Solar Energy Research
Institute of Singapore

Laboratory Thermal Performance Testing of Inflector Radiant Barrier Window Insulator

Report number: CHB0060/S0032

Report prepared for

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by

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1. Overview of Tests

The objective of the test is to evaluate the thermal performance, including thermal transmittance (U-value) and solar heat gain coefficient (SHGC, G-value), of Inflector radiant barrier window insulator.

According to the client's website information, the Inflector radiant barrier window insulator is to be used as window attachment for improved thermal insulation and solar heat gain control. The window insulator can be installed as panel, roller blinds or vertical blinds on the indoor side of existing windows. In the summer, the silver side of the window insulator faces outdoor to reflect solar radiation back and achieve low solar gain; in the winter, the black side of the window insulator faces outdoor to absorb more solar radiation and achieve high solar gain. When installed as panel, the window insulator is usually attached onto the frame of the window by Velcro hooks, with a gap size of 20 mm – 40 mm between the window insulator and glass surface.

The present laboratory testing simulates the summer operation mode of the Inflector radiant barrier window insulator and the Inflector radiant barrier window insulator specimen (hereafter referred to as "specimen") was installed as panel. Two typically used glazing types, i.e. low-e coated double glazing unit (DGU, hereafter referred to as "DGU") and clear single glazing (hereafter referred to as "single glazing"), in the tropical and subtropical climates were used as the baseline system. Combined systems were formed by installing the specimen with the DGU and the single glazing as panel on the indoor side. Thermal transmittance and SHGC of the combined systems were tested. The table below summarizes the tests conducted.

No.	Combined system	Glazing type	Specimen facing	Installation type	Test type
1	Specimen with DGU	DGU	Silver side facing outdoor	As panel	Thermal transmittance
2	Specimen with DGU	DGU	Silver side facing outdoor	As panel	SHGC
3	Specimen with single glazing	Single glazing	Silver side facing outdoor	As panel	Thermal transmittance
4	Specimen with single glazing	Single glazing	Silver side facing outdoor	As panel	SHGC

2. Description of the Combined Systems

2.1 Specimen

The specimen, as specified in the table below, was selected and delivered by the client. The original specimen is of trapezoidal shape, with constant width and one side slightly longer than the other.

Specimen ID	S0032
Date of receipt	10/11/2011
Product	Inflector radiant barrier window insulator
Total thickness	0.3 mm
Total width	1367 mm (constant)
Total length	1013 mm (shorter side), 1067 mm (longer side)

One side of the specimen is of silver color (Figure 1 left) and the other side of the specimen is of black color (Figure 1 middle). There are uniformly distributed small circular holes of the diameter approximately 1 mm over the entire specimen, except the 4 mm wide edge area (Figure 1 right). The hole grid is of rectangular pattern, with 6 holes for every 10 mm. The black side of the specimen is covered by a layer of thin transparent plastic film. The plastic film is continuous, i.e. without holes on it, and is not permeable to airflow. The specimen is flexible and allows a see-through view through it.

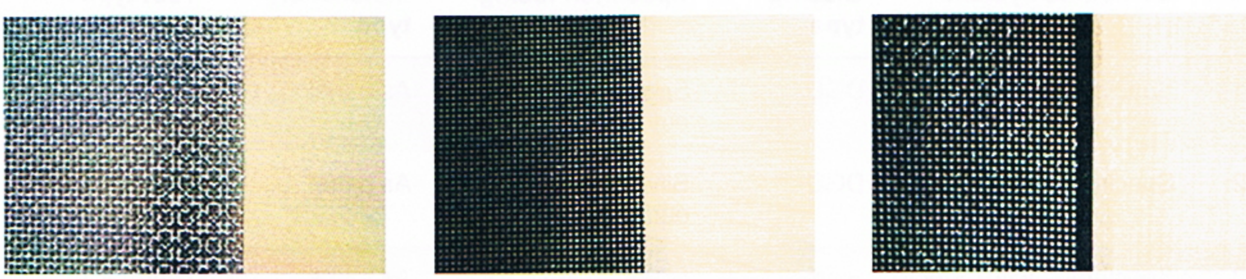

Figure 1. Detailed views of the specimens. Left: silver side of the specimen; middle: black side of the specimen; right: edge of the specimen

2.2 DGU

The DGU is an in-house sample provided by SERIS, with known thermal transmittance value and SHGC value. The table below lists the specification of the DGU.

