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Report No. 8219-1

For the attention of: Mr. Dennis Whittaker

Subject of report: Test results for Weather Screen Material, in response to your P. O. No. 26526

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1. Summary.

The laboratory evaluation of a sample of aluminized, perforated weather screen material has been completed at the Yellott Solar Energy Laboratory with the following results:

1.1 Items 1, 2, 3 and 4 of your purchase order (solar-optical properties):

	Trans-mittance	Reflec-tance	Absorp-tance
Aluminized surface facing sun:	0.28	0.65	0.07
Black surface facing sun:	0.30	0.19	0.51

1.2 Item 4, Shading Coefficient determination:

When used with double strength glass, weather screen indoors:

Aluminized surface facing sun: SC = 0.37

Black surface facing sun: SC = 0.70

1.3 Item 5, longwave emittance of both sides of Weather Screen:

Aluminized surface, emittance = 0.69

Black surface, emittance = 0.86

1.4 Item 6, guarded hot plate test to determine system U-value:

Aluminized surface towards hot plate, U = 0.60

Summer conditions, 1.25 in. spacing

2. Test Procedures.

2.1 The solar-optical properties of the Weather Screen were measured in accordance with ASHRAE Standard No. 74-73. Transmittance was measured with a thermopile-type pyranometer mounted within a blackened box which could be turned and tilted to make the instrument point directly towards the sun. The signal from the pyranometer was recorded on a strip chart recorder and the sample of Weather Screen was then interposed between the instrument and the sun. The ratio of the millivolt signal with the sample in place to the signal received without the sample is taken as the total solar transmittance of the sample.

Reflectance is measured with the same apparatus but with a silicon cell sensor which is so small that it casts a negligible shadow on the sample which is stretched tightly over a blackened surface. The cell is connected through a potentiometer to the millivolt recorder; when the cell is pointed directly at the sun, the potentiometer is adjusted to give a 10 mV signal on the strip chart recorder. The cell is then rotated to look directly at the sample and the recorder signal, divided by 10, is taken as the reflectance.

The absorptance is found by subtracting the sum of the transmittance and the reflectance from 1.00, in accordance with the equation:

$$\text{Absorptance} = 1.00 - (\text{Trans.} + \text{Reflect.}) \quad (1)$$

The tests were run first with the aluminized side facing the sun and then with the black side facing the sun. The results of at least ten tests in each position were as follows:

	Trans.	Reflect.	Abs.
Aluminized surface towards the sun	0.28	0.65	0.07
Black surface towards the sun	0.30	0.19	0.51

2.2 The Shading Coefficient was calculated from these solar-optical properties by using the Pennington and Moore equation which was adopted in 1964 by the ASHRAE Technical Committee on Fenestration. A Xerox copy of the relevant page from Pennington and Moore's ASHRAE paper No. 2039, presented in Detroit in February, 1967, is attached to this report. The entire paper is to be found in the ASHRAE Transactions, Vol. 73, Part I, 1967, pp. VIII.3.1 - 3.13. The pertinent equations are to be found on p. VIII.3.8 and they may be simplified in the following manner:

Shading Coefficient for a single glazing plus an interior shade

$$= 1.15 \times \left(\begin{array}{l}\text{Transmittance} \\ \text{of Glazing} \\ \text{plus Shade}\end{array} + 0.215 \times \begin{array}{l}\text{Total} \\ \text{Absorption} \\ \text{in Glazing}\end{array} + 0.75 \times \begin{array}{l}\text{Total} \\ \text{Absorption} \\ \text{in Shade}\end{array}\right) \quad (2)$$

To account for inter-reflection between the glazing and the shade,

$$\begin{array}{l}\text{Transmittance} \\ \text{of Glazing} \\ \text{plus Shade}\end{array} = \frac{\text{Trans. of Glazing} \times \text{Trans. of Shade}}{1.0 - \text{Reflect. Glazing} \times \text{Reflect. of Shade}} \quad (3)$$

For the aluminized surface of the Weather Screen facing the sun through double strength single glazing, the pertinent values are:

