REPORT

In-Situ Solar Heat Gain Coefficient (SHGC) Determination for Curtain Wall Glazing

[redacted] Tower

Presented to:

[redacted]

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APPENDIX A: Scope of Work

1. INTRODUCTION

1.1 Terms of Reference and Scope of Services

We were retained by [redacted], LLC to determine the solar heat gain coefficient (SHGC) of glass installed in four office suites at the [redacted] Tower.

The scope of our services was provided in our proposal letter dated [redacted] and is included in Appendix A for reference purposes.

1.2 Background

We understand that occupants of these four office spaces experienced thermal discomfort associated with solar radiation transmitted via architectural glazing within.

Therefore, the building management chose to verify whether the glass installed in these office suites complies with the solar heat performance criteria specified by the architect.

1.3 General Information

The [redacted] Tower is a 40-story tall structure of rectangular plan, located in downtown [redacted], built in [redacted], designed by [redacted], and clad with aluminum-framed glazing. The average window to floor ratio is approximately 50% and the window to wall ratio approximately 60%. The adjacent northern development is predominantly high-rise, while the southern development is low-rise, single family residential.

1.4 Assessment Work

The field work was preceded by development, production, and testing of the apparatus used for measurements throughout the month of January.

The assessment field work was carried out on site on the following days:

- [redacted] (verification of the apparatus, setup, and procedure),
- [redacted] (measurements in [redacted]),

- [redacted] (measurements in [redacted], [redacted], and [redacted]),

The field work consisted of calibration and measurements. The resulting SHGC was calculated by comparison of readings obtained on the terrace located on the [redacted]th floor and in the office suites.

Observations and tests were conducted by Karol Kazmierczak (Kaz), the Senior Building Science Architect of Building Enclosure Consulting, LLC. The building maintenance staff provided access to the restricted areas.

1.5 Documents Reviewed

We had opportunity to review an architectural specification sections 08800 "Glass and Glazing' and 08910 "Glazed Aluminum Curtain Walls" bearing no indication of an author and date, and a Viracon glass data sheet dated [redacted].
We found that the specification section 08800/2.2 leaves the glass types to be determined by Architect, effectively giving no information on the intended glass makeup.
The Viracon datasheet specifies the glass makeup and its basic performance indices but gives no indication of its applicability to the project. The makeup is ¼" clear VE-42, 30mil PVB, ¼" PPG Caribia and the SHGC listed is 0.34.

2. METHODOLOGY

2.1 Background

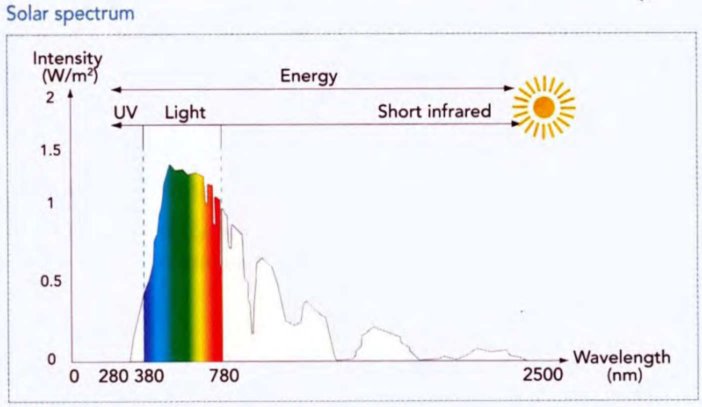
2.1.1 What is SHGC?

According to the European Standard EN ISO 410 cited by American NFRC standards, SHGC is the glass transmittance in range from 300nm to 2500nm, as shown on the chart below. This range embraces ultraviolet (UV) rays, visible (VIS) range, and near-infrared (NIR) range called also "solar range," or "short infrared.

Composition of the solar spectrum

Type of radiation	Wavelength (nm)	Proportion of energy
UV	280 to 380	approx. 5 %
Visible	380 to 780	approx. 50 %
IR	780 to 2,500	approx. 45 %

