SHADING COEFFICIENTS AND U-FACTORS FOR THE NATURAL LIGHTING COMPANY 4' BY 4' PASSIVE DAYLIGHTING SYSTEM MODEL NLSM 5252 SKYLIGHT FOR TUCSON ELECTRIC POWER COMPANY

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OUTLINE

1.0 Introduction

To determine the energy loss or gain through a fenestration system, it is necessary to know the heat transfer coefficients of the system in question. Using the U-factor, the Shading Coefficient (SC), the area, the orientation, and the weather characteristics for the geographical location, the heat gain or heat loss of the fenestration system in question can be determined.

The Shading Coefficient and U-factor of a window or skylight can generally be determined theoretically or experimentally. The accuracy of the theoretical method depends upon the complexity of the fenestration unit. The experimental method is considered more accurate than the theoretical method because the test is done on an actual sample of the fenestration unit, under typical operating conditions.

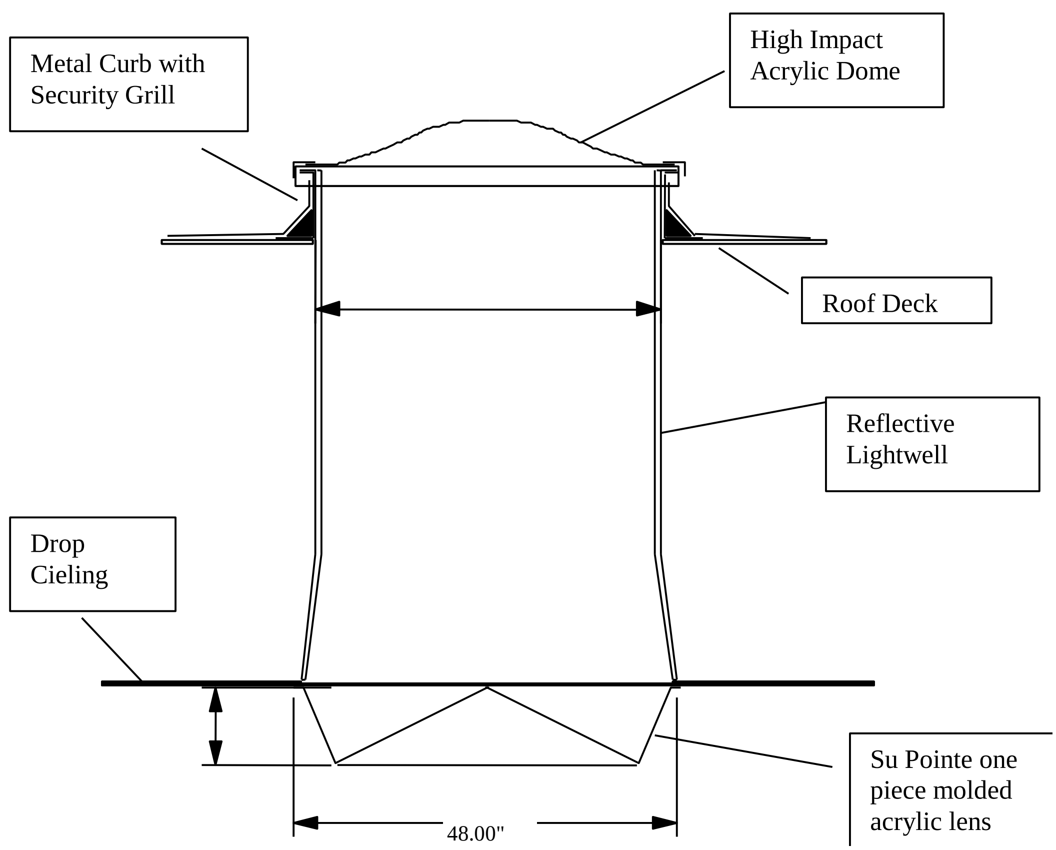
This report describes the test methods used and the results obtained during tests run to determine the Shading Coefficients of one NLC passive daylighting system for simulated solar altitude angles ranging from 0 degrees (sunrise) to 90 degrees (high summer sun) at ten degree intervals. The solar altitude angles were set by having the solar calorimeter track the sun on the horizontal (surface-solar azimuth angle=0) and then adjusting the calorimeter tlit angle. The Shading Coefficients were measured without the drop shaft since it would not be possible to mount it on the calorimeter. The measured values were then adjusted to account for the 8' drop shaft- The U-factors were determined for two conditions, heat flow up (winter) and heat flow down (summer) by analyzing the frame and air spaces created by the daylighting system, including the inner diffusing lens and the drop shaft. The drop shaft was assumed to be 8' in length. All testing described and results given in this report were completed in Tempe, Arizona during February and March of 1998.

