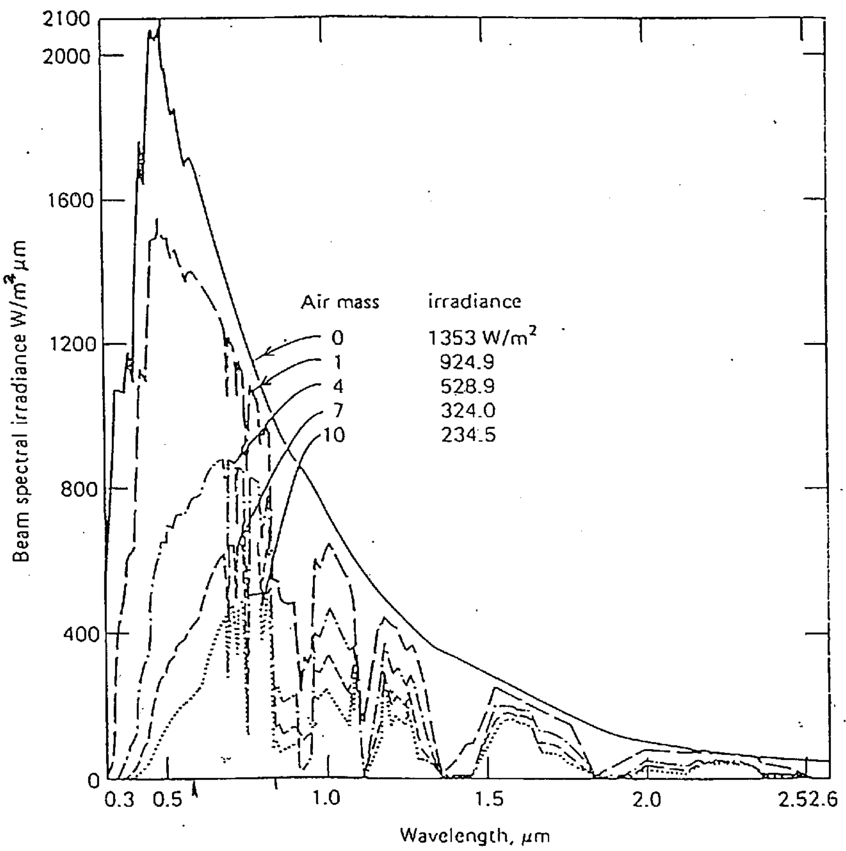

Figure 1: Spectral distribution of solar beam for different air masses

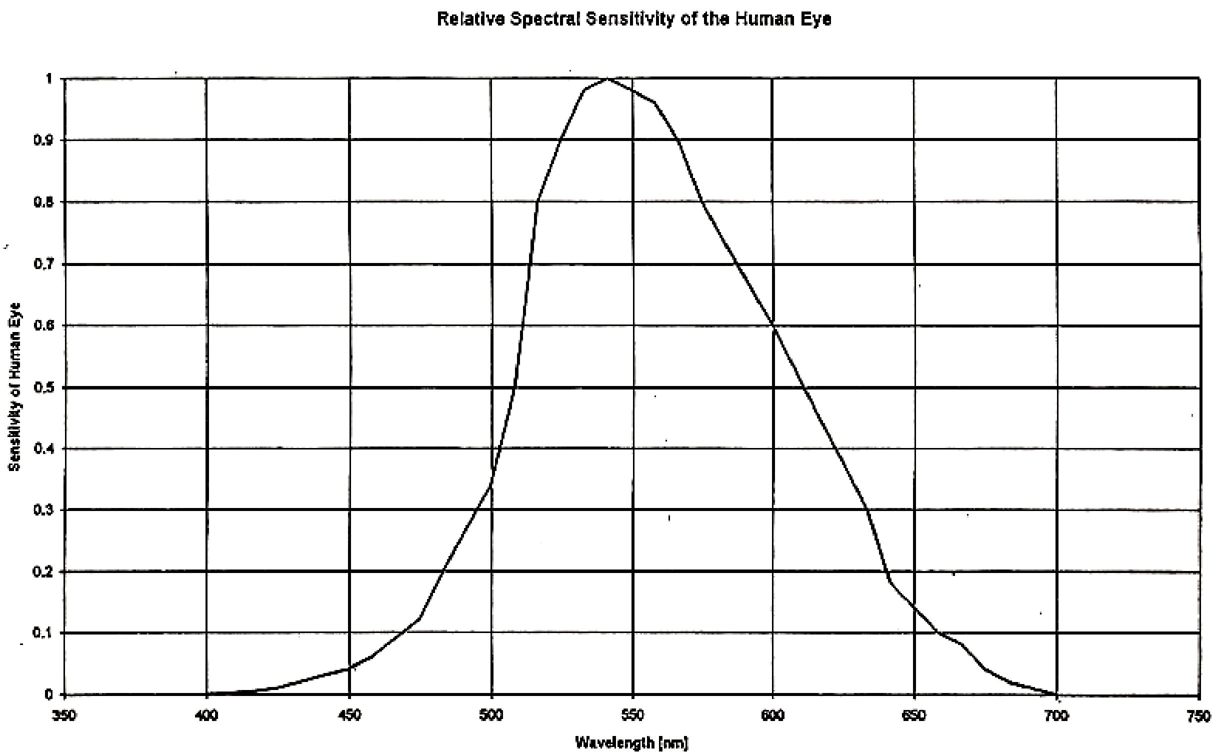

Figure 2: CIE-Spectral Luminous Efficiency Curve

The solar transmittance of the samples was calculated using the following formula in the wavelength bands of 250nm to 2500nm.

$$\%\,\text{Solar Transmittance} = \frac{\sum t(\lambda) \times S(\lambda)}{\sum S(\lambda)} \times 100\%$$

where S (λ) is the Air Mass 1 solar spectrum and t (λ) is the Spectral transmission of the sample.

The visible solar transmittance of the samples was obtained by using:

$$\%\,\text{Visible Transmittance} = \frac{\sum t(\lambda) \times S(\lambda) \times \varepsilon(\lambda)}{\sum S(\lambda) \times \varepsilon(\lambda)} \times 100\%$$

where S (λ) is the Air Mass 1 solar spectrum, t (λ) is the absolute transmittance of the sample and ε(λ) is the Luminous Efficiency of human eye.

4. RESULTS

The measured solar transmittance, reflectance, absorptance and visible solar transmittance for the Alsynite *Topglass Cool – TS20 Twin Skin Natural Rooflighting* and clear fibreglass products are shown in Table 1, along with their combined properties as a twin skin system in Table 2.

These parameters were used to calculate the following parameters that relate to the solar heat transfer characteristics of the material.

4.1 CALCULATION OF SOLAR HEMISPHERICAL PROPERTIES

Solar radiation incident on a fenestration system is partly transmitted, partly reflected and the remaining is absorbed within the glazing or the coatings on their surfaces. The sum of the transmitted, reflected and absorbed portions of a glazing layer is unity:

