National Fenestration Rating Council
REQUEST FOR PROPOSAL

Date: January 21, 2004
Title: Experimental U-Factor Research To Validate NFRC Simulation Procedure For Tubular daylighting Devices (TDD)
Due Date: **February 23, 2003**.

All bidders shall submit two copies of all bid proposals and shall be received by the NFRC office on or before the due date 5:00 pm (Eastern Time), at the address mentioned below:

Attn: Bipin Shah (Technical Director)
National Fenestration Rating Council
8484 Georgia Avenue, Suite 320
Silver Spring, Maryland 22091

BACKGROUND:

The TDD industry has been working with NFRC on establishing a thermal transmittance (U-factor) rating system based on a computer simulation procedure for their products for several years. Such a procedure has been approved and is being used to rate TDD products. However, this current simulation procedure has never been validated by physical testing. The current NFRC 102 "Test Procedure for Measuring the Steady-State Thermal Transmittance of Fenestration Systems" is used to test fenestration (including skylight) products at a vertical orientation (NFRC 102, 2002). The standardized test results obtained through NFRC 102 tests are compared with simulation results for the purpose of validation so that the simulated U-factors may be used to rate the associated products. Currently, there is no approved NFRC test procedure for testing TDD products at typical conditions, while the approved simulation procedure addresses these conditions as shown in Figure 1 (Figure 17 on page 7-19, NFRC 100:2001, 2002). These conditions include horizontal installation on a roof deck located above an attic space. The attic is not conditioned, and the roof is not insulated while the ceiling is insulated with a 10-inch surround panel material (mostly extruded polystyrene, EPS, is used). An experimental U-factor measurement procedure would be beneficial to validate and improve the currently adopted simulation procedure under these conditions.

OBJECTIVES:

The objective of this project is to develop a standard test method and procedure to measure the thermal transmittance (U-Factor) of TDD products under typical residential application conditions. A TDD test apparatus shall be designed and constructed. Calibration on the test apparatus heat loss and specimen surface heat transfer coefficients shall be conducted. Representative manufacturer's TDD products shall then be tested using this test apparatus. These products also shall be simulated following the NFRC simulation procedure for TDD products. Detailed comparison study on heat flow, temperatures, surface heat transfer coefficients, and U-factors shall be conducted between experimental and simulation results. Conclusions and recommendations shall be drawn and proposed to NFRC for the validation and improvement of the TDD U-factor simulation procedure.

