ROLLAC
ROLLING SHUTTERS

SHUTTER TESTING: FIRE, SOUND & THERMAL RESISTANCE

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Celotex Corporation
Testing Services

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FIRE TESTING LABORATORY REPORT

May 28, 1999

Client:	Rollac Shutter of Texas, Inc.	**MTS Job No.:**	520274B
	10800 Blackhawk Blvd.	**Test Date:**	May 28, 1999
	Houston, TX 77089	**Metro-Dade Notification No.:**	CAE 99092

Project: Surface Burning Characteristics of ROLLAC A-150-H Slats, with BASF P12041 R/ P1001 U Foam Plastic Core

Introduction:

This report presents the results of a fire test conducted on material submitted to our laboratory on April 28, 1999. Testing was completed on May 28, 1999. The test was performed in accordance with the following American Society for Testing and Materials (ASTM) test standard:

ASTM E 84 - 98, "Standard Test Method for Surface Burning Characteristics of Building Materials"

The test method was used to determine the relative burning behavior of the material by observing the flame spread along the specimen. Flame spread and smoke developed index numbers are reported for the tested material.

Specimen Identification:

Thirty-nine (39) nominally 72 inch long by 1.57 inch wide by 3/16 inch thick rigid shutter slats were submitted and identified as "ROLLAC A-150-H" with foam plastic core manufactured by BASF Corporation 1609 Biddle Ave., Wyandotte, MI 48192. Three (3) separate panels were constructed, each consisting of thirteen slats joined together longitudinally by a joint detail. Each completed panel was 72 inches long by 21 inches wide by 3/16 inch thick.

Fire Test Chamber:

The fire test chamber or "Steiner Tunnel" consists of a horizontal 25 foot length furnace duct with a nominal interior width of 17.75 inches and depth of 12 inches. The furnace walls are insulated with refractory firebrick. Observation windows, placed 24 inches on center, are provided the entire length of one side of the tunnel. Specimens are supported on a 1 inch wide ledge along the top of the chamber. A removable insulated, stainless steel cap is used to completely cover the chamber and the test samples. The lid's edges, submerged in a perimeter water tray, prevent air leakage into the test chamber with a complete seal. The chamber was constructed in accordance with Section 5, "Apparatus", of the above standard.

R.G. Miller, #23335
Celotex Corporation, #7823
10301 9th St. N.
St. Petersburg, FL 33716
Date: 3-23-00

This report is for the information of the client. It may be used in its entirety for the purpose of securing product acceptance from duly constituted approval authorities; however, this report or the name of Celotex Corporation shall not be used in publicity or advertising.

Client: Rollac Shutter of Texas, Inc. **MTS Job No.:** 520274B

Specimen Preparation and Installation:

The three (3) nominally 72 by 21 by 3/16 inch Shutter panels were placed atop of support rods per standard and end to end on the furnace support ledge with the convex/grooved surface towards the chamber floor. The 24 foot length test specimen consisted of the three sections. Three (3) 24 by 96 inch and one (1) 24 by 12 inch flat, inorganic reinforced cement boards were placed end to end on top of the test specimen for furnace lid protection.

The samples were conditioned in a controlled laboratory at 70°F and 50% relative humidity a minimum of 72 hours prior to testing.

Test Procedure:

The flame spread distances, smoke obscuration percentages, and furnace temperatures were transmitted to an automated data acquisition system with a linear voltage transducer, a linear photometer system, and 18 gage, Type K thermocouples, respectively. The average flame front was observed and followed, with the linear voltage transducer, by a trained technician. Measurements were recorded over a 10 minute test time period.

Test Results:

The rounded test results as required by Section 9, "Interpretation of Results", are summarized on the following table. The unrounded test results, test data and graphical plots for flame spread, smoke, and temperature developed data are located in the Appendix.

Specimen Identification	Flame Spread Index (Unitless)	Smoke Index (Unitless)
ROLLAC A-150-H	50	400

Observations:

No afterburn or afterglow of shutter material was visible after the test was completed.

Tested by: William M. Gwynn
Research Technologist

Approved by: Mark E. Hennis
Research Chemist

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FIRE TESTING LABORATORY REPORT

May 28, 1999

Client:	Rollac Shutter of Texas, Inc. 10800 Blackhawk Blvd. Houston, TX 77089	**MTS Job No.:** **Test Date:** **Metro-Dade Notification No.:**	520274A May 28, 1999 CAE 99091

Project: Surface Burning Characteristics of Rollac A-200-H slats with BASF P12041 R/P1001 U foam plastic core.

Introduction:

This report presents the results of a fire test conducted on material submitted to our laboratory on April 28, 1999. Testing was completed on May 28, 1999. The test was performed in accordance with the following American Society for Testing and Materials (ASTM) test standard:

ASTM E 84 - 98, "Standard Test Method for Surface Burning Characteristics of Building Materials"

The test method was used to determine the relative burning behavior of the material by observing the flame spread along the specimen. Flame spread and smoke developed index numbers are reported for the tested material.

Specimen Identification:

Thirty (30) nominally 72 inch long by 2.17 inch wide by 3/8 inch thick rigid shutter slats were submitted and identified as "ROLLAC A-200-H" with foam plastic core manufactured by BASF Corporation 1609 Biddle Ave., Wyandotte, MI 48192. Three (3) separate panels were constructed, each consisting of ten slats joined together longitudinally by a joint detail. Each completed panel was 72 inches long by 22 inches wide by 3/8 inch thick.

Fire Test Chamber:

The fire test chamber or "Steiner Tunnel" consists of a horizontal 25 foot length furnace duct with a nominal interior width of 17.75 inches and depth of 12 inches. The furnace walls are insulated with refractory firebrick. Observation windows, placed 24 inches on center, are provided the entire length of one side of the tunnel. Specimens are supported on a 1 inch wide ledge along the top of the chamber. A removable insulated, stainless steel cap is used to completely cover the chamber and the test samples. The lid's edges, submerged in a perimeter water tray, prevent air leakage into the test chamber with a complete seal. The chamber was constructed in accordance with Section 5. Apparatus, of the above standard.

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Date: 3-23-00

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Client: Rollac Shutter Of Texas, Inc