Solar spectrum



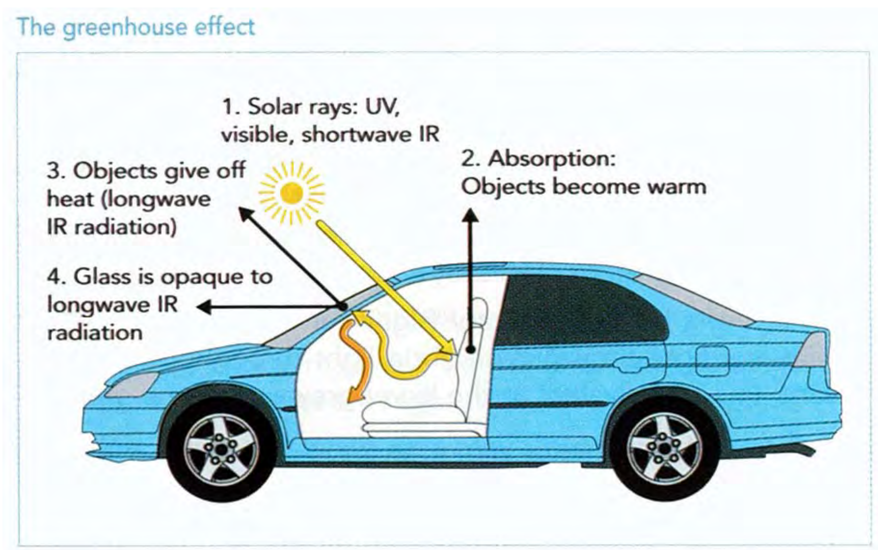
Picture by AGC

2.1.2 Why is SHGC important?

SHGC is one of the glass benchmarks allowing comparison of different glass types. It illustrates glass transmittance of solar radiation, as opposed to the U factor illustrating thermal transmittance in range from 2,500nm to 50,000nm (which we feel as heat).

In the context of the situation at hand, human body generally cannot directly and instantaneously detect solar radiation other than the visual (VIS) light range, but the near-infrared NIR radiation is absorbed by objects such as human skin and re-radiated in the thermal range which we can feel as heat.

This phenomena contributes to “greenhouse” effect. An example a car windshield below illustrates such condition.



Picture by AGC

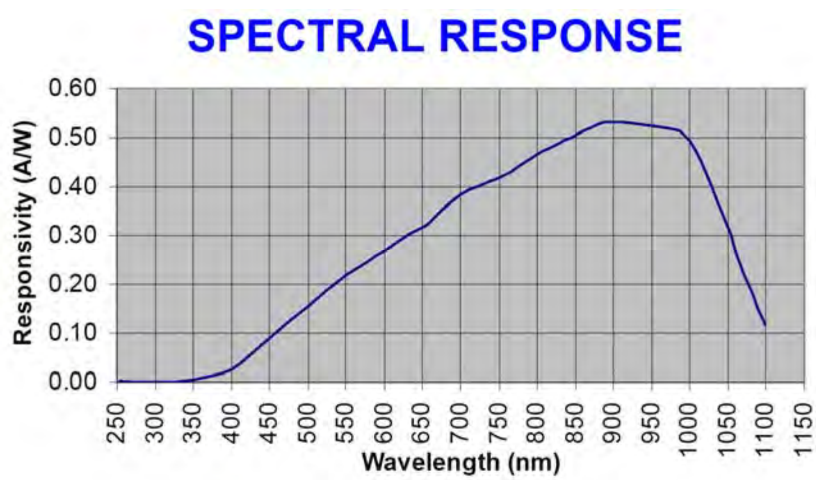
2.1.3 Field Measurements

The recognized glazing industry standard that allows for a precise measurement of an unknown glass is a laboratory test developed by the National Fenestration Rating Council (NFRC) 201 standard titled “Interim Standard Test Method for Measuring the Solar Heat Gain Coefficient of Fenestration Systems Using Calorimetry Hot Box Methods,” which entails the use of solar calorimeters. This method of measurement is quite cumbersome; thus glazing and research industries often use versatile, wide range UV-VIS-NIR spectrophotometers, to verify the compliance with European standards, such as EN ISO 410. Such spectrophotometers require access to the edge and do not allow in-situ measurements. They are also heavy and cumbersome, which made them unsuitable for field measurement.

2.2 The Apparatus

We were challenged to design an applicable portable tool to measure SHGC of a fixed glass.

So, we developed and built two identical solar cell pyranometers, based on the modified design of Mr. [redacted], PhD of [redacted] in [redacted]. Two silicon photodetectors [redacted] loaded with 470-Ohm resistors, were employed and installed in plastic tubes with 1 mm (0.039") thick x 3/8" diameter Teflon® disks placed at the front. The spectral response of the photodetectors is in range of 300-1100nm, as shown in the chart below.



The two milivoltmeters used projected an output that is proportional to the amount of sunlight falling on the detector. We picked two diodes and two voltmeters out of four and reduced the thickness of the Teflon disk placed in front of one sensor in order to achieve identical output from both sensors. The resulting discrepancy between two readings was less than 1%.