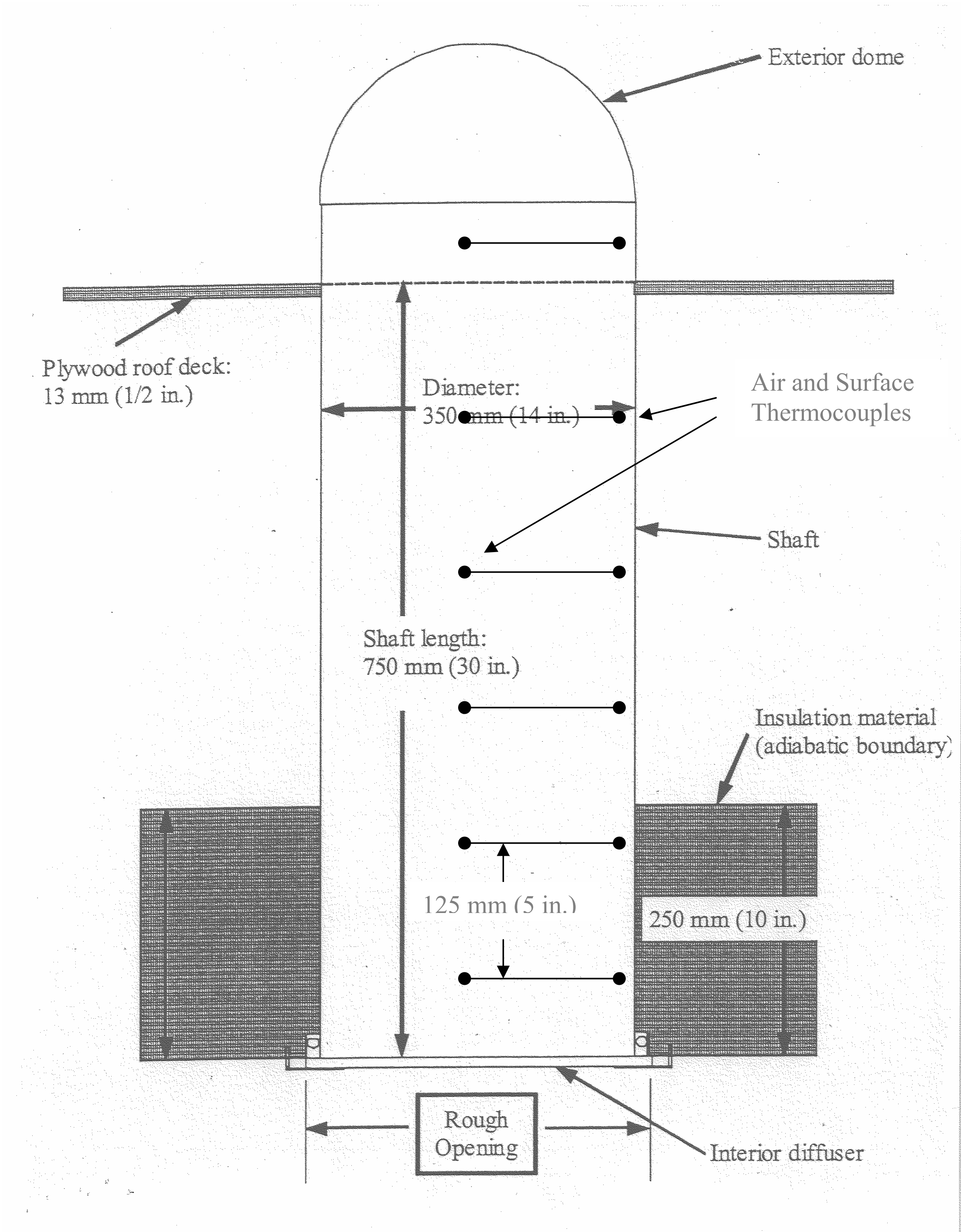

Figure 1 The Simulation Schematic of a Tubular Delighting Device (Figure 17, NFRC 100:2001)

SCOPE:

To achieve the main objective of validating and improving the NFRC TDD U-factor simulation procedure, this research project needs to establish a viable test procedure. A test apparatus in accordance with the test method needs to be designed and constructed. Calibrations on the test apparatus are also important for testing TDD products. Specifically, the scope of this research work includes the following:

1. ***TDD test apparatus:***

   A test apparatus shall be designed and constructed to measure the thermal transmittance of TDD products at ASHRAE standard winter conditions. The test apparatus includes three major spaces to install the test specimen and establish steady-state test conditions. They are: a) guarded metering chamber on the bottom of the test apparatus; b) attic plenum space with the tube of the test specimen installed vertically in a 10-inch thick surround panel (EPS material) on the bottom and a half-inch plywood roof deck on top (residential applications); c) weather chamber on top of the roof deck with the dome of the test specimen installed.

   Another TDD specimen installation that simulates commercial applications shall be designed and constructed by changing part b) to: attic plenum space with the tube of the test specimen installed vertically in a half-inch plywood ceiling on the bottom and a 10-inch thick surround panel (EPS material) roof deck on the top. For both installations, 6-row air and surface thermocouples shall be placed inside the tube with the first row at the bottom of the tube, and 5-inch apart for each row from the first, as shown in Figure 1.

   The guarded metering chamber provides natural convection conditions to the bottom of the tube with or without a diffuser. A metering chamber baffle is installed 6 inches away from the surround panel. Total energy input to all heaters and fans inside the metering chamber shall be measured and recorded.

   The attic plenum space shall be conditioned to 0°F and natural convection conditions shall be established. The heat transfer through the tube sidewall shall be obtained using the measured surface temperature difference and tube material thermal conductivity value. The material thermal conductivity of the surround panel and plywood roof deck shall be measured using either an ASTM C 518 guarded hot plate or C 177 heat flow meter apparatus.

   The weather chamber shall contain a blower, an evaporator of the refrigeration system, and a baffle to provide ASHRAE standard outdoor forced convection winter conditions of 15 mph wind and 0°F air temperature.

2. ***TDD test procedure:***

   A TDD test specimen shall be installed in the test apparatus with the dome on top of the roof deck, and the tube between the top surface of roof deck and the bottom surface of surround panel. If the specimen has a diffuser, install the diffuser on the bottom of the tube. Installation includes sealing and thermocoupling. Then close the test apparatus and establish test conditions at each space: a) guard space of 70°F and natural convection; b) metering space of 70°F and natural convection; c) attic plenum space of 0°F and natural convection; d) weather space of 0°F and forced convection. Control and maintain these conditions for a minimum of an 8-hour steady-state period and measure and record all temperatures, power inputs, metering chamber relative humidity and wind speeds of the metering chamber, attic plenum and weather chamber.

The U-factor of the TDD test specimen is the total power input to the metering room (less any metering chamber wall and surround panel flanking losses using calibration correlations) divided by the product of the tube opening projected area and the air temperature difference between the metering chamber and the weather chamber.

3. ***Heat loss and CTS calibrations:***

Under standard ASHRAE winter design conditions, the TDD test apparatus shall be calibrated for any box wall and flanking loss. Install a full surround panel and plywood roof deck with no openings in the test apparatus. Use 1-inch EPS foam boards and install a four-sided well in between the roof deck and the surround panel. Following the test procedure outlined in section 2, conduct six calibration tests with reference to ASTM C 1199 to obtain chamber wall heat loss and surround panel flanking loss.

A non-planar (pyramidal shape) CTS (Calibrated Transfer Standard) shall be constructed and used for specimen surface heat transfer coefficients calibration. Together with this CTS, a four-sided 1-inch EPS foam well in the attic space and a single layer diffuser shall be used for the surface coefficients calibration. Results include CTS exterior surface coefficient, four-sided well attic surface coefficient and interior diffuser surface coefficient.

