



National Fenestration Rating Council **REQUEST FOR PROPOSAL**

REQUEST FOR PROPOSALS (RFP) – 05-105-AR

TITLE: Complex Product VT Rating

Issue Date: May 14, 2007

Bidder Response Due Date: June 14, 2007

All bidders shall submit two copies of all bid proposals to the NFRC office on or before the 5:00 pm (Eastern Time) on due date at this address:

National Fenestration Rating Council
Attn: Ray McGowan
8484 Georgia Avenue, Suite 320
Silver Spring, Maryland 20910

All bidders will bid by the NFRC Agreement in the *2005 NFRC Research Manual, appendix G*. If government funding is used for the project then the bidder shall bid by form K requirements (staff will provide upon request).

BACKGROUND:

There are a number of complex shading (e.g., Venetian blinds and sunscreens) and glazing systems (e.g., dome skylights or glass block) that cannot be evaluated for Visible Transmittance (VT) using an NFRC standard. There are also still more complex daylighting systems (such as tubular daylighting devices, TDDs) needing a means for rating their illumination performance. Furthermore, the future promises an increasing variety of complex fenestration and daylighting systems, all requiring either total system or component VT ratings. NFRC would benefit from the development of a methodology to rate the VT for such complex products that would allow these products to be more completely and fairly compared. This research project will attempt to develop a methodology for determining the VT of complex glazing and shading systems, and TDDs.

OBJECTIVES:

Develop a methodology for determining the Visible Transmittance (VT) of complex shading and glazing systems. The project will seek to analyze a range of complex products using integrating sphere testing similar to that specified in ASTM E 1175, and ray-tracing computer simulation. This project will develop and evaluate a rating methodology for determining the VT of complex products. This methodology will be evaluated against alternate measurement methodologies, and



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will be compared with ray-tracing results to determine appropriate rating procedures for complex products.

Not all complex products are amenable to accurate ray-tracing evaluation, primarily due to the difficulty in obtaining accurate spectral and directional optical properties for all the components. It is expected that the successful bidder will select among all that are selected for evaluation a subset of complex fenestration systems deemed appropriate for ray-tracing evaluation. For these classes, both integrating sphere tests and ray-tracing simulations will be used to evaluate the same individual products. All the potential methodologies examined will be evaluated for accuracy and economic practicality, and these assessments will be included in the final report. This inclusion of a ray-tracing component in the current RFP should not be construed as a comprehensive assessment of ray-tracing as a methodology for rating complex systems for VT. Instead, this component of the research project intends to compare experimental results with ray-tracing analyses in a few cases, as a means of better understanding the complex optical processes involved.

The NFRC rating system provides data for whole products. Since dome skylights are often symmetrical along the vertical and horizontal axis, this research project will also investigate methodologies of determining the VT of these products without having to evaluate a complete assembly at the NFRC size, which may not fit completely into the 35" port diameter specified below for the integrating sphere test.

Finally, in the process of developing a VT rating system for TDDs, this research project will investigate the ramifications of rating TDDs at solar incident angles other than normal. NFRC currently rates the VT of all products with the incident direction of the light source at right angles to the plane of the glazing system.

SCOPE AND APPROACH:

This research project will consist of seven (7) tasks:

Task 1: Design Visible Light Transmittance Test Apparatus

1.A Selection of Sphere Diameter

Based on the analysis provided in a. the latest revision of "*Ratio of Port Size to Integrating Sphere Diameter*" an NFRC Background Paper by Dr. Ross McCluney, b. Goebel, David G., "*Generalized Integrating Sphere Theory*," *Applied Optics*, Vol. 6, 125- No. 1, January 1967, and c. Kessel, Jeffrey, "*Transmittance measurements in the integrating sphere*," *Applied Optics*, Vol. 25, 2752-, August 15, 1986, a rationale will be prepared justifying a selection of the smallest integrating sphere interior diameter capable of making measurements of complex product visible transmittance with a precision of better than $\pm 5\%$, for a selected entrance aperture size of no less than 35" in diameter (allowing for a 25" x 25" test article).



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1.B Design Integrating Sphere

Provide design and specification of an integrating sphere according to ASTM E 1175, the above technical papers, and industry standard practices for integrating spheres to perform photometric analysis of visible light transmittance, except as modified within this RFP. Deliver a description and justification of the selected design to the NFRC Project Monitoring Task Group (PMTG) for review and approval. The schematic diagram shown in Figure 1 is one general representation of a possible testing methodology. The selected design should include a means for shading the interior light sensor(s) from the entrance port so that all light reaching it must have been scattered at least once inside the sphere.