We also tested a combination of the measurements by our pyranometers and two pyrometers manufactured by [redacted]. No data is available to verify the spectral characteristics of these pyrometers, but they are typically characterized by a fairly broad spectral infrared range.

Test was also done on the “Solar Transmission and Power Meter” gauge produced and recommended for this job by EDTM, the manufacturer of a glass measuring equipment; however, this gauge proved to be inadequate and EDTM eventually admitted no tool meeting our requirements is commercially available.

The calibrations and measurements were recorded by camcorder Sony HDR-CX550 and camera Panasonic LUMIX DMC-FZ18. Thermal images were taken by thermal imager IRISYS IRI4010.

2.3 The Calibration

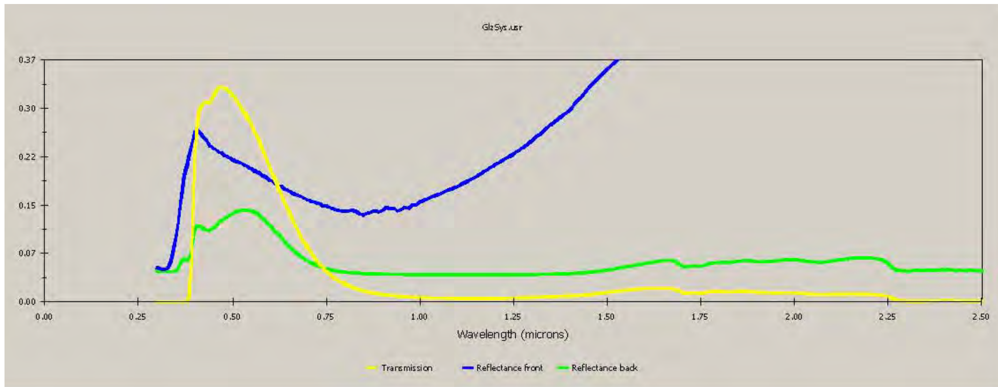
2.3.1 Early Calibration

- Samples. We used a demonstration set of glass samples manufactured by Pilkington, consisting of different types of glass: clear, tinted, clear low E, and tinted low E.
- Sample SHGC Verification. We verified the SHGC numbers printed on the glass samples against respective numbers published in the International Glass Database ver. 14.1.
- Artificial vs. Natural Light. The samples were tested against an artificial light source: 250 W infrared light. The results were found to be less accurate than with the natural light.
- Pyranometer Results. We tested the transmission of the samples against sun light and noted the discrepancies between readings and the published values. They turned out to be fairly significant in case of a tinted glass and a tinted low E glass.
- Commercial Gauge Results. The test done showed that the EDTM tester is much less accurate than the numbers obtained from our pyranometers.
- Pyrometers. Subsequently, we added to the measurement two pyrometers and developed a formula for calculation of each group of glass. It turned out that the pyrometer reading is on average 4 to 5 times more important than the pyranometer reading for the SHGC determination, and this finding was reflected in the formula developed to calculate the SHGC from the two readings. The combination of the measurements obtained yielded the desired +-5% maximum variation between our readings and the published results.

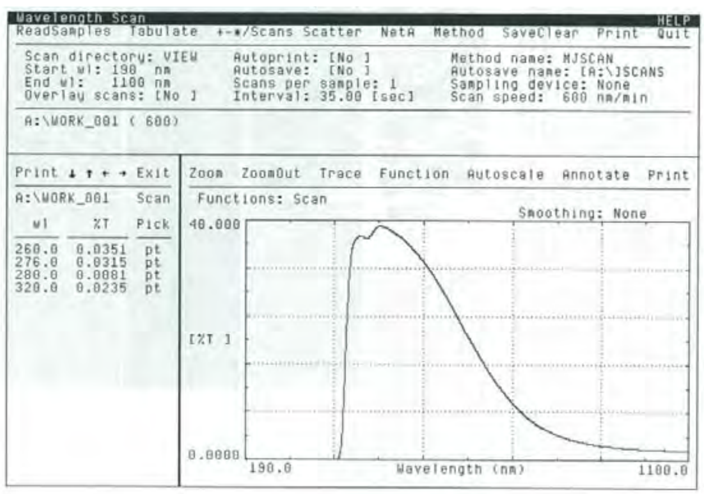
As a result, we developed an apparatus that allows comparison of typical glass SHGC to the precision of two SHGC points, provided the type of glass used is identified (e.g. tinted, clear low E, or tinted low E). This determination can be easily done with a naked eye and commercially available tools.