Specimen ID	S0030
Product	DGU with low-e coating
Total thickness	24 mm
Total width	1000 mm
Total length	1000 mm
External pane type	6 mm thick clear tempered glass with low-e coating on the inner side
Internal pane type	6 mm thick clear tempered glass
Gas fill type	12 mm thick dry air
Thermal transmittance	1.88 ± 0.14 W/(m^2 K), summer condition
SHGC	0.429 ± 0.014, summer condition

2.3 Single Glazing

The single glazing is an in-house sample provided by SERIS, with known thermal transmittance value and SHGC value. The table below lists the specification of the single glazing.

Specimen ID	S0033
Product	Clear single glazing
Total thickness	4 mm
Total width	1000 mm
Total length	1000 mm
Glass pane type	4 mm thick clear tempered glass (without coating)
Thermal transmittance	5.22 ± 0.15 W/(m^2 K), summer condition
SHGC	0.866 ± 0.026, summer condition

2.4 Specimen with DGU

The combined system of specimen with DGU consists of a specimen and a DGU. The specimen was installed as panel, with the silver side facing outdoor. Figure 2 shows a schematic representation of the combined system.

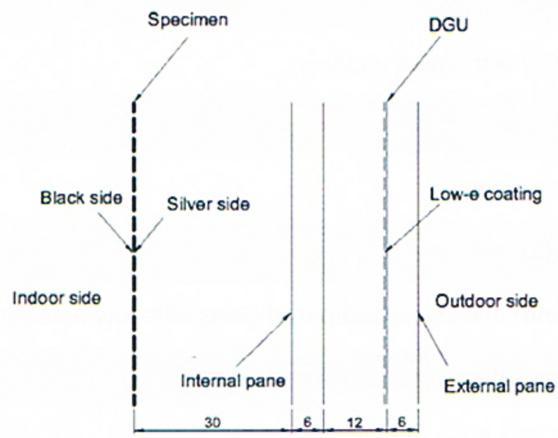

Figure 2. Schematic representation of the combined system consisting of the specimen and the DGU (unit of length: mm)

2.5 Specimen with Single Glazing

the combined system of specimen with single glazing consists of a specimen and a single glazing. The specimen was installed as panel, with the silver side facing outdoor. Figure 3 shows a schematic representation of the combined system.

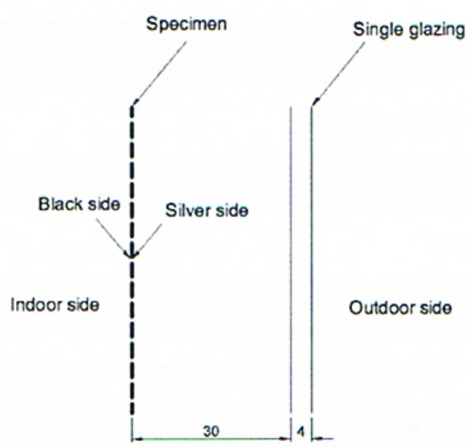

Figure 3. Schematic representation of the combined system consisting of the specimen and the single glazing (unit of length: mm)

2.6 Installation of the Combined Systems

The specimen was cut into the same dimension of the DGU and the single glazing, i.e. 1000 mm x 1000 mm. A frame made of plywood was fabricated to support the specimen at the perimeter. The thickness of the plywood is 6 mm and the width of the frame is 12 mm. The gap between the specimen and glass surface was adjusted to 30 ± 5 mm. The glass was installed into the opening of surround panel with small gaps filled by cotton wool and joints between the glass and the surround panel were further sealed by tape to ensure airtightness. The joints between the specimen and the surround panel are not airtight, but airflow is restricted as the gap between plywood frame and surround panel opening is very small (less than 2 mm). For SHGC testing, the perimeters of the combined system were further masked by 20 mm wide insulation material on both indoor and outdoor sides, so that the edge portion of the system does not affect the measured SHGC and the SHGC result reported is center-of-glazing SHGC.

