IN'FLECTOR®

The See Through Radiant Barrier Window Insulator

Effects of the In'flector Solar Screen on the Thermal Properties of Windows

Final Report

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1 Introduction

1.1 Overview

Today, many energy-saving shading options exist with a uniform means to determine their solar optical properties and their affects on the thermal properties of windows. Thus, with no recommended standards or procedures when making spectroradiometric measurements (NFRC 2002), this study uses industry accepted fenestration software to determine the thermal and optical effects of solar screen material on windows.

In this study, the thermal calculations for the window are made using the recommended Window 4.1 program (Finlayson et al. 1994). The thermal properties of the solar screen material were measured at the Yellott Solar Energy Laboratory under the direction of John Elliot Engineering Associates, Inc. (1982). See Appendix. In addition, the glass optical properties were determined using the spectral database for Varicon glass products. It is important to note that field measurements were not within the scope of this study.

1.2 The Solar Screen Material

The solar screen material is a three-layer material consisting of a transparent polyester film, a perforated vinyl screen, and a perforated aluminum film. It is designed to reflect heat outward during the summer months and to conduct heat inward during the winter months. However, this study makes no recommendations or assertions to the configuration of the solar screen material. Accordingly, the solar screen thermal properties are shown in Table 1 .

Table 1 . Solar Screen Thermal Properties

	Transmittance[1]	Reflectance[1]	Absorbtance[1]	Emittance
Aluminized Surface	0.28	0.65	0.07	0.69
Black Surface	0.30	0.19	0.51	0.86

[1] The value was determined with the indicated surface facing the sun.

Source: John Elliot Engineering Associates, Inc. (1982)

In the case of the transparent polyester film, no values were determined. In this study, the polyester film is presumed to have no significant effect on the solar screen values. However, additional testing of the transparent polyester film is required.

2 Methods

2.1 Overview

This study developed a prototype, single glazed window using Window 4.1. The window was then modified by adding a second layer for the solar screen material.

Overall the study varied the winter and summer environmental conditions and the orientation of the solar screen. Four window conditions were studied using the optical data for 1/8 inch single pane glass manufactured by Varicon and compared to the base case for winter and summer conditions defined within the environmental conditions library. In this study ASHRAE winter conditions (for both U-VALUE and SOLAR subsets) and ASHRAE summer conditions (for both U-VALUE and SOLAR subsets) were used.

	A_1	A_2
B_1	y_{11}	y_{12}
B_2	Y_{21}	Y_{22}

Figure 1 . Window Assessment Model

Figure 1 is the model used to compare the window conditions. "A" represents the orientation of the solar screen (aluminized facing outward and black facing outward). "B" represents the environmental conditions used to develop the thermal properties of the window, which were summer and winter. To analyze the data, the U-value, the shading coefficient, the solar heat gain coefficient, and the visible transmittance of the four conditions were compared.

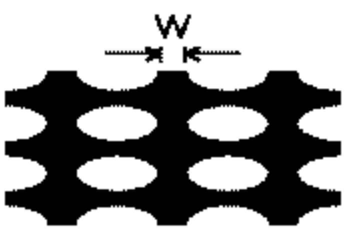

Figure 2 . Solar Screen Cutting Method.

2.2 Solar Transmittance of the Solar Screen Material

After review of the laboratory result discussed earlier in this report, transmittance of the solar screen material was reexamined. As a result, the transmittance values for the solar screen was determined using equations for circular cutting methods defined by Ishikawa (1994) and verified by Sylvester and Haberl (2000) (Table 2). The transmittance, t, of the solar screen is determined by a defined relationship between the area of each unit hole, *S,* and the width of photovoltaic area between each hole, *W*, yielding,

$$\tau = \frac{S}{\left(2\sqrt{\frac{S}{\pi}} + W\right)^2}$$

(2 . 1)

for the circular laser cutting method. It is assumed that the solar screen material is designed to block all light equally, visible and infrared. Thus, the solar screen was given no spectral selectivity. The values used for the solar screen properties are shown in Table

2 . Please note that the calculated solar transmittance was 44% was used to adjust the original laboratory transmittance data. A transmittance of 35% was used because the sum of the transmittance (calculated) and reflectance (measured) cannot be greater that 100%.

Table 2 . Solar Screen Thermal Properties Used in the Simulation

	Transmittance[1]	Reflectance[2]	Absorbtance[2]	Emittance
Aluminized Surface	0.35	0.65	0.07	0.69
B l a c k Surface	0.35	0.19	0.51	0.86

[1] This value was determined using the maximum allowable transmittance, which is less than are equal to the calculated value.