$$\tau + \alpha + \rho = 1$$

where τ = the fraction of the incident flux that is transmitted or transmittance

α = the fraction of the incident flux that is absorbed or absorptance

ρ = the fraction of the incident flux that is reflected or reflectance

Tables 1 and 2 below summarises results of the measurements of solar transmittance, reflectance and calculations of absorptance based on the equation above for Table 1 and the equations in *ISO9050:2003* for the calculation of spectral transmittance (Section 3.3, eqn. 2) and reflectance (Section 3.4, eqn. 5) for Table 2.

SAMPLE	Transmittance τ (%)	Reflectance ρ (%)	Absorptance α (%)	Visible Transmittance (%)
Topglass TS20 upper surface	58	19	23	55
Topglass TS20 lower surface	-	19	-	-
Backing Glass*	76	14	10	80

***Results taken from previous test**

Table 1: Results of solar optical measurements for the individual samples of Alsynite sheeting

TOTAL	Transmittance τ (%)	Reflectance ρ (%)	Absorptance α (%)	Visible Transmittance (%)
TS20 Twin Skin System Total	48	24	28	45

Table 2: Results of solar optical measurements for the samples of Alsynite Topglass Twin Skin sheeting

4.2 SHADING COEFFICIENT, SOLAR HEAT GAIN COEFFICIENT AND SOLAR HEAT GAIN CALCULATION

4.2.1 Assumptions

Several assumptions must be made in order to carry out the calculations of Shading Coefficient, Solar Heat Gain Coefficient and Solar Heat Gain. The standard summer conditions as per ASHRAE Fundamentals 1993 (except for the temperatures) will serve as a basis for performing these calculations. These assumptions are as follows:

1. Surface's position is horizontal with heat flowing downward
2. Surface emittance is taken as 0.9 as per Table 3 p. 3.8 ASHRAE Fundamentals 1993 for class 5 surface at 10 to 40°C
3. Thermal conductivity of the sample is 0.096 W/m.K
4. Exterior condition is moving air with wind speed of 12 km/h or 3.3 m/s
5. Interior condition is still air
6. Temperature outdoor is 30°C
7. Temperature indoor is 30°C
8. Total glazing thickness is approximately 3mm
9. Outer surface heat transfer coefficient combining the effect of radiation and convection, h_o is 22.7 W/m^2.K
10. Inner surface heat transfer coefficient combining the effect of radiation and convection, h_i is 6.13 W/m^2.K
11. The total solar irradiance, E_t reaching the surface is 782 W/m^2

The temperature difference between indoor and outdoor is assumed to be zero, to eliminate the heat transfer due to thermal gradient. Therefore, the results presented are only for the heat transfer due to solar radiation in relation to the material's solar heat transfer properties.

4.2.2 Definitions

Shading Coefficient (SC) is the ratio of the Solar Heat Gain Coefficient of the sample under test to the Solar Heat Gain Coefficient of a single-pane, double-strength, clear (DSA) glass with 0.86 transmittance, 0.08 reflectance and 0.06 absorptance which for standard summer conditions, is 0.87 for normal incidence.

Solar Heat Gain Coefficient (SHGC) is the fraction of incident irradiance that enters through the glazing as heat gain. It is the sum of the directly transmitted portion and the absorbed and re-emitted portion of the incoming solar radiation, without taking into account the heat flow due to outdoor-indoor temperature difference.

Solar Heat Gain Factor (SHGF) is the solar radiation that a surface receives with respect to its location, conditions, orientation, day and month of the year and time of the day. This parameter is not relevant to the scope of work for this project thus not in discussion.

Solar Heat Gain is the total heat admission through the glazing due to incoming solar radiation. This includes the ultraviolet, visible, and infra red components of the solar radiation transmitted through the material as well as absorbed energy re-radiated from the inner surface.

Total Heat Gain is the sum of Solar Heat Gain and heat flow due to outdoor-indoor temperature difference.

4.2.3 Calculations

4.2.3.1 SHADING COEFFICIENT CALCULATIONS

$$SC = \frac{F \text{ of Test Sample}}{F \text{ of reference glass}} = \frac{\tau + N_i\,\alpha}{0.87}$$

where N_i = inward-flowing fraction of absorbed radiation and can be approached by

$$N_i = \frac{U}{h_0}$$

where U = overall heat transfer factor, $W/m^2.K$

The overall heat transfer factor of the Test Sample is calculated as:

$$R_t = \frac{1}{h_i} + \frac{x}{k} + \frac{1}{h_0} = 1/U$$

where R_t = total thermal resistance from inside to outside surface (K.m^2/W)

x = total thickness of the glazing = 3mm = 0.003m

k = thermal conductivity of the material, taken as 0.096 W/m.K as in the assumptions

Substituting the values for h_o and h_i taken from the assumptions above, will give:

$$R_t = 0.2384 \text{ K.m}^2\text{/W}$$

thus,

$$U = 1/R_t = 4.194 \text{ W/m}^2\text{.K}$$

The inward flowing fraction of the absorbed radiation is:

$$N_i = \frac{U}{h_0} = \frac{4.194}{22.7} = 0.185$$

therefore the Shading Coefficient for **TS20** twin skin is:

$$SC = \frac{\tau + N_i\ \alpha}{0.87} = \frac{0.48 + 0.185 \times 0.28}{0.87} = 0.611$$

4.2.3.2 SOLAR HEAT GAIN COEFFICIENT (SHGC) AND SOLAR HEAT GAIN CALCULATIONS

Solar Heat Gain Coefficient (SHGC) = Transmittance + N_i (Absorptance)

$$SHGC_{TS20} = 0.48 + 0.185 \text{ x } 0.28 = 0.532$$

Solar Heat Gain = E_t (τ + $N_i.\alpha$) where the quantity in parentheses is the Solar Heat Gain Coefficient (SGHC).