2.3.2 Reference Samples

We requested and received two reference samples from Viracon made to order to match the glass claimed as the glass used on the building (¼" clear VE-42, 30mil PVB, ¼" PPG Caribia). We also modeled and simulated the glass spectral response in Optics software by Lawrence Berkeley National Laboratory. The result is presented in the chart below.



The glass samples were tested by a spectrophotometer Beckman DU 640 in range 180-1100nm and the result is presented below. Both charts are identical, with the characteristic double peak signature; therefore, we believe the glass we received is the glass specified. Flipping the glass produced an identical chart.



Subsequently, we noted the readings produced from our apparatus on the reference samples. We covered the entire sample with a black cover, leaving only a small hole for sunlight to get through, thus eliminating possible stray light reaching sensors. The pyranometers indicated 25/245 (10%) and pyrometer indicated 106/458 (23%).

Figure 6. The measurement of the reference sample on the 35th floor. The pyranometers read 245 (sensor in direct sun) and 25 (sensor sees the sun via the reference sample).

2.4 The Procedure

We developed a testing procedure which was verified and modified in field before actual measurements were taken.

1. Locate a sunny spot on the open terrace on 35th floor without sun interferences (balustrade shade or reflections).

2. General note: Wait for a clear sky; clouds formation may obstruct the path of sunlight.

3. Place a video camera on a tripod and record the measurements.

4. Point both pyranometers directly at the sun and adjust their positions to achieve the peak readings. Note the readings.

5. Point both pyrometers directly at the sun and adjust their positions to achieve the peak readings. Note the readings.

6. Move one set of sensors to the measured office space and position them behind each glass pane.

7. Point sensors directly at the sun and adjust their positions to achieve the peak reading through the glass. Note and repeat the readings for a period of time, and move sensors to find the peak reading to screen against glass blemishes and dirt. Repeat for each glass pane in a suite.

8. Repeat for each elevation (East, South, and West).

2.4.1 Noted Variations

1) The video camera and the second pyrometer went haywire during measurements in suites 24143 and 24144 and the terrace on the 35th floor on 02/16/2011, most likely due to the exposure to the excessive heat radiation.

2) Pyrometers were not measuring simultaneously.

3) Large discrepancies were noted in the pyrometer readings due to the high air humidity levels on 02/10/2011. Humidity affecting long IR radiation is a well known phenomena.

4) The results obtained by tilting the reference sample were not matched by the results obtained by angular measurements through the facade; however, the differential measurements turned out to be consistent within the façade itself, with approximately 20% difference between results obtained at different incidence angles versus the normal position of a sensor. This is inconsistent with ratios provided by the Fig. 7 of Chapter 15 of 2009 ASHRAE Handbook of Fundamentals.

5) We manually deducted 10dF from interior readings of the pyrometers to account for the higher ambient due to greenhouse effect.

6) We have not measured the west-facing glass pane in 24144.

2.5 The Results

a) The results are tabulated below by using the following formula:
0.34 x pyranometer reading + 1.33 x pyrometer reading = SHGC x 100

Room	Glass pane # from left to right looking out	SHGC
[redacted]	1	0.33-0.36
[redacted]	2	0.33-0.36
[redacted]	1	0.33
[redacted]	2	0.33
[redacted]	1	0.36
[redacted]	2	0.36
[redacted]	3	0.36
[redacted]	1	0.33-0.34
[redacted]	2	0.35
[redacted]	4	0.35
[redacted]	5	0.36

Figure 7. The pyranometer measuring the glass pane #2 in suite #[redacted].

2.6 Other Observations

Dry-bulbTemperatures. We measured and noted some ambient and surface temperatures of the areas covered and listed them in the table below.

Room #	Time	Weather	Exterior ambient	Diffuser temperature	Glass center temperature	Interior ambient
[redacted]	09:10-10:42	No rain, high humidity	80 ºF	62 ºF	117 and 119 ºF (shade 100ºF)	76 ºF
[redacted]	15:45-15:50	No rain, dry	83ºF	61 ºF	107 ºF	74 ºF
[redacted]	12:20-14:45	No rain, dry	83 ºF	60 ºF	100 ºF (shade also 100 ºF)	77 ºF
[redacted]	11:55-13:48	No rain, dry	83 ºF	60 ºF	98 ºF (shade 100ºF)	76 ºF

We also took thermal images of the exterior facades of the building and the interiors of the office suites and found the surface temperature of glass to be similar throughout the entire building. No differences were found between the glass belonging to the four office suites and the adjacent glass belonging to other offices.

