Contract

Validation of WINDOW 6 and THERM 6 for Use in Determining the Solar Heat Gain Coefficients and U-Factors of Complex Glazing Systems Research Project

NFRC Project Number: 07-101-DR1

Submitted to:
NFRC Research Subcommittee

April 16, 2008

Submitted by: William C. duPont/Sunergy Consulting

BACKGROUND:
An upgrade to the software specified by NFRC 100 and NFRC 200, WINDOW 6 and THERM 6, is currently under development by Lawrence Berkeley National Laboratory (LBNL). Some of the new features in this software are the capability to calculate the SHGC and U-Factor of glazing and shading systems including woven shades, Venetian blinds, and fritted glass.

The recently approved *NFRC Software Approval Guidelines* state that the "vendor shall establish that the software tool is accurate by comparing the results, if possible, to available reference standards, test results, and advanced computer modelling." Although previous research projects have generated some of the data needed to perform comparisons among WINDOW 6 and THERM 6, solar calorimeter, and hot box test results, additional SHGC and U-factor test results are needed. In addition, it would be worthwhile to perform comparisons of simulated and tested performance characteristics of some simple glazing systems to increase our confidence in rating all types of products using WINDOW 6 and THERM 6.

This proposal has been modified based on revisions provided by the NFRC Membership at the NFRC Research Subcommittee Meeting on March 3, 2008. Some of these revisions are mandatory.

OBJECTIVES:
Sunergy Consulting, with support from Ross McCluney/Sun Pine Consulting, proposes to perform and coordinate the data collection, research, and testing specified herein to validate the new features within WINDOW 6 and THERM 6 as requested by the recent RFP solicited by the NFRC Research Subcommittee (07-101-DR1). As Sunergy Consulting does not have facilities to perform the tests required by this research project, all testing specified in this proposal will be separately contracted by the manufacturer of the test specimen, Sunergy Consulting and/or NFRC with the appropriate testing laboratories, and with the guidance of the Project Monitoring

Task Group (PMTG). In addition to these new test results, Sunergy Consulting will attempt to utilize the results from previous testing and advanced computer simulation with the goal of checking and evaluating WINDOW 6 and THERM 6. For the purposes of this proposal, the entire contractual team, including Sun Pine Consulting will be identified as "Sunergy Consulting." The résumés of the proponents of this project are attached.

Sunergy Consulting will gather and generate SHGC and U-Factor test data for comparison with the results of simulations of selected complex glazing systems using WINDOW 6 and THERM 6. The first task will be to gather any pertinent SHGC and U-Factor test results and advanced computer simulation results from previous research projects (e.g., ASHRAE and NFRC), and determine if it is appropriate for comparison to WINDOW 6 and THERM 6 results. The second task will be to select and test actual windows in NFRC 201 solar calorimeters and NFRC 102 accredited thermal chambers for comparison with WINDOW 6 and THERM 6 simulation results. Finally, the results from solar calorimeter and hot box testing will be compared with WINDOW 6 and THERM 6 simulation results and the reasons for any differences will be identified and explained where possible.

Sunergy Consulting will provide recommendations in the final report as to which fenestration attachments and product types can be adequately simulated using WINDOW 6 and THERM 6 and which cannot. Sunergy Consulting will include suggested modifications to improve to the software, where appropriate.

SCOPE:

This research project consists of four tasks. Part of the first task is to gather existing test and advanced computer simulation results from manufacturers or previous research projects, and evaluate the quality, accuracy and compatibility of those results for comparison with the results from WINDOW 6 and THERM 6. The compilation of a list of alternate simulation methodologies is the other objective of the first task. The second task is to perform actual SHGC and U-Factor tests of a few simple and all of the new complex glazing and shading systems, and to simulate the performances of those systems with WINDOW 6 and THERM 6 (See Tables 1 for SHGC and 2 for U-factor specimens in Annex). The third task is to compare the results from the literature search and actual testing to the SHGC and U-Factor results from WINDOW 6 and THERM 6 to ascertain the accuracy of WINDOW 6 and THERM 6. The final task is to develop a peer-reviewed technical paper for approval and publication (i.e., ASTM, ASHRAE). A more detailed description of these tasks follows:

Task 1a – Compile and Evaluate Existing SHGC and U-Factor Test Results:
Sunergy Consulting will perform a comprehensive literature search to gather additional SHGC or Shading Coefficient (SC) test results, and U-Factor test results for all of the test specimens identified in Tables 1 and 2. We will also acquire, where possible, unpublished test results and advanced computer simulation results from research and other laboratories and evaluate the accuracy and suitability of those results for use in this project. In addition to the actual test results, as much information as possible will be compiled about the test specimens, test apparatus and methodology, calibration procedures and accuracy of the measurements. All of the gathered information and test results will be evaluated for their suitability in making direct comparison to results generated by WINDOW 6 and THERM 6.