$$\mathrm{SHG}_{TS20} = 782 \text{ x } 0.532 = 416 \text{ W/m}^2$$

The absorbed heat radiated into the indoor can be obtained by:

$$\textit{Absorbed heat radiated in} = N_i\left(\alpha\, E_t\right)$$

$$\mathrm{AHRI}_{TS20} = 0.185 \text{ x } 0.28 \text{ x } 782 = 40 \text{ W/m}^2$$

The remaining heat absorbed is radiated out and equal to total heat absorbed subtracted by the heat radiated in.

$$\textit{Absorbed heat radiated out} = \left(\alpha\, E_t\right) - \textit{Absorbed heat radiated in}$$

$$\mathrm{AHRO}_{TS20} = (0.28 \text{ x } 782) - 40 = 179 \text{ W/m}^2$$

4.2.3.3 TOTAL HEAT GAIN

The total rate of heat flow inward by radiation and convection equals the sum of the radiation transmitted through the fibreglass, the inward flow of absorbed solar radiation and the heat flow due to outdoor-indoor temperature difference, i.e.

$$q_A = E_t\, \tau + N_i(\alpha\, E_t) + U(t_o - t_i)$$

Since there is no temperature difference assumed, the last component in the equation above is deemed as zero and the Total Heat Gain is equal to Solar Heat Gain.

5. RESULTS SUMMARY

Test Sample Type	Transmittance (%)	Reflectance (%)	Absorptance (%)	Visible Transmittance (%)	Absorbed Heat Radiated In (W/m^2)	Absorbed Heat Radiated Out (W/m^2)	Solar Heat Gain (W/m^2)	Solar Heat Gain Coefficient	Shading Coefficient
Tolerance	**± 2%**				**± 5 W/m^2**			**± 0.1**	
TS20 Twin Skin	48	24	28	45	40	179	416	0.532	0.611

Table 3: Summary of Solar Properties for the Twin Skin Test Sample

APPENDIX A - TEST SAMPLE SPECTRA

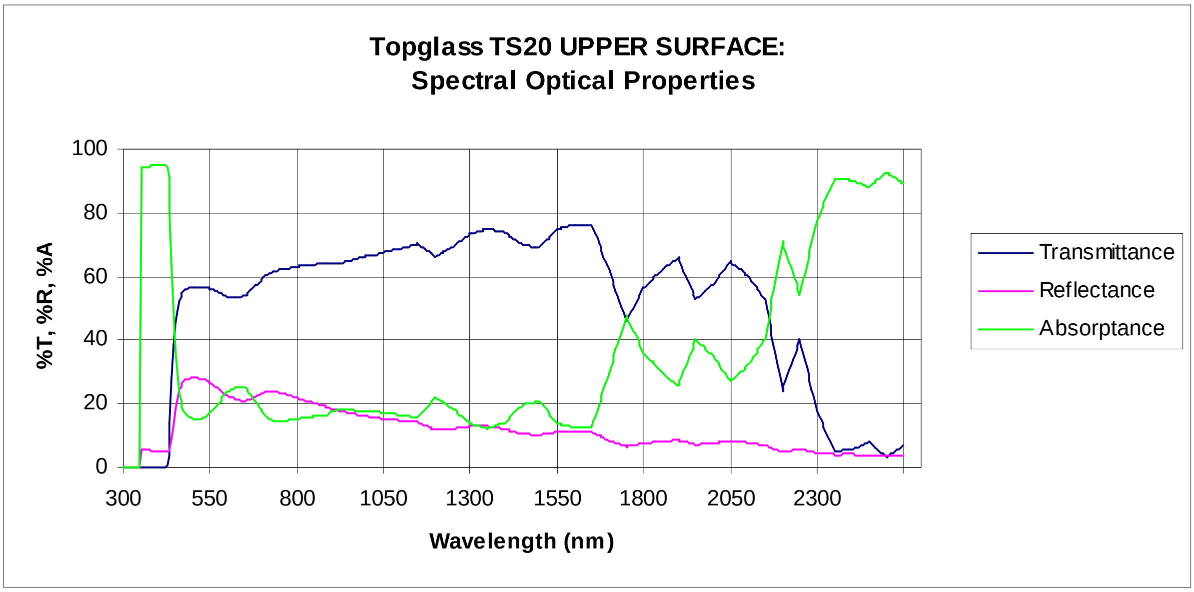

Figure A1 –Graph showing the Spectral Optical Properties of the Alsynite TS20 UPPER SURFACE Topglass sample.