The selected sphere and its test article will track the sun together to ensure uniformity of solar radiation incident across the aperture. The tracking of the sun should be accurate to a tolerance of less than 3°. Include in the design an ability to track the sun so that the angle of incidence to the plane of the test article entrance aperture is other than 0° (normal) for a portion of the test period, ideally at angles off-axis of 30°, 45° and 60°, for example. The solar-surface azimuth angle of the test specimen should be maintained constant within 3° over the period of these off-normal incident angle tests.

The apparatus must be able to accommodate the installation of both round and square test specimens of a variety of sizes fitting within a 35” minimum diameter port in the sphere (allowing for a 25” x 25” test article). Since it is anticipated that baffles might be used to limit the field of view of the test specimen to the solar disk only, these baffles will have to be designed to expose each test specimen to the same solid angle surrounding the solar disk. The contractor should investigate various baffling geometries and arrangements and provide a rationale for the use or exclusion of baffled tubes to delimit the direct solar beam incident on the test specimen.

An alternative approach, more suitable for TDDs, would be to perform measurements with both sun and sky illuminating the test specimen on a clear day and the same with a direct beam occulting disk shading the test specimen. Due to the greater angular selectivity of commercial TDDs, however, illuminating them during test with both sun and sky illumination (no baffling) should be acceptable, if it can be assured through measurement that the incident diffuse sky and ground reflected component is a relatively small fraction of the direct beam irradiance. This can be determined, for example, by including a second photometric sensor near the aperture shadowed by its own sun-occulting disk. Subtracting this reading from the global normal illuminance gives approximately the direct normal illuminance. The remainder of the subtraction is the diffuse normal, thereby allowing a determination of the direct-to-diffuse illuminance ratio incident on the test specimen during the test.

If multiple apparatus configurations or methodologies are used to perform this research, the contractor shall compare their measurements on at least three identical test specimens



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and consider the usefulness and practicality of each suggested methodology for each type of complex product.

Task 2: Construct Visible Light Transmittance Test Apparatus

Construct an integrating sphere according to PMTG-approved specifications and design. Submit a report to the PMTG regarding experiences in constructing the integrating sphere including as-built drawings and photographs upon completion of this task. Include this documentation in the final report.

Task 3: Develop and Evaluate Calibration Protocol

Develop a calibration protocol for the integrating sphere apparatus utilizing known standards and best practices. Verify the calibration of the apparatus by demonstrating that it can accurately measure the VT of at least three non-complex reference samples having transmittances determined accurately and separately that cover the range of transmittance anticipated in this research project. The selection of these reference sample test specimens shall be approved by the PMTG. Document and evaluate the calibration methodology developed in the final report.

Task 4: Development of Test Method and Conduct Measurements of Test Specimens

4.A Selection of Test Specimens

Select at least 20 representative complex shading and glazing systems plus at least three TDDs to test with the new equipment and procedure. The PMTG must approve the test specimens prior to the actual tests. At least six of these products shall be homogenous, to allow for smaller samples to be sent for comparative testing with the LBNL integrating sphere transmissometer (*at LBNL's discretion*). Descriptions or diagrams shall be provided to the PMTG indicating how each type of test specimen will be installed and supported in the aperture of the integrating sphere.

4.B Measurement of Incident Solar and Visible Irradiation

One hemispherical solar pyranometer (full solar spectrum) and two hemispherical photometric sensors (visible spectrum only) shall be used to simultaneously measure the incident irradiation on the plane of the test specimens over the duration of each test. One photometric sensor shall be shielded from direct solar irradiation to measure the diffuse radiation. The ratio of their outputs shall be recorded and reported for each test measurement. The contractor shall be allowed to replace the shaded photometric sensor with a shaded pyranometer, if desired.