2.0 Product Description

The NLC passive daylighting system consisted of an outer polycarbonate "bubble" with an inner layer of clear plastic which created a dead air space below the dome. The bottom internal material was a white diffusing acrylic lens with another layer of clear plastic above it. The clear plastic also created another dead air space. The upper (outer) dome and the inner lens and separated by a 8' drop shaft which is lined with a reflector and insulated.

2.1 NL-SM 5252 Cross-Sectional Drawing

Fig. No.1
Cross Sectional Drawing of the NL-SM 5252 Passive Daylighting System
(Drawing Provided by Natural Lighting Co., Inc.)



3.0 U-factor Calculation Procedure

The U-factor for the NL-SM 5252 skylight with the 8' drop shaft and inner lens was calculated for two heat flow conditions, The first condition was heat flow up and the second was heat flow down. The method used to determine the U-factor was to analyze each air space individually and determine it's resistance following the procedure in the Housing Research paper No. 32, The Thermal Insulating Value of Airspace's. Then, by combining the resistance of each air *space, the outer* and inner surface resistances, the total resistance is found. The inverse of the total resistance gives the U-factor.

4.0 U-factor Results

The U-factors for both conditions are given below in Table No. 1.

Table No. I- Calculated U-factors

Sample Description	U-Factor
NL-SM 5252 Skylight (Heat Flow Up)	0.35
NL-SM 5252 Skylight (Heat Flow Down)	0.33

5.0 Shading Coefficient Test Procedure

The Shading Coefficient of the NL-SM 5252 skylight was measured at ten degree intervals of the solar altitude angle from 0 degrees to 90 degrees by adjusting the orientation (surface-solar azimuth = 0) and tilt of the calorimeter. The water-flow solar calorimeter is motorized and computerized so that the tracking is done automatically using Opto 22 Mistic Control hardware. The solar radiation falling on the aperture is measured with an Epply PSP solar radiometer which is connected to the Opto 22 system through an analog input module.

The objective of the test is to determine the Shading Coefficient (SC) of the product which is mounted on the face of the calorimeter. The Shading Coefficient is determined by measuring the Solar Heat Gain Coefficient (SHGC) of the product in question and then dividing that by the SHGC of the ASHRAE reference glazing which is 1/8" clear double strength single glazing.

The flow rate is measured with a Flow Measurement Systems axial turbine flow meter which is connected to the Opto 22 hardware through a pulse input module. The temperature rise of the water across the each calorimeter is measured with a fifteen-junction thermopile which is connected to a calibrated amplifier and then to another Opto 22 analog input module with a range of O to 100 mV. The inside and outside box temperatures are measured with 17 thermocouples each which are averaged electrically to determine the average temperatures and then connected to the Opto 22 system with a type T analog input module.

The inside air temperature is measured with a thermocouple which is shielded from long-wave radiation and solar radiation. The thermocouple is first dipped into a low emittance coating and then placed in the center of a copper tube which has also been dipped into the low eminence and reflective coating. Again, the thermocouple is connected to the Opto 22 system with an analog input module for type T thermocouples.

Using the Opto 22 data input modules and system in combination with the computer, data is measured on a one second interval and averaged every 20 seconds, The qnet (Btu/hr, $ft^{2)}$ for the calorimeter is determined and dividing by the incident solar radiation to determine the SHGC. The Shading Coefficient is then determined by dividing the SHGC of the product in question by the SHGC of the ASHRAE reference glazing, The qnet calculation includes any heat gain or loss across the calorimeter wall and back as well as the glazing configuration. The final Shading Coefficient values are determined by averaging the data over the test period for the condition in question after equilibrium has been reached,

6.0 Shading Coefficient Test Results

The Shading Coefficient test results are shown below in Fig. No. 1.