3. Test Procedures

3.1 Test Methods

The measurement equipment and procedure for thermal transmittance testing are in compliance with ASTM C 1199 – 09e1 (*Standard test method for measuring the steady-state thermal transmittance of fenestration systems using hot box method*), for SHGC testing are in compliance with NFRC interim standard 201-2010 (*Procedure for interim standard test method for measuring the solar heat gain coefficient of fenestration systems using calorimetry hot box methods*).

3.2 Test Apparatus

The SERIS calorimetric hot box is a combined thermal transmittance and SHGC testing instrument. Figure 4 shows the schematics of calorimetric hot box in thermal transmittance measurement mode. The specimen is mounted onto the opening of a well-insulated surround panel. Temperatures in room side and weather side are kept constant with a difference (refer to Section 3.3 for details). Air flow velocities, surface temperatures and emittances on both sides are controlled or monitored in order to maintain a desired surface heat transfer coefficient. Steady state heat flow through specimen due to temperature difference is measured to deduce the thermal transmittance value.The method defined in ASTM C 1199 is used for thermal transmittance calculation.

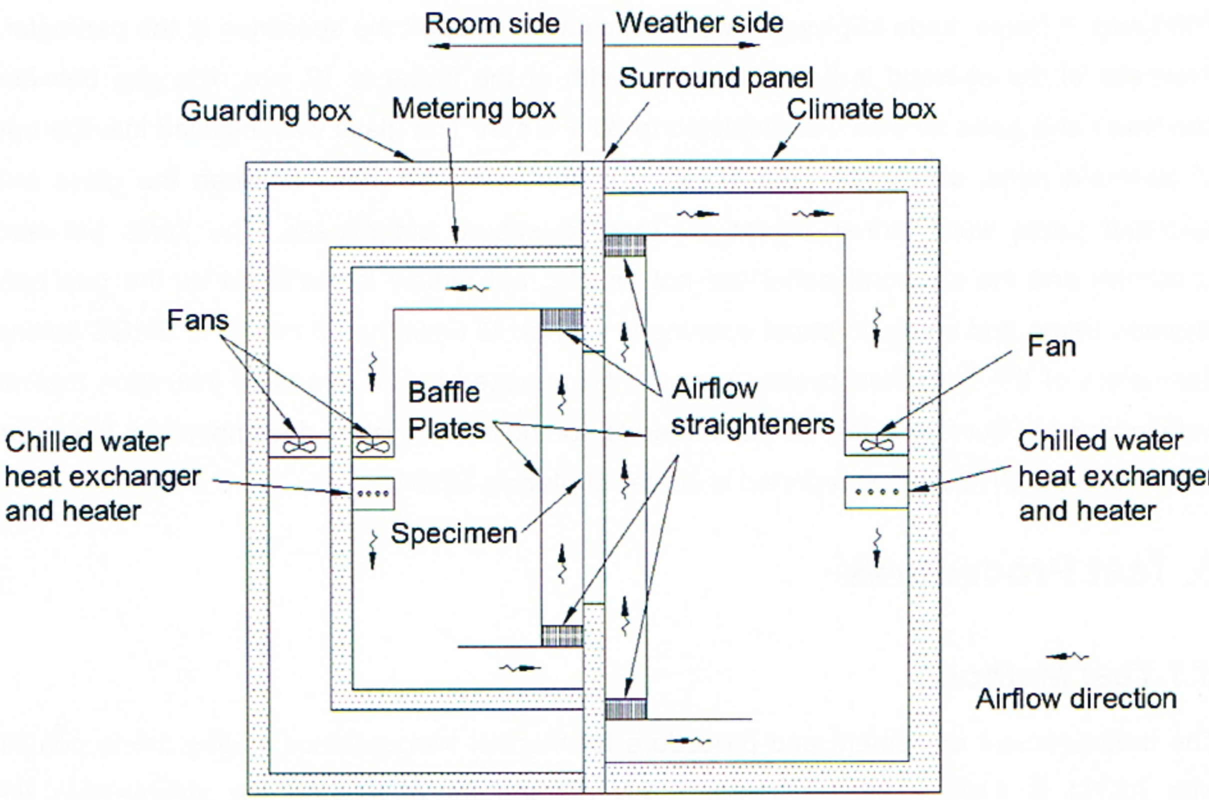

Figure 4. Schematics of the SERIS calorimetric hot box in thermal transmittance measurement mode