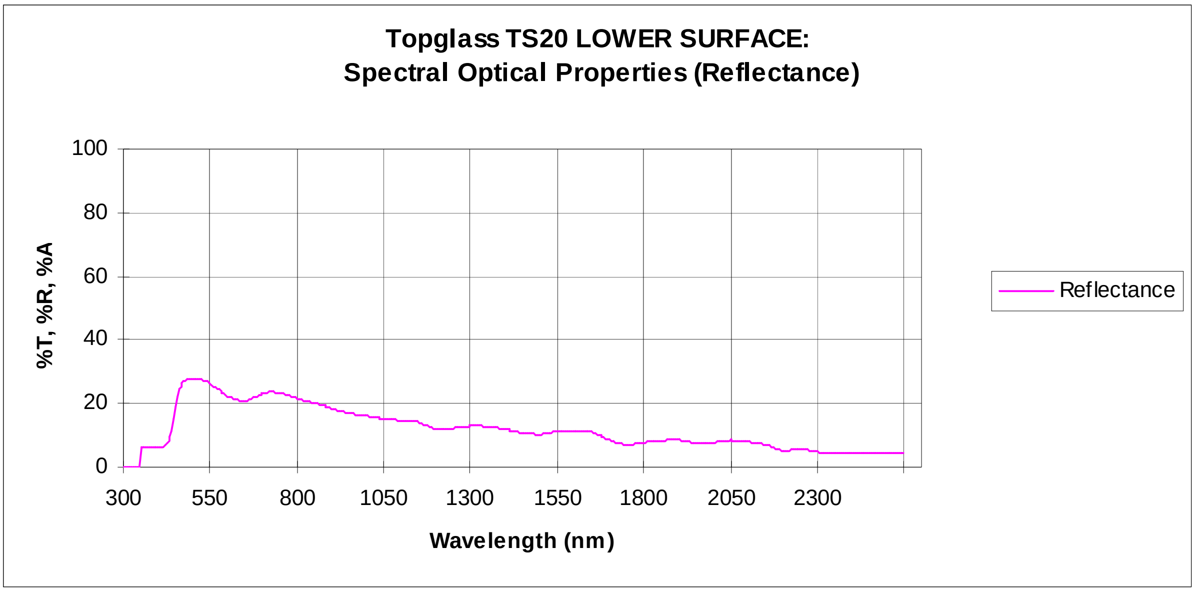

Figure A2 –Graph showing the Spectral Optical Properties (Reflectance) of the Alsynite TS20 LOWER SURFACE Topglass sample.