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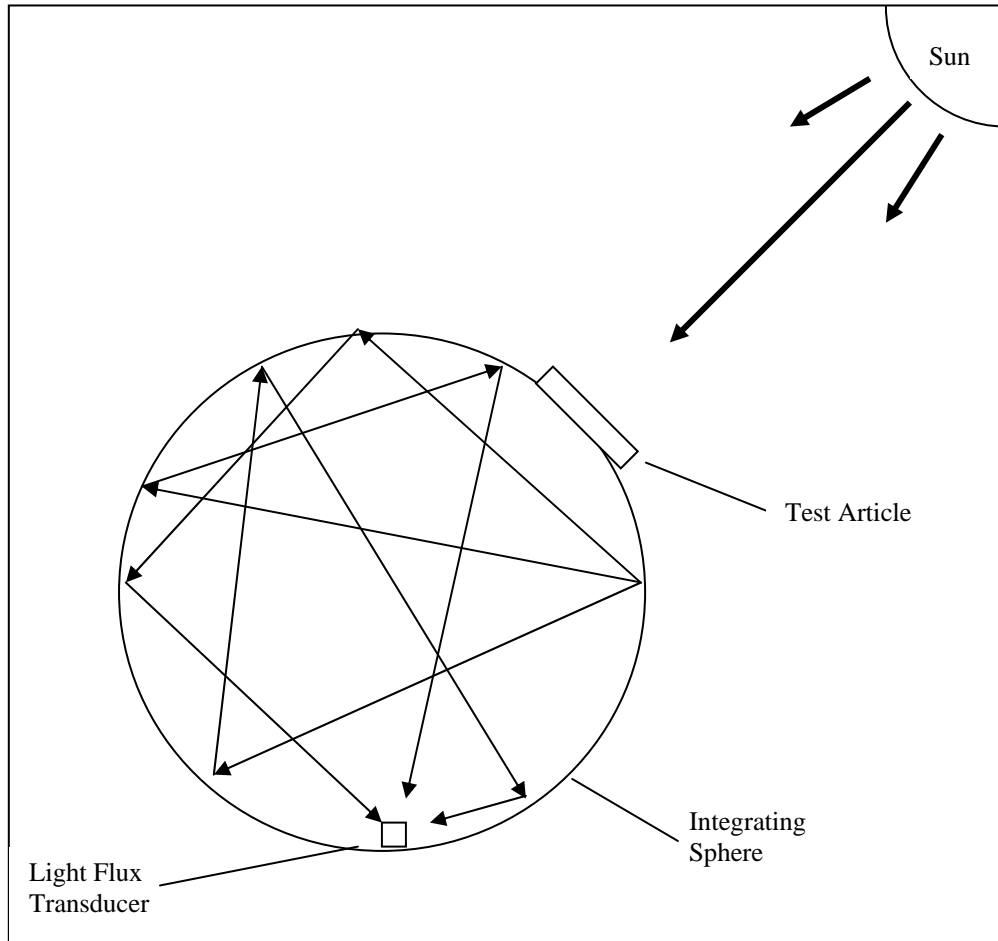


Figure 1: Schematic Diagram of ASTM E 1175 Integrating Sphere Apparatus

4.C Measurement of Visible Transmittance

The test methodology will likely involve measurements of the flux inside the sphere both before and after the test specimen is placed over the port. Typically, the specimen transmittance is calculated as the ratio of the sensor signal with the sample in the port to the average of that signal with the port empty before and after the specimen installation, multiplied by a correction factor to correct for the change in sphere efficiency resulting from the placement of the specimen in the entrance port. A description of the test methodology shall be included in the final report including any recommended revisions to ASTM E 1175. Measurements of each test specimen shall be made during the middle portion of clear days, when the sun is relatively high in the sky, for example at least 20° above the horizon.



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For certain contractor-selected samples, (selected with the approval of the project monitoring task group), including the TDD test article and at least one Venetian blind sample, measurements must be repeated at least three different angles of incidence on the entrance aperture of the test specimen (e.g., 30°, 45° and 60°). The effect of tube length (e.g., 14" tube diameter with 48" and 84" tube lengths) shall be investigated using off-axis testing. Top dome orientation (e.g., 0°, 45° and 90° solar-surface azimuths) shall also be investigated for non axially asymmetric domes using off-axis testing. The selected off-axis incident angle tests shall be approved by the PMTG based on justifications submitted by the Contractor.

4.D Dome Skylight Testing Methodology

Develop and explore methodologies to measure the VT of skylights with dome glazing that does not require that a full-sized product be installed in the apparatus. Document, justify, and evaluate this proposed methodology for inclusion in NFRC or ASTM methods.

Task 5: Conduct Ray-Tracing Simulations of Selected Test Specimens

The contractor shall recommend at least six of the 20 test specimens described above as being amenable to ray-tracing evaluation. The PMTG shall review and approve those selections. The contractor shall select a computerized optical ray-tracing computer program for use on this project, and ensure that personnel are properly trained in its use. Alternatively, the contractor shall subcontract with an optical engineer having expertise and experience in computerized optical ray-tracing¹. The contractor will develop a computerized optical ray-tracing methodology suitable for the samples selected for this task and evaluate the usefulness and feasibility of performing computerized optical ray-tracing on the selected products by performing ray-tracing simulations on those products deemed acceptable for this approach. Report on the findings of this evaluation. That report shall include problems encountered in determining the specific, optically significant geometry of the selected complex fenestrations and in obtaining the optical properties of their optically significant component parts. This will allow for comparisons of the visible transmittance values determined experimentally with the integrating sphere transmissometer in the contractor's facility, the LBNL integrating sphere transmissometer measurements already completed, and the computerized optical ray-tracing calculations.