[2] The value was determined with the indicated surface facing the sun.

3 Results

3.1 Overview

As discussed earlier, three conditions were simulated and compared. The base case used the single glazed system with no solar screen. For the four alternative conditions, the solar screen was added. The aluminized and black surfaces were analyzed for summer and winter conditions when facing outward.

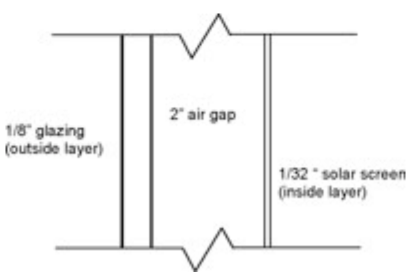

Figure 3 . Window Configuration

Base on installation requirement of the In'flector solar screen, air was used as the gas within a two-inch gap between the two surfaces, which it is not a sealed space. Thus, some infiltration will occur, but it can only be quantified within an energy simulation of a select building. Overall, the simulated window is 48 inches in width and 72 inches in height and contained no breaks in the framing system (Figure 3). The glazing and solar screen values used in the simulation are shown in Table 3.

Table 3 . Window Data Used Within Simulation Program

	Thick	Tsol[1]	Rsol		Tvis[2]	Rvis		Tir	Emis		Keff
			1	2		1	2		1	2	
Aluminized[3]	0.0312	0.35	0.650	0.190	0.35	0.650	0.190	0.000	0.690	0.860	0.07
Black[3]	0.0312	0.35	0.190	0.650	0.35	0.190	0.650	0.000	0.860	0.690	0.51
1/8 glazing	0.120	0.834	0.075	0.075	0.899	0.082	0.082	0.000	0.840	0.840	0.520

[1] This value was determined using the maximum allowable transmittance, which is less than are equal to the calculated value.

[2] This value was not measured in the laboratory experiment. Thus, the study assumes it to be equal to the total solar.

[3] The indicated surface faces outward for the listed values.

3.2 Glazing and Window Systems Analysis

The results show that the glazing performs best with the aluminized surface facing outward during the summer for all thermal properties (Table 4). In the case of the winter condition, the glazing performs better with the black surface facing outward. However, the thermal performance of the window shows no significant change for the orientation of the window (Table 5).

Table 4 . Analysis of Glazing Systems for Summer Conditions

Window Condition	**Keff** (Btu/h-ft-F)	**Width (in.)**	**Uc** (Btu/h-ft-F)	**SCc**	**SHGCc**	**VTc**
Base	-	0.120	1.03	1.00	0.86	0.90
Black	-	2.151	0.54	0.45	0.39	0.33
Aluminized	-	2.151	0.49	0.37	0.32	0.32

Table 5 . Analysis of Glazing Systems for Winter Conditions

Window Condition	**Keff** (Btu/h-ft-F)	**Width (in.)**	**Uc** (Btu/h-ft-F)	**SCc**	**SHGCc**	**VTc**
Base	-	0.120	1.11	-	-	0.90
Black	0.1544	2.151	0.50	-	-	0.33
Aluminized	0.1697	2.151	0.51	-	-	0.32

To further analyze the glazing, a frame was added to factor a typical frame effect. This condition will now be referred to as the window system (Figure 4).

Figure 4 . Frame Values used in the Simulation

Type	**Source**	**U-Value**	**Edge Corr**[1]	**Width**	**Abs**
Aluminum with no breaks	ASH/LBL	1.9	1	2.250	0.90

[1] The fifth correlation is recommend when modeling single glazing (Arasteh, 1989). More research of these correlations is required.

As expected, the frame effect negatively affected the performance of the window system. Likewise, as with the glazing, the results show that the window system performs best with the aluminized surface facing outward during the summer (Table 6). In the case of the winter condition, the window system performs better with the black surface facing outward. However, the window's performance shows no significant change for the orientation of the window (Table 7).