Figure 5 shows the schematics of calorimetric hot box in SHGC measurement mode. The room side boxes, i.e. metering box and guarding box, are maintained at steady state temperature and airflow condition. On the weather side, the specimen is exposed to room air and solar radiation from the solar simulator. An external air curtain is available to maintain a required airflow velocity. Steady state heat flow through specimen due to the transmission of solar radiation is measured to deduce SHGC value. The method defined in NFRC 201 standard is used for SHGC calculation.

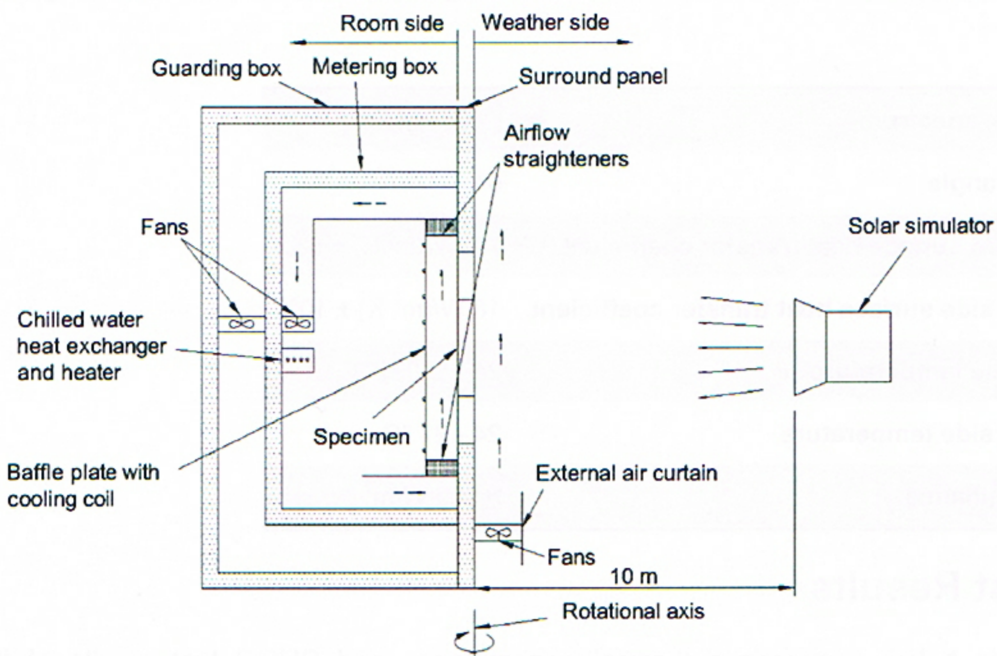

Figure 5. Schematics of the SERIS calorimetric hot box and solar simulator in SHGC measurement mode

3.3 Boundary Conditions

The thermal transmittance test was carried out with summer environmental condition, as given in the table below.

Room side surface heat transfer coefficient	7.7 W/(m^{2}K) ± 5%
Weather side surface heat transfer coefficient	18 W/(m^2 K) ± 10%
Room side temperature	24 ± 0.025 °C
Weather side temperature	32 ± 0.025 °C

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The SHGC test was carried out with the following environmental condition, as given in the table below.

Radiation spectrum	Near AM1.5
Incident angle	0°
Room side surface heat transfer coefficient	7.7 W/(m^2 K) ± 5%
Weather side surface heat transfer coefficient	18 W/(m^2 K) ± 10%
Room side temperature	24 ± 0.025 °C
Weather side temperature	24 - 27 °C
Solar irradiance	> 500 W/m^2

4. Test Results

The table below summarizes thermal transmittance and SHGC test results of the combined systems. The known values of the DGU and the single glazing are included for reference.