Task 6: Conclusions and Recommendations

Based on the findings from the previous tasks, produce a final report detailing the research performed, the results and analysis, and proposed rating methods for NFRC to evaluate, aimed for possible adoption into the current rating system.

Task 7: Peer Review Paper

¹ Expertise in ray trace simulation of complex solar systems exists with Dr. Ross McCluney (under contract for technical services with the NFRC in 2007) and at LBNL, either of which may be consulted for advice on this task.



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Following NFRC acceptance of the final report, prepare a peer reviewed manuscript and submit to the PMTG and, following the approval of that group, for publication in a recognized national technical journal.

DELIVERABLES:

Task 1

Four months from the start of the project, present to the PMTG a proposed design for the integrating sphere that can ultimately accommodate shading, glazing, and tubular daylighting systems (with exit apertures equal to or less than 35" diameter) typically found within the NFRC program.

Duration: 2 months.

Task 2

Immediately following acceptance by the PMTG of the design, construct the integrating sphere utilizing the general design criteria of Task 1 plus any recommendations provided by the PMTG. Construction should be complete within six months after the acceptance of the design by the PMTG. Submit a report to the PMTG regarding experiences in constructing the integrating sphere including as-built drawings and photographs upon completion of this task.

Duration: 6 months.

Task 3

Upon completion of the construction of the integrating sphere, commence work to calibrate and validate the Large Integrating Sphere, the goal being to establish its credibility for use in VT measurements within the NFRC program. After the PMTG approves the use at least three reference samples, verify and report the calibration results from the apparatus.

Duration: 2 months.

Task 4

Select and test a selection of at least 20 representative shading and glazing systems covering a broad range of performance. At least six of these test specimens shall be homogenous to allow smaller samples to be tested using LBNL's integrating sphere for comparison (*at LBNL's discretion*). Report the results of comparisons of the visible transmittance values determined experimentally with the integrating sphere transmissometer in the contractor's facility with any other visible transmittance measurement results that might be available. In addition, report to the PMTG on proposed methodologies to measure the VT of dome skylights without having to test a full-size product.

Duration: 5 months.

Task 5

Report to the PMTG on the results of the computerized optical ray-tracing calculations. If possible, include both experimental and ray-tracing comparisons from other organizations or projects.



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Duration: 3 months (performed concurrently with Task 4)

Task 6

Upon completion of the construction of the integrating sphere apparatus and testing of the calibration standards and test specimens, a final report shall be written detailing the findings and results along with a recommendation of further research. The report shall include a recommendation of how to incorporate any new methodologies into the current NFRC rating program or reasons why one or more of the methods evaluated cannot.

Duration: 2 months.

Task 7

Prepare one or more manuscripts following acceptance of NFRC research report. Submit a draft for review to the PMTG, and the revised manuscript to a peer-reviewed technical journal.

Duration: 3 months

ESTIMATED COSTS

Labor	Material	Total
\$120,000	\$30,000	\$150,000

Note: Financial requirements exceeding \$150,000 will have to be met by non NFRC sources such as the bidder or other interested parties.

ESTIMATED DURATION:

20 months

PARTIAL PAYMENT SCHEDULE:

- 33% advance (after contract is signed)
- 15% upon completion of task 1
- 16% upon completion of task 2
- 16% upon completion of tasks 3,4, 5, and 6
- 20% upon completion of task 7 and RSC-RTC-Board approval

POTENTIAL CO-SPONSORS:

Fenestration manufacturers' in-kind contributions, California Energy Commission

SOLE SOURCING:



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None

TERMS:

Any prospective bidder shall submit a proposal that identifies the total cost of performing all the documented requirements in this RFP. Any terms of payment shall also be outlined in the proposal. A schedule outlining all RFP tasks shall be included with the bid submittal including all associated dates and times.

REFERENCES:

- McCluney, R. “*Ratio of Port Size to Integrating Sphere Diameter*” an NFRC Background Paper, 10 December 2006 draft.
- Goebel, David G., “*Generalized Integrating Sphere Theory*,” *Applied Optics*, Vol 6, 125-No. 1, January 1967
- Kessel, Jeffrey, “*Transmittance measurements in the integrating sphere*,” *Applied Optics*, Vol. 25, 2752-, August 15, 1986
- ASTM International. 2003. “ASTM E1175-87. (Reapproved 2003): *Standard Test Method for Photopic Reflectance, Transmittance, and Absorptance of Materials Using a Large Diameter Integrating Sphere*.” ASTM International, West Conshohocken, Pennsylvania.

NFRC RESOURCES:

NFRC Staff Labor: Not to exceed 25 hours.

NFRC Consultant Labor: Not to exceed 10 hours.

NFRC STAFF CONTACT:

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