4' x 4' Natural Lighting Skylight
Shading Coefficient Test Results

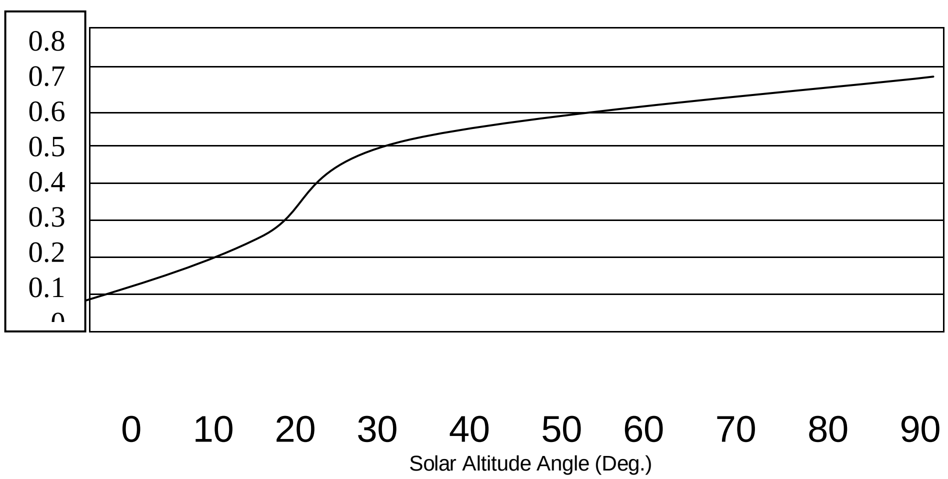


Figure No. 1 - **Measured Shading** Coefficients w/o Drop **Shaft**

6.1 Sample Calorimeter Test Data

Figure No. 2, below, shows the typical data measured during a calorimeter measurement of Shading Coefficients en February 28, 1998. The first data line (top down) is the incident solar radiation value, the second data line is the wind speed, the third is the outdoor temperature and the bottom data line is the Shading Coefficient. Note that the first hour's data is on dear dssg (double strength single glazing) alone, which is tun for reference purposes.