4. ***Testing of representative TDD products:***

The following representative TDD products will be tested:

Table 1 TDD Test Specimen Matrix for Residential Applications

No.	Diameter (inches)	Dome*	Tube Interior	Diffuser Material	Diffuser Layer
1	14	Acrylic, single	Emissivity 1	Acrylic	Single
2	14	Acrylic, single	Emissivity 2	Acrylic	Single
3	14	Acrylic, single	Emissivity 1	Acrylic	Double
4	14	Acrylic, single	Emissivity 2	Acrylic	Double
5	21	Acrylic, single	Emissivity 1	Acrylic	Single
6	21	Acrylic, single	Emissivity 2	Acrylic	Single
7	21	Acrylic, single	Emissivity 1	Acrylic	Double
8	21	Acrylic, single	Emissivity 2	Acrylic	Double
9	14	Acrylic, double	Emissivity 1	Acrylic	Single
10	14	Acrylic, double	Emissivity 2	Acrylic	Single

- Polycarbonate assumed to have same thermal property as Acrylic

Table 2 TDD Test Specimen Matrix for Commercial Applications

No.	Diameter (inches)	Dome	Tube Interior	Diffuser Material	Diffuser Layer
11	14	Acrylic, single	Emissivity 1	Acrylic	Single
12	21	Acrylic, single	Emissivity 1	Acrylic	Single
13	14	Acrylic, double	Emissivity 1	Acrylic	Single

5. ***Simulation of representative TDD products:***

Following the current NFRC simulation procedure, NFRC 100, simulate 13 TDD products as listed in Tables 1 and 2.

6. ***Comparison study of test and simulation results:***
   Using U-factor results obtained from both testing and simulation for these 13 TDD products, conduct a comparison study including statistical analysis. Detailed comparison on surface heat transfer coefficients obtained from testing and standardized values used for simulation shall also be conducted.

7. ***Study of the gap between test and simulations results:***
   Conduct study on the gap between test and simulation models and results. Identify and present analysis results such as differences of boundary conditions, specimen installation, surface conditions, etc.

8. ***Conclusion and recommendation:***
   Based on testing and simulation results and analyses conducted in Section 6, conclusions and recommendations on NFRC TDD simulation procedure shall be drawn and presented to the NFRC Research Subcommittee and the U-factor Subcommittee. Also a new test procedure may be presented to NFRC for consideration of integration into NFRC 102.

REFERENCES:

NFRC 102, 2002. "*Test Procedure for Measuring the Steady-State Thermal Transmittance of Fenestration Systems*," National Fenestration Rating Council, 8484 Georgia Avenue, Suite 320, Silver Spring, MD 20910, November 2002.

NFRC 100:2001, 2002. "*Procedure for Determining Fenestration Product U-factors*," National Fenestration Rating Council, 8484 Georgia Avenue, Suite 320, Silver Spring, MD 20910, November 2002.

ASHRAE 2001. *2001 ASHRAE Handbook – Fundamentals*. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. 1791 Tullie Circle, N.E., Atlanta, GA 30329.

ASTM C 1199-00. *"Standard Test Method for Measuring the Steady State Thermal Resistance of Fenestration Systems Using Hot Box Method,"* American Society of Testing and Materials, 2000.

ASTM C 177. *"Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded Hot Plate Apparatus,"* American Society of Testing and Materials, 2000.

ASTM C 518. *"Test Method for Steady-State Thermal Heat Flux Measurements and Transmission Properties by Means of the Heat Flow Meter Apparatus,"* American Society of Testing and Materials, 2000.

ASTM E 1585 "*Test Method forMeasuring and Calculating Emittance of Architectural Flat Glass Products Using Spectrometric Measurements,"* American Society of Testing and Materials, 2000.

DELIVERABLES: Detailed documentation of the test apparatus design, photos of the apparatus, test procedure, instrument calibration records, calibration procedures and records, CTS design and construction, raw test data, data analysis, U-factor results, and test reports for all 13 tests on the TDD products. Also simulation reports on 13 TDD products, comparison study results and conclusion and recommendation shall be included in the deliverables. A peer-review paper shall be prepared and presented in a technical journal such as ASHRAE or ASTM.

ESTIMATED DURATION: 18 months

SOLE SOURCING:

This project need not be sole sourced.

TERMS:
Any prospective bidder shall submit a proposal that identifies the total cost of performing all the requirements as documented in this RFP, which shall include individual quotations for Task 2 and a combination of Tasks 3 and 4, if bidding all three. Any terms of payment shall also be outlined in the proposal. A schedule which outlines all tasks of the RFP shall be included with the bid submittal, including all associated dates and/or times.

ADDITIONAL RESOURCES BEING REQUESTED FROM NFRC:
None.

NFRC STAFF CONTACT:
The NFRC staff contact for the project is Bipin V. Shah, NFRC, Georgia Avenue, suite 320, Silver Spring, Maryland 20910. Phone: (301) 589-1776, Facsimile: (301) 589-3884.

RESOURCES BEING SOUGHT FROM SOURCES OTHER THAN NFRC:
Donation of test specimens from NFRC manufacturers.