System	**Thermal transmittance [W/(m^2 K)]**	**SHGC [-]**
DGU	1.88 ± 0.14	0.429 ± 0.014
Specimen with DGU	1.48 ± 0.14 (CHB0056/S0032)	0.251 ± 0.010 (CHB0057/S0032)
Single glazing	5.22 ± 0.15	0.866 ± 0.026
Specimen with single glazing	2.83 ± 0.14 (CHB0058/S0032)	0.391 ± 0.014 (CHB0059/S0032)

Note:

a) The value following the "±" sign is the expanded uncertainty estimated with a coverage factor of k = 2 and a level of confidence of approximately 95%.

b) The reference numbers listed in the bracket (e.g. CHB0056/S0032) are the corresponding detailed report reference number.

The results listed in the table above are presented in Figures 6 and 7 as histogram graphs.

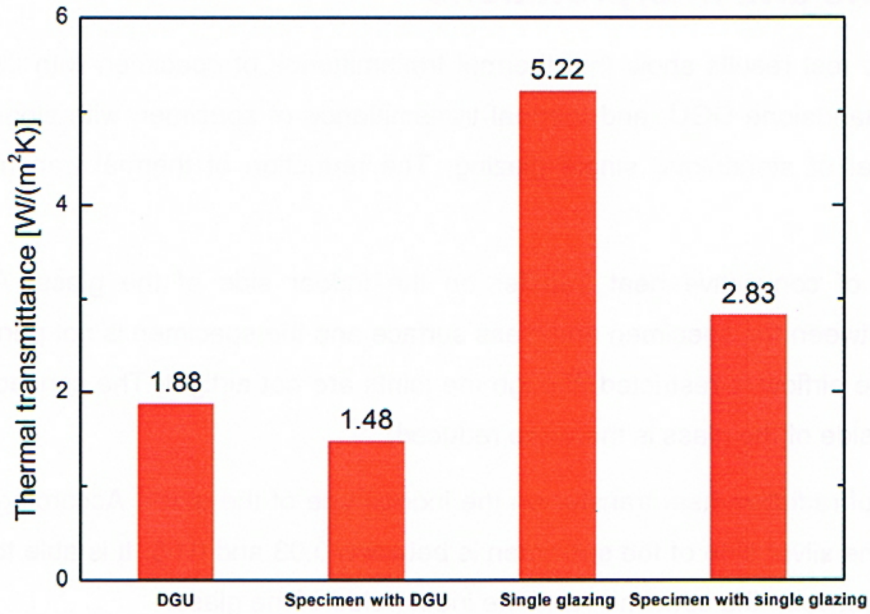

Figure 6. Histogram graph of thermal transmittance results listed in the table

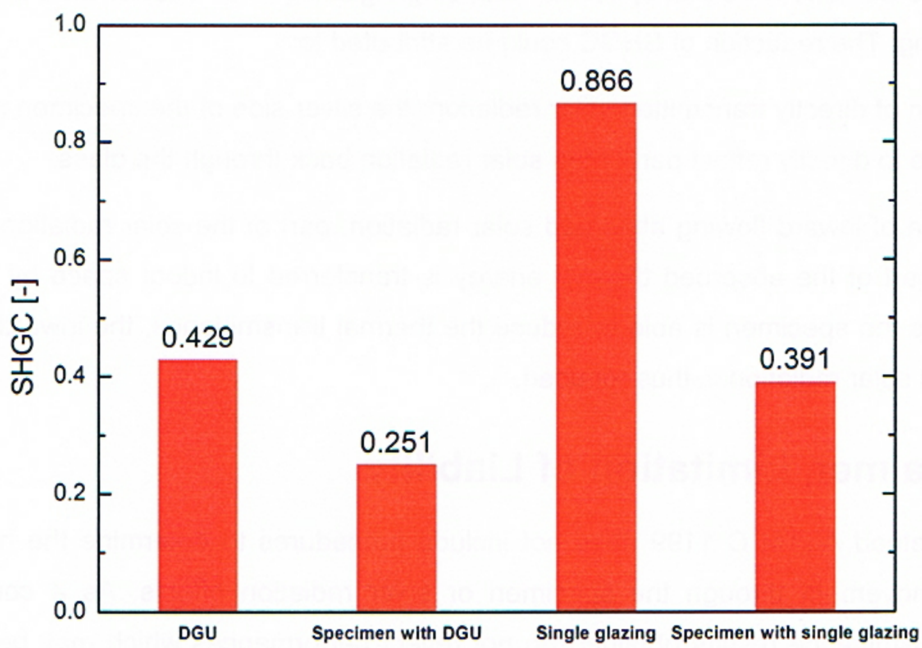

Figure 7. Histogram graph of SHGC results listed in the table

5. Opinions and Interpretations

The laboratory test results show that thermal transmittance of specimen with DGU is 21% lower than that of standalone DGU, and thermal transmittance of specimen with single glazing is 46% lower than that of standalone single glazing. The reduction of thermal transmittance could be attributed to:

1) Reduction of convective heat transfer on the indoor side of the glass. A 30 mm gap is maintained between the specimen and glass surface and the specimen is not permeable to airflow. The convective airflow is restricted, though the joints are not airtight. The convective heat transfer on the indoor side of the glass is therefore reduced;

2) Reduction of radiative heat transfer on the indoor side of the glass. According to the client, the emittance of the silver side of the specimen is between 0.03 and 0.05. It is able to reduce radiative heat transfer between the specimen and the indoor side of the glass.

The laboratory test results show that SHGC of specimen with DGU is 41% lower than that of standalone DGU, and SHGC of specimen with single glazing is 55% lower than that of standalone single glazing. The reduction of SHGC could be attributed to:

1) Reduction of directly transmitted solar radiation: the silver side of the specimen is very reflective and it is able to directly reflect part of the solar radiation back through the glass.

2) Reduction of inward flowing absorbed solar radiation: part of the solar radiation is absorbed by glass and part of the absorbed thermal energy is transferred to indoor space by convection and radiation. As the specimen is able to reduce the thermal transmittance, the inward flowing portion of absorbed solar radiation is thus reduced.