Task 1b – Describe Existing Methods of Calculating SHGC and U-Factors:
Sunergy Consulting will list and briefly summarize other currently available methodologies or methods under development for calculating the SHGC and U-Factor of the specimens listed in Tables 1 and 2. The intent is to identify any other simulation methodologies that may be used to determine the SHGC and U-Factor results of the types of specimens in Tables 1 and 2, which may generate results that are different from WINDOW 6 and THERM 6.

Task 2a – Identify and Procure Test Specimens in Tables 1 and 2:
Sunergy Consulting will develop a list of test specimens representing the glazing and shading systems in Tables 1 and 2. We will attempt to use as many glazing systems as possible from the *NFRC Research Project Revision of Standard Spectral Weighting Function for Calculation of Solar Optical Properties and Solar Heat Gain*. Sunergy Consulting will provide instructions on how each test specimen will be installed in the solar calorimeter and hot box. A list of test specimens, installation instructions and laboratories will be submitted to the Project Monitoring Task Group (PMTG) for review and approval before testing commences. After the test specimen lists and installation instructions are finalized, Sunergy Consulting will procure the test specimens, and send them to the appropriate testing laboratories. Sunergy Consulting is responsible for the test specimen installation and configuration during the test. The NFRC Membership will be solicited to donate as many test specimens as possible.

Task 2b – Perform SHGC and U-Factor Tests:
SHGC tests will be performed by at least one NFRC 201 Accredited Laboratory. U-Factor tests will be performed by at least one NFRC 102 Accredited Laboratory, and at least two specimens will be tested by four different NFRC 102 Accredited Laboratories.

As previously mentioned, all testing will be performed by laboratories under contract with Sunergy Consulting and/or NFRC. Each laboratory will be visited by a representative from Sunergy Consulting to witness at least one test of a specimen from this project. The laboratories will be instructed to provide all of the raw measured and calculated data from NFRC 102 and NFRC 201 tests in electronic format.

Task 2c – Perform SHGC and U-Factor Simulations Using WINDOW 6 and THERM 6:
With the assistance of LBNL, and an NFRC Accredited Simulation Laboratory, Sunergy Consulting will calculate the SHGC and U-Factor of all the test specimens represented in Tables 1 and 2. Each specimen shall be simulated in a configuration that is as close as possible to the configuration in which it is tested. Any assumptions not covered by NFRC 100, NFRC 200, or the NFRC Simulators Manual shall be fully documented.

Task 3 – Compare and Evaluate SHGC and U-Factor Results:
Sunergy Consulting will compile the results from the literature search, the tests and the simulations using WINDOW 6 and THERM 6. The suitability of comparing the measured results directly with results generated by WINDOW 6 and THERM 6 will be evaluated for each case. Those measured results deemed to be suitable will be used to help determine the accuracy of WINDOW 6 and THERM 6 for the relevant test specimens represented in Tables 1 and 2. Sunergy Consulting will attempt to identify and explain any discrepancies between

WINDOW 6 and/or THERM 6 simulation results and measurement results. If possible, Sunergy Consulting will suggest modifications to improve the software. Finally, Sunergy Consulting will provide a recommendation to the NFRC Software Approval Subcommittee as to which glazing and shading systems in Tables 1 and 2 can have their SHGC or U-Factor accurately computed using WINDOW 6 and THERM 6.

Task 4 – Write and Submit Status Reports and Peer-Reviewed Paper for Publication: During the course of the project, Sunergy Consulting will deliver written progress reports to the PMTG, and prepare and deliver presentations for each NFRC Research Subcommittee Meeting. At the completion of the project, Sunergy Consulting will develop a paper (or papers) describing the research project and conclusions for submission to a peer-reviewed journal such as published by ASTM or ASHRAE. Any papers will also be submitted for review and approval by the PMTG before publication.

DELIVERABLES AND DURATION:

The deliverables and timelines for each task are described below. Status reports will be submitted to the PMTG before each NFRC Research Subcommittee Meeting over the duration of the project. The final report is expected to be delivered eleven months after the project is initiated. In addition, a technical paper will be submitted to one of the peer-reviewed publications (i.e., ASHRAE Transactions, Solar Energy, etc.) within 3 months of the delivery of final report.