(Photo Removed)

Figure 8. South façade on [redacted]. The windows [redacted]and [redacted] show similar thermal signatures to the adjacent windows.

Air speed. The air speed in the spaces verified was measured with a handheld anemometer. The air was practically stagnant both inside and outside, with the air speed measured outside in range of 0-2mph and inside 0-0.1mph directly below diffusers.

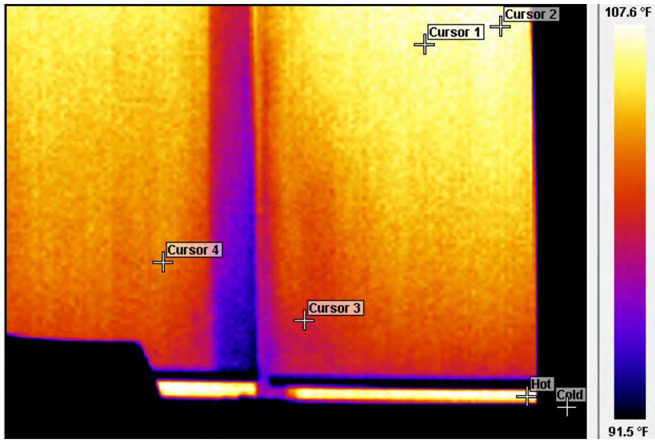


Figure 10. The suite #[redacted] at 10:20am on [redacted]. Fragment of the photograph above in the long IR range. Temperature of the shade is approximately 100 ºF.

Figure 11. The suite #[redacted] at 10:34am on [redacted]. The glass measurements and the tripod with the camera recording the measurements photographed in the long IR range. Note the approx. 127 ºF radiation.

Glare. We have not measured the glare; however, it was plain to see, particularly the reflection from the aluminum framing and sill surfaces.

Glass type determination. We searched for the sun with the thermal imager through the measured glass and could not find it. The dispersion of the sun signature is an indication that a low E coating was used. We also found minor imperfections characteristic for the existence of a laminate interlayer; therefore, we believe the glass is laminated type.

Other measurements. We randomly measured glass installed in the lobby and at the 35th floor and we found the results to be similar to the glass measured in the office suites.

Sun reflections. The east elevation receives triple reflection: 1) from the Bay, 2) from the south glazed curtain wall of the [redacted]Tower, 3) from the Bay re-reflected from the south glazed curtain wall of the [redacted] Tower. There is also a fourth, smaller reflection from the high-albedo roof below. The glass temperatures read on the east side were approximately 10 ºF higher from the suites on the south and west sides. We have not found anything in the mechanical or building enclosure design that would address this difference.

2.7 Findings.

On basis of our observations and measurements, we found the installed glass to be a blue-tinted, laminated, low-E glass, with SHGC in range 0.31-0.38 (including the measurement error).

We also found the glass installed in the four subject suites to be no different from the glass installed in adjacent suites, and in randomly selected fields on the [redacted]th floor and in the lobby.

Therefore, it is our professional opinion that the installed glass is the Viracon glass presented to us as originally specified for this project.

3. CONCLUSIONS

3.1 Summary

It is our professional opinion that the installed glass is the Viracon glass presented to us as originally specified for this project.

We reached this conclusion by 1) building and calibrating an apparatus capable of SHGC comparison, 2) verifying the reference sample by laboratory testing, 3) measuring the subject glass and comparing with the readings taken from the sky 4) comparing the results with the analogical readings taken from the reference sample.

The diagnostic work has led to the determination of the SHGC 0.31-0.38. We effectively confirmed the glass installed in the building is the one which was presented to us as the one originally specified by the architects.

3.2 Further Assessment/Testing

Based on the outcome of our findings, no additional testing and assessment will be required to identify the SHGC of the glass.

3.3 Final Remarks

This document has been prepared to assist you in finding the SHGC of the glass panes installed in the specified four office suites. The comments contained in this report are not to be viewed as being fully comprehensive in nature, but are representative of observed conditions. We have no other direct knowledge of (and offer no warranty regarding) any concealed conditions that may subsequently affect the performance of the various building systems beyond what was revealed during our site visit.

We reserve the right to alter or amend our comments regarding these items if new circumstances associated with the condition of the project site or materials are brought to light by further investigations at a later date. If you have any questions regarding these observations or our general conclusions, please contact me at your earliest convenience at (786) 877-7108.

We thank you for your confidence in Building Enclosure Consulting LLC.

Karol Kazmierczak AIA,ASHRAE,CSI,CDT,LEED-AP, NCARB
Senior Building Science Architect

APPENDIX A:
Scope of Services