	Transmittance	Reflectance	Absorptance
Glazing alone	0.86	0.08	0.06
Weather Screen, Al. to sun	0.28	0.65	0.07

$$\begin{array}{l}\text{Transmittance} \\ \text{of Glazing} \\ \text{plus Shade}\end{array} = (0.86 \times 0.28)/(1.0 - 0.08 \times 0.65) = 0.254$$

$$\text{Total Absorp. in Glazing} = \text{Absorptance of Glazing Alone} \times \left(1.0 + \frac{\text{Trans. of Glaz.} \times \text{Reflect. of Shade}}{1.0 - \text{Ref. Glazing} \times \text{Ref. of Shade}}\right) \quad (4)$$

$$= 0.06 \times (1.0 + (0.86 \times 0.65))/(1.0 - 0.08 \times 0.65)$$

$$= 0.0954$$

$$\text{Total Absorption in Shade} = \frac{(\text{Trans. of Glazing} \times \text{Absorp. of Shade})}{(1.0 - \text{Ref. Glazing} \times \text{Ref. Shade})} \quad (5)$$

$$= (0.86 \times 0.07) / (1.00 - 0.08 \times 0.65)$$

$$= 0.0635$$

$$\text{Shading Coef.} = 1.15 \times (0.254 + 0.215 \times 0.0954 + 0.75 \times 0.0635)$$

$$= 1.15 \times (0.254 + 0.0205 + 0.0476) = \underline{0.3705}$$

For Weather Screen with the black surface turned towards the sun,

Transmittance = 0.30, Reflectance = 0.19 and Absorptance = 0.51

$$\text{Transmittance of Glazing plus Shade} = (0.86 \times 0.30)/(1.0 - 0.08 \times 0.19) = 0.262$$

$$\text{Total Absorption in Glazing} = 0.06 \times (1.0 + (0.86 \times 0.19)/(1.0 - 0.08 \times 0.19)$$

$$= 0.070$$

$$\text{Total Absorption in Shade} = (0.86 \times 0.51) / (1.00 - 0.08 \times 0.19) = 0.4454$$

$$\text{Shading Coef.} = 1.15 \times (0.262 + 0.215 \times 0.070 + 0.75 \times 0.4454)$$

$$= 1.15 \times 0.611 = \underline{0.703}$$

2.3 Longwave Emittance of Weather Screen

The longwave emittance of both surfaces of the Weather Screen sample were measured at DSET Laboratories, located near Phoenix, using a properly calibrated meter which compares the emittance of some unknown surface with that of a very black surface with known emittance. For the radiation spectrum with wavelengths from approximately 3.0 to 30 micrometers, covering all of the energy emitted from a typical sun-heated surface, the emittances were found to be:

Aluminized surface, e = 0.69

Black surface, e = 0.86

The perforated vinyl screen is actually covered with a transparent polyester film and the characteristic emittance of such films is about 0.86, as found at DSET Laboratories. The aluminum film is also covered by a second polyester film, but there is just enough transmittance of longwave radiation in the film to account for the reduction in emittance found by DSET.

2.4 Determination of U-value by the Guarded Hot Plate Process

The thermal resistance added to a single glazed window or door by using Weather Screen was determined by using a 4 ft by 8 ft guarded hot plate. The heated surface was a sheet of 1/4 in. clear glass which was pressed tightly against an electrically-heated sheet of Masonite. The power supplied to the heating circuit was measured by a calibrated digital ammeter and a calibrated digital voltmeter. Since the circuit contained only resistance, the power input was the product of the current in amperes and the voltage applied to the circuit. The heated panel was insulated on its rear surface by 2 in. of Styrofoam and a similar heating panel was pressed against the rear surface of the insulation. Twelve thermocouples were fastened to each surface of the insulation and the power applied to the guard heater was adjusted until the temperature difference across the insulation was virtually zero.

Heat loss from the edges of the hot plate was prevented by another layer of Styrofoam insulation and an edge heater which was also controlled to produce a zero temperature difference between the two surfaces of this insulation.

The temperature of the outer surface of the heated glass was measured by 12 copper-constantan thermocouples which were connected in parallel to give an electrical average of the surface temperature. The ambient air temperature in front of the hot plate was measured with copper-constantan thermocouples.