Compile and Evaluate Existing SHGC and U-Factor Test Results (Task 1a)

- List of test reports, advanced computer simulation results, research projects or other sources of information containing SHGC and U-Factor test results for windows and/or glazing systems similar to those identified in Tables 1 and 2, including an evaluation of each source for their suitability in making direct comparisons with WINDOW 6 and THERM 6 results.

Duration: *Three Months*

Describe Existing Methods of Calculating SHGC and U-Factors (Task 1b):

- Provide a list and a description of references, research projects or other sources of information containing alternate means of calculating SHGC and U-Factors of glazing and shading systems represented in Tables 1 and 2.

Duration: *Three Months (Concurrent with Task 1a)*

Identify and Procure Test Specimens in Tables 1 and 2 (Task 2a):

- List and describe actual glazing and shading system test specimens represented in Tables 1 and 2 for approval by the PMTG.
- Document installation instructions for each test specimen.
- Provide a list identifying which laboratories will test each test specimen.

Duration: *Two Months (Concurrent with and completed before Task 1)*

Perform SHGC and U-Factor Tests (Task 2b):

- Provide SHGC test reports for each test specimen from each NFRC 201 testing laboratory.

- Provide U-Factor test reports for each test specimen from each NFRC 102 testing laboratory.

Duration: *Seven Months*

Perform SHGC and U-Factor Simulations Using WINDOW 6 and THERM 6 (Task 2c):

- Calculate SHGC of each test specimen calculated using WINDOW 6 and THERM 6.
- Calculate U-Factor of each test specimen calculated using WINDOW 6 and THERM 6.

Duration: *Seven Months (Concurrent with Task 2b)*

Compare and Evaluate SHGC and U-Factor Results (Task 3):

- Write a comparison and evaluation of the tested SHGC and U-Factor of each specimen with the SHGC and U-Factor calculated using WINDOW 6 and THERM 6.
- Provide explanations, where possible, for any discrepancies between the test and simulation results, and recommendations to the software.
- List the complex shading and glazing systems that can be accurately simulated using WINDOW 6 and THERM 6.

Duration: *Two Months*

Write and Submit Peer-Reviewed Paper for Publication (Task 4):

- Develop a peer-reviewed technical paper for approval and publication.

Duration: *Three Months*

COST:

Labor	Testing and Simulation[1]	Material	Total
$48,400	**$80,000**	**$4,000**	**$132,000**

[1] Based on 26 SHGC Tests, 20 U-Factor Tests, and 26 simulations

NOTES:

(i) The total cost of the research project shall not exceed $132,400 without authorization from the NFRC Board of Directors. Although this proposal attempts to estimate the individual costs associated with labor, testing and materials, these estimates shall not be considered to be fixed or maximums as long as the total cost of the research project does not exceed the authorized total cost.

(ii) Material costs shall be reimbursed to Sunergy Consulting within thirty days of submitting the invoice and receipt.

(iii) The entire $132,400 is being requested from NFRC. No funding is being sought from other sources, although LBNL's expected contribution may be significant enough to be considered a donation.

(iv) Donation of test specimens, the measured optical properties of those test specimens, and SHGC and U-factor tests will be solicited from the NFRC membership, which will reduce estimated material and testing costs.

(v) Other than facilitating funding and guidance from the PMTG and NFRC Membership, NFRC staff assistance will be requested to negotiate and pay

directly (not via research contractor) contracts to perform tests and simulations with laboratories.

RECOMMENDED PAYMENT SCHEDULE (Estimated Labor Cost Only, not material or testing):

30% at start of project (after contract is signed)
35% upon completion of Task 2a
15% upon completion of Task 3
20% upon delivery of peer-reviewed paper

QUALIFICATIONS OF THE PROJECT TEAM

Both William duPont and Ross McCluney have been active in NFRC, the NFRC Solar Heat Gain Subcommittee, and the NFRC Research Subcommittee since the organization's conception. We are involved in current research projects, and have participated in previous research projects with this organization. Résumés for both individuals are attached to this proposal.

REFERENCES:

NFRC 100-2004: Procedure for Determining Fenestration Product U-Factors, Silver Spring, MD (2004).

NFRC 102-2004: Procedure for Measuring the Steady-State Thermal Transmittance of Fenestration Systems, Silver Spring, MD (2004).

NFRC 200-2004: Procedure for Determining Fenestration Product Solar Heat Gain Coefficient and Visible Transmittance at Normal Incidence, Silver Spring, MD (2004).