Table 6 . Analysis of Window Systems for Summer Condition

Window Condition	U (Btu/h-ft^2-F)	SC	SHGC	VT
Base	1.16	0.95	0.82	0.76
Black	0.76	0.49	0.42	0.28
Aluminized	0.72	0.42	0.36	0.27

Table 7 . Analysis of Window Systems for Winter Condition

Window Condition	U (Btu/h-ft^2-F)	SC	SHGC	VT
Base	1.23	-	-	0.76
Black	0.72	-	-	0.28
Aluminized	0.74	-	-	0.27

4 Conclusions

As noted earlier the scope of this study included simulation testing only base on previously measured thermal properties of the In'flector solar screen and existing optical data for the glazing.As seen in the results, the data shows that the heat gain attributed to the windows of a building using the In'flector solar glazing will be significantly reduced. Specifically, the U-value of the glazing improved by an average of 54% for the winter condition and 50% for the summer condition (Table 8 ; Table 9). It is also noted that the system performs best with the aluminized system facing outward during the summer and with the black surface facing outward during the winter. When factoring framing, the U-value of the window system improved by an average of 41% for the winter condition and 36% for the summer condition (Table 10 ; Table 11).

Table 8 . Effects of Solar Screen for Summer Conditions on Glazing

Window Condition	Uc (Btu/h-ft^2-F)	SCc	SHGCc	VTc
Base	-	-	-	-
Black	47.6%	55.0%	54.7%	63.3%

Aluminized	52.4%	63.0%	62.8%	64.4%

Table 9 . Effects of Solar Screen for Winter Conditions on Glazing

Window Condition	**Uc** (Btu/h-ft^2-F)	**SCc**	**SHGCc**	**VTc**
Base	-	-	-	-
Black	55.0%	-	-	63.3%
Aluminized	54.1%	-	-	64.4%

Like the glazing only condition, the window system performs best with the aluminized system facing outward during the summer and with the black surface facing outward during the winter. In addition, the framing around the window has a significant effect on the window's overall performance and requires a more detailed analysis and accurate framing data to improve the predictive capability of the simulation for a select building.

Table 10 . Effect of Solar Screen for Summer Conditions on Window

Window Condition	**U** (Btu/h-ft^2-F)	**SC**	**SHGC**	**VT**
Base	-	-	-	-
Black	34.5%	48.4%	48.8%	63.2%
Aluminized	37.9%	55.8%	56.1%	64.5%

Table 11 . Effect of Solar Screen for Winter Conditions on Window

Window Condition	**U** (Btu/h-ft^2-F)	**SC**	**SHGC**	**VT**
Base	-	-	-	-
Black	41.5%	-	-	63.2%
Aluminized	39.8%	-	-	64.5%

In review of these findings, the researcher recommends three levels of analysis: 1) glazing specific window analysis, 2) glazing and framing specific window analysis, and 3) a thermal energy simulation of the selected building which uses specific glazing and framing data to determine an overall effect of the window glazing on the energy consumption of the building. A thermal simulation of a select building would factor the building's materials, configuration, and mechanical systems.

5 References

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6 Appendix

6.1 Yellot Solar Energy Laboratory Report

6.2 Terminology

Abs: frame absorptance for solar radiation at normal incidence.

Emis: infrared emittance of the glazing layer (exterior facing surface is 1, and interior oriented surface is 2).

Keff: a conductivity or effective conductivity of a window component (frame, divider, glass, gap)

Rsol: solar reflectance of the glazing layer (exterior-facing surface is 1, and interior-facing surface is 2).

Rvis: visible reflectance (exterior-facing surface is 1, and interior-facing surface is 2).

Rb: the back (interior) surface reflectance of a glazing system

Rf: the front (exterior) surface reflectance of a glazing system

SC: the shading coefficient for the total window system representing the ratio of the solar heat gain through the window system relative to that through 3 mm (1/8") clear glass at normal incidence.

SCc: the shading coefficient for the glazing system (center-of-glass).

SHGC: the solar heat gain coefficient of the total window system representing the solar heat gain through the window system relative to the incident solar radiation.

SHGCc: the solar heat gain coefficient for the glazing system (center-of-glass) only.

Source: source of information for a frame or divider element.

Thick: glass thickness (SI:mm, IP:in).

Tir: thermal infrared transmittance of a glazing layer.

Tsol: solar transmittance of the glazing layer.

Tvis: visible transmittance of the glazing layer.

U-value: the total heat transfer coefficient for the window system (SI:W/m2-°C, IP:Btu/h-ft2-°F).

Uc: the U-value for the glazing system (center-of-glass) only (SI:W/m2-°C, IP:Btu/h-ft2-°F).

VT: the total window system's visible transmittance at normal incidence.

Vtc: visible transmittance of the glazing system (center-of-glass) only.