NLSM 4' by 4' Skylight
30 Degree Incident Angle

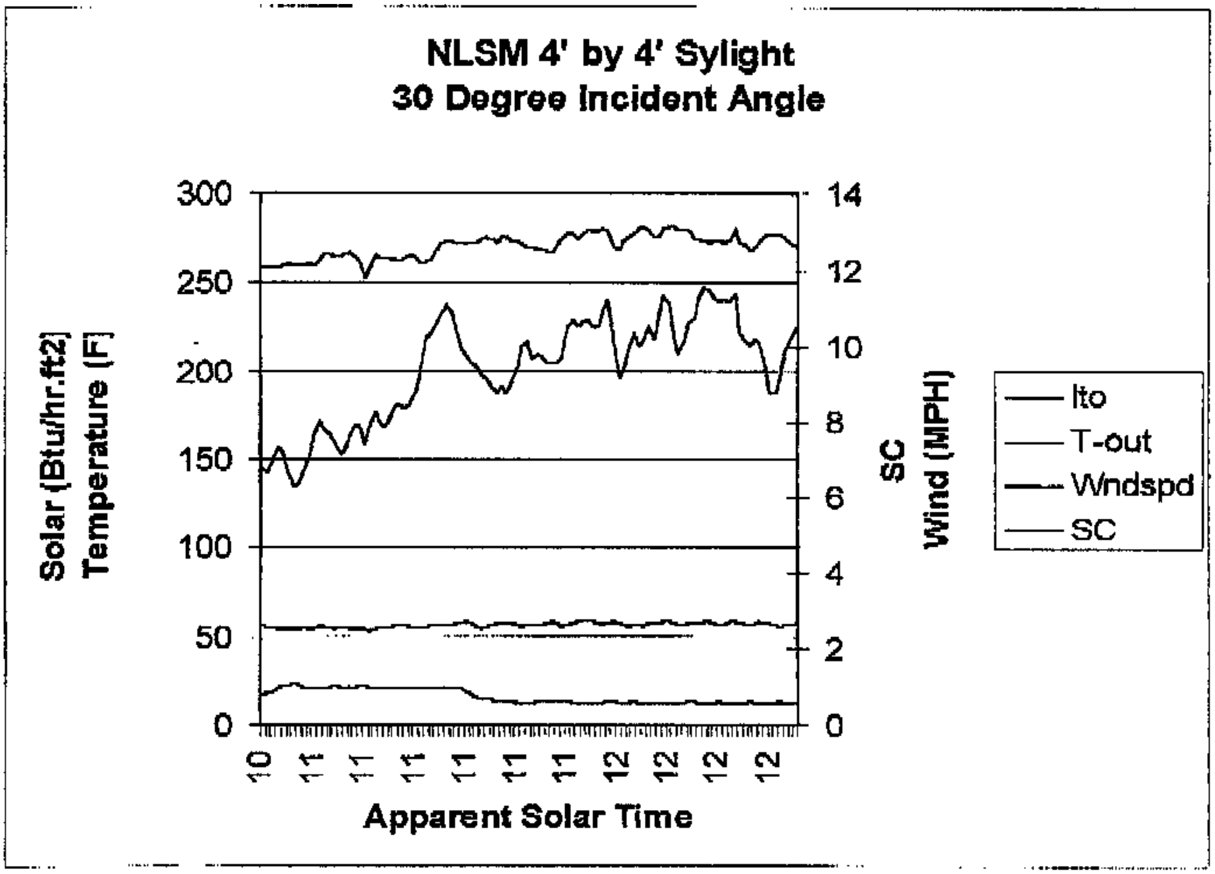


Fig. No. 2 - Sample Calorimeter Test Data

<u>7.0 Shading Coefficients Adjusted for 8' Drop Shaft</u>

The Shading Coefficients that were measured using the water-flow solar calorimeter were done without the 8' drop shaft since it could not be mounted on the calorimeter. Because the standard installation of the Natural Lighting skylight generally includes the 8' drop shaft, the measured values have been adjusted using data found in the ASHRAE Handbook of Fundamentals. The adjusted Shading Coefficients for the skylight with the 8' drop shaft are shown below in Fig, No. 3.

4' x 4' Natural Lighting Skylight Adjusted Shading Coefficients With 8' Drop Shaft

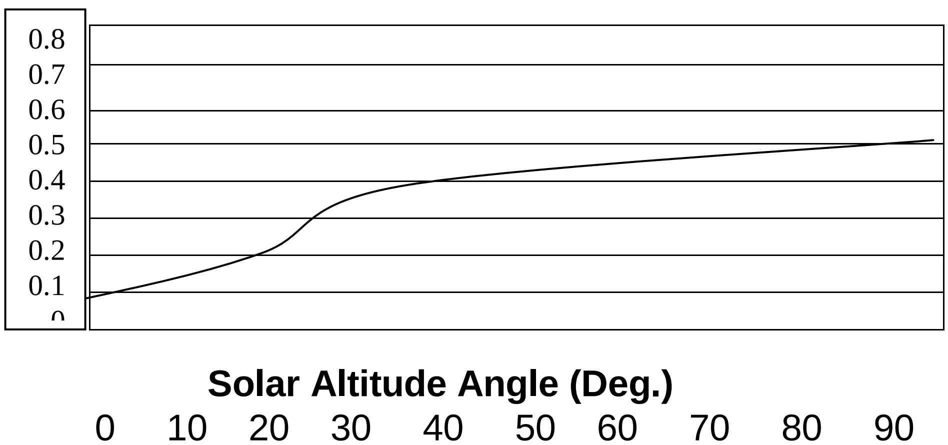


Fig No. 3 - Shading Coefficients for Skylight With for 8' Drop Shaft

8.0 Photograph of NL-SM. 5252 Skylight Mounted on Solar Calorimeter

9.0 Statement of Warranty

The foregoing test report contains only findings and results arrived at after employing the specific test method listed above. It does not constitute a recommendation for or endorsement of the product or material tested, Tait Solar Co., Inc. warrants only that the tests have been performed upon the samples furnished by the client. It is the client's responsibility that the product furnished is representative of the product line.

Respectfully submitted,

Tait Solar Co. Inc.

David B. Tait, C.E.M., President