NFRC 201-2004: Procedure for Interim Standard Test Method for Measuring the Solar Heat Gain Coefficient of Fenestration Systems Using Calorimetry Hot Box Methods, Silver Spring, MD (2004).

NFRC 06-103-DR1: Revision of Standard Spectral Weighting Function for Calculation of Solar Optical Properties and Solar Heat Gain, Silver Spring, MD (NFRC Research Project currently underway by Sunergy Consulting)

THERM 6: Lawrence Berkeley National Laboratory, Berkeley, California (Software currently under development).

WINDOW 6: Lawrence Berkeley National Laboratory, Berkeley, California (Software currently under development).

Annex A1
Proposed Test Specimens

Table 1 – List of Representative SHGC Test Specimens

Test Specimen Description	Glazing System Description	Frame Description	Comments
Simple Glazing Systems			
High SHGC and U-Factor	CLEAR_3.DAT	Metal [1]	
High LSG [2]	CLEAR_3.DAT + Low-E & CLEAR_3.DAT	Wood or Vinyl	
Low LSG	GRAY_6.DAT + Gold	Wood or Vinyl	
Double Clear	CLEAR_3.DAT & CLEAR_3.DAT	Wood or Vinyl	
Double-Pane Fritted Glass (Low Density [3])	CLEAR_3.DAT + WHITE FRIT & CLEAR_3.DAT	Wood or Vinyl	Frit Coating on Surface 2
Double-Pane Fritted Glass (High Density [4])	CLEAR_3.DAT + WHITE FRIT & CLEAR_3.DAT	Wood or Vinyl	Frit Coating on Surface 2
Interior Shading Systems			
Loose Weave Low Absorptance Woven Blind	CLEAR_3.DAT & CLEAR_3.DAT + Low-E	Wood or Vinyl	White Blind [5]
Loose Weave High Absorptance Woven Blind	CLEAR_3.DAT & CLEAR_3.DAT + Low-E	Wood or Vinyl	Black Blind [6]
Low Absorptance Venetian Blind (Closed)	CLEAR_3.DAT & CLEAR_3.DAT + Low-E	Wood or Vinyl	White Blind
Low Absorptance Venetian Blind (45 Degree)	CLEAR_3.DAT & CLEAR_3.DAT + Low-E	Wood or Vinyl	White Blind
Low Absorptance Venetian Blind (Open)	CLEAR_3.DAT & CLEAR_3.DAT + Low-E	Wood or Vinyl	White Blind
Between Glass Shading Systems			
High Absorptance Woven Blind	CLEAR_3.DAT & CLEAR_3.DAT	Wood or Vinyl	Black Blind
High Absorptance Woven Blind with Low-E	CLEAR_3.DAT & CLEAR_3.DAT + Low-E	Wood or Vinyl	Black Blind
Low Absorptance Venetian Blind (Closed)	CLEAR_3.DAT & CLEAR_3.DAT + Low-E	Wood or Vinyl	White Blind
High Absorptance Venetian Blind (Closed)	CLEAR_3.DAT & CLEAR_3.DAT + Low-E	Wood or Vinyl	Black Blind
Low Absorptance Venetian Blind (45 Degree) w/Wide Pane Spacing [7]	CLEAR_3.DAT & CLEAR_3.DAT + Low-E	Wood or Vinyl	White Blind
High Absorptance Venetian Blind (45 Degree) w/Wide Pane Spacing	CLEAR_3.DAT & CLEAR_3.DAT + Low-E	Wood or Vinyl	Black Blind
Low Absorptance Venetian Blind (Open) w/Wide Pane Spacing	CLEAR_3.DAT & CLEAR_3.DAT + Low-E	Wood or Vinyl	White Blind
High Absorptance Venetian Blind (Open) w/Wide Pane Spacing	CLEAR_3.DAT & CLEAR_3.DAT + Low-E	Wood or Vinyl	Black Blind