6. Disclaimer, Limitation of Liability

The test method ASTM C 1199 does not include procedures to determine the heat flow due to either air movement through the specimen or solar radiation effects. As a consequence, the thermal transmittance results obtained do not reflect performances which may be expected from field installation due to not accounting for solar radiation, air leakage effects, and the thermal bridge effects that may occur due to the specific design and construction of the fenestration system opening. The later can only be determined by in-situ measurements. Therefore, it should be recognized that the thermal transmittance results obtained from this test method are for ideal laboratory conditions and should only be used for fenestration product comparisons and as input to thermal performance analyses which also include solar, air leakage and thermal bridge effects.

The test method NFRC 201-2010 does not include separate procedures to determine the heat flows due to either air movement or nighttime U-factor effects. As a consequence, the SHGC results obtained do not reflect the overall performance which may be found in field installations due to temperature differences, wind, shading, air leakage effects and the thermal bridge effects specific to the design and construction of the fenestration system opening. Since there are a wide variety of fenestration openings in residential, commercial and industrial buildings, it is not feasible to select a "typical" surround panel construction in which to mount the fenestration test specimen. The selection of a relatively high thermal resistance surround panel places the focus of the test on the thermal performance of the fenestration system alone. Therefore, it should be recognized that the thermal transmittance results obtained from this method, for ideal laboratory conditions in a highly insulating surround panel, should only be used for fenestration product comparisons or as input to thermal performance analyses which also include thermal, air leakage and thermal bridge effects due to the surrounding building structure. To determine air leakage effects for windows and doors, refer to ASTM E 283. For thermal transmittance refer to ASTM C 1199.

The results stated in this test report only relate to the specimen tested. This test report shall not be reproduced, except in full, without the approval of the laboratory.

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