The thermal resistance between the glass surface and the surrounding air was found by the following calculation:

Energy Input = Volts x Amperes x 3.413 = Btu/hr = Q

Net Energy to Glass = Q - heat losses through back and edges = Q_{net}

q_u = net heat loss per sq ft of hot plate = $Q_{net}/32$

Δt_{ga} = temperature of glass - temp. of ambient air

R_{ga} = thermal resistance, glass to air = $\Delta t_{ga} / q_u$

To find the total thermal resistance under summer conditions, the thermal resistance of the glass, 0.03 resistance units, and the resistance at the outdoor surface, 0.25 R-units, must be added to obtain

$R_{total} = R_{ga} + 0.28$; $U = 1 / R_{total}$

The guarded hot plate is calibrated by operating the apparatus without any shading device over the glass until all temperatures come to equilibrium and the U-value reaches 1.04, the standard ASHRAE value of unshaded single glass, + or - 2%.

To find the resistance added by the Weather Screen, it was attached to the hot plate frame, 1.25 in. away from the glass, and the testing was continued until new equilibrium temperatures were attained.

Δt_{gda} = temp. of glass - air temp., shading device in place

$R_{gda} = \Delta t_{gda}/q_u$

$R_{total} = R_{gda} + 0.28$; $U = 1.0 / R_{total}$ Btu/hr.sq ft.F

The units of thermal resistance are degrees F/ (Btu/hr.sq ft).

The average U-value for the 1/4 in. glass plus the Weather Screen, plus the standard summer outer surface and glass resistances, proved to be 0.596. The actual data from Test No. 8, for which the U-value proved to be 0.598 Btu/hr.sq ft.F, are given below:

Date: September 3, 1982, at 8:00 pm; air temp adjacent to hot plate

= 79.6 F. Average Temp. of glass = 95.8 F; Δt_{gda} = 16.2 F.

Power = 84.8 volts x 1.53 amps = 129.74 watts = 442.8 Btu/hr

Heat loss through back and edges = 70.66 Btu/hr; Q_{net} = 376.16 Btu.

q_{net} = 372.16/32 = 11.63 Btu/hr.sq ft;

R_{gda} = 16.2 F/ 11.63 Btu/hr.sq ft = 1.393 Resistance units

R_{total} = 1.393 + 0.28 = 1.673, from outdoor air through glass, air space and Weather Screen

$U = 1.0 / 1.673 = 0.598$ Btu/hr.sq ft. F.

A conservative value of the overall heat transfer coefficient U for summer conditions is therefore <u>0.600</u> Btu/hr.sq ft.F.

For winter conditions, when the glass temperature would be far lower than the test value of 95.8 F, the U-value would be significantly lower. The standard ASHRAE value of U for a double-glazed window with 1/2 in. air space is 0.56 in summer and 0.59 in winter. Using this as an example, the winter U-value for single glazing plus Weather Screen would be 0.525 Btu/hr.sq ft.F.

3. Summary

In summer, using the standard ASHRAE values of 89 F outdoor and 75 F inside air temperatures, 7.5 mph wind velocity outdoors, the heat gain through a single glazed window with the aluminized surface of the Weather Screen turned towards the sun would be:

$$q_{total} = 0.37 \times 248.3 + 0.60 \times (89 - 75) = 91.9 + 8.4 = 100.3 \text{ Btu/hr.ft}^2$$

In winter, with the solar irradiance on a south-facing window at noon, 40 deg north latitude, = 263 Btu/ft^2; air temperatures = 20 F outdoors, 70 F indoors, black surface facing the sun:

$$q_{total} = 0.70 \times 263 - 0.53 \times (70 - 20) = 184.1 - 26.5 = 131.1 \text{ Btu/hr.}$$

Thus the Weather Screen, with the aluminum surface facing the sun, would be an effective means of reducing solar heat gains when they are not wanted. In winter, with the black surface facing the sun, the solar heat gain would be 131 Btu/hr.sq ft. A 4 ft square window, with 16 sq ft of single glazing, would have a heat gain of 2096 Btu/hr. which is equivalent to a 600 watt electric heater.

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