Test Specimen Description	Glazing System Description	Frame Description	Comments
Between Glass Shading Systems *(continued)*			
Low Absorptance Venetian Blind (45 Degree) w/Thin Pane Spacing [8]	CLEAR_3.DAT & CLEAR_3.DAT + Low-E	Wood or Vinyl	White Blind
High Absorptance Venetian Blind (45 Degree) w/Thin Pane Spacing	CLEAR_3.DAT & CLEAR_3.DAT + Low-E	Wood or Vinyl	Black Blind
Low Absorptance Venetian Blind (Open) w/Thin Pane Spacing	CLEAR_3.DAT & CLEAR_3.DAT + Low-E	Wood or Vinyl	White Blind
High Absorptance Venetian Blind (Open) w/Thin Pane Spacing	CLEAR_3.DAT & CLEAR_3.DAT + Low-E	Wood or Vinyl	Black Blind
High Absorptance Venetian Blind (Retracted) w/Thin Pane Spacing	CLEAR_3.DAT & CLEAR_3.DAT + Low-E	Wood or Vinyl	Black Blind
High Absorptance Woven Blind (Retracted)	CLEAR_3.DAT & CLEAR_3.DAT + Low-E	Wood or Vinyl	Black Blind
Exterior Shading Systems			
High Absorptance Sunscreen	CLEAR_3.DAT & CLEAR_3.DAT + Low-E	Wood or Vinyl	Black Screen

[1] High conductance frame with solar absorptance greater than 0.80.
[2] Light to Solar Gain Ratio (LSG) or T_{vis}/SHGC.
[3] Low density frit coatings cover a surface area less than 0.30 of the total glazed area.
[4] High density frit coatings cover a surface area greater than 0.70 of the total glazed area.
[5] White materials have a solar absorptance of less than 0.20.
[6] Black materials have a solar absorptance of greater than 0.80.
[7] Wide pane spacing indicates that the interior glazing cavity is greater than 12 mm wider than the slat width.
[8] Thin pane spacing indicates that the interior glazing cavity is less than 6 mm wider than the slat width.

Table 2 – List of Representative U-Factor Test Specimens

Test Specimen Description	Glazing System Description	Frame Description	Comments
Simple Glazing Systems			
High SHGC and U-Factor	CLEAR_3.DAT	Metal [1]	
High LSG	CLEAR_3.DAT + Low-E & CLEAR_3.DAT	Wood or Vinyl	
Low LSG	GRAY_6.AFG + Gold	Wood or Vinyl	
Double Clear	CLEAR_3.DAT & CLEAR_3.DAT	Wood or Vinyl	
Double-Pane Fritted Glass (High Density)	CLEAR_3.DAT + WHITE FRIT & CLEAR_3.DAT	Wood or Vinyl	Frit Coating on Surface 2
Interior Shading Systems			
Tight Weave Tight-Fit Blind [2]	CLEAR_3.DAT & CLEAR_3.DAT + Low-E	Wood or Vinyl	
Tight Weave Loose-Fit Blind [3]	CLEAR_3.DAT & CLEAR_3.DAT + Low-E	Wood or Vinyl	
Venetian Blind (Closed)	CLEAR_3.DAT & CLEAR_3.DAT + Low-E	Wood or Vinyl	
Venetian Blind (45 Degree)	CLEAR_3.DAT & CLEAR_3.DAT + Low-E	Wood or Vinyl	
Venetian Blind (Open)	CLEAR_3.DAT & CLEAR_3.DAT + Low-E	Wood or Vinyl	
Between Glass Shading Systems			
High Absorptance Woven Blind	CLEAR_3.DAT & CLEAR_3.DAT	Wood or Vinyl	
High Absorptance Woven Blind with Low-E	CLEAR_3.DAT & CLEAR_3.DAT + Low-E	Wood or Vinyl	
High Absorptance Woven Blind	CLEAR_3.DAT & CLEAR_3.DAT + Low-E	Wood or Vinyl	
High Absorptance Woven Blind	CLEAR_3.DAT & CLEAR_3.DAT	Wood or Vinyl	
Venetian Blind (Closed)	CLEAR_3.DAT & CLEAR_3.DAT + Low-E	Wood or Vinyl	
Venetian Blind (45 Degree)	CLEAR_3.DAT & CLEAR_3.DAT + Low-E	Wood or Vinyl	
Venetian Blind (Open)	CLEAR_3.DAT & CLEAR_3.DAT + Low-E	Wood or Vinyl	
Venetian Blind (Retracted)	CLEAR_3.DAT & CLEAR_3.DAT + Low-E	Wood or Vinyl	
High Absorptance Woven Blind (Retracted)	CLEAR_3.DAT & CLEAR_3.DAT + Low-E	Wood or Vinyl	
Exterior Shading Systems			
Sunscreen	CLEAR_3.DAT & CLEAR_3.DAT + Low-E	Wood or Vinyl	

[1] High conductance frame.
[2] Tight-fit indicates that the height and width of the window is less than 6 mm greater than the height and width of the blind in each dimension.
[3] Loose-fit indicates that the height and width of the window is more than 50 mm greater than the height and width of the blind in each dimension.