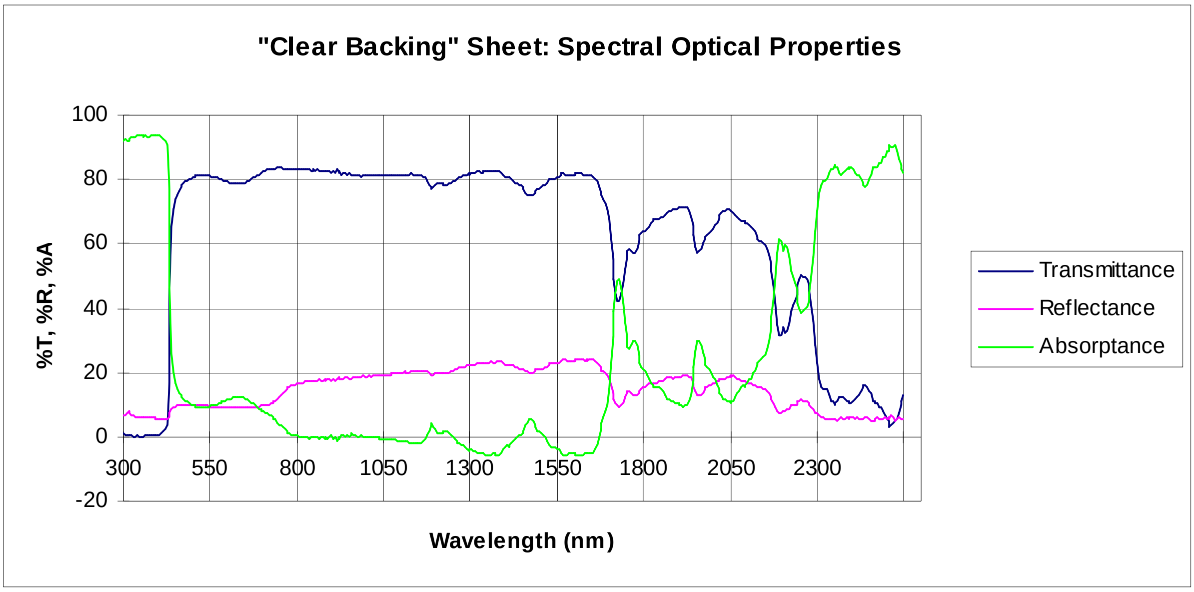

Figure A3 –Graph showing the Spectral Optical Properties of the Alsynite "Clear Backing" Fibreglass sample.

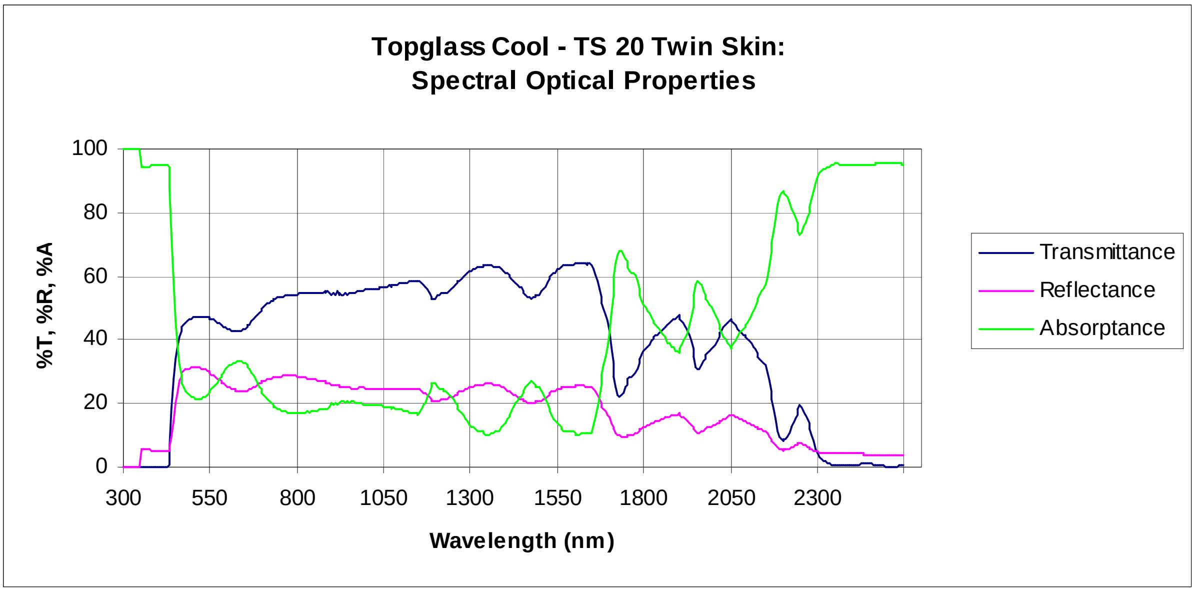

Figure A4 –Graph showing the combined Spectral Optical Properties of the Alsynite TS20 twin skin system.

REFERENCES

- *1993 ASHRAE Handbook*, *Fundamentals*, American Society of Heating, Refrigerating, and Air Conditioning Engineers, Atlanta, GA, 1993.
- C. P. Arora: *Refrigeration and Air Conditioning,* McGraw Hill, Naveen Shahdara, New Dehli, 1996.
- W. F. Stoecker and J. W. Jones: *Refrigeration and Air Conditioning*, McGraw Hill, Singapore, 1982.
- J. L. Threlkeld: *Thermal Environmental Engineering*, Prentice Hall, Englewood Cliffs, N. J., 1970.
- ISO 9050 2003: *Glass in building – Determination of light transmittance, solar direct transmittance, ultraviolet transm,mittance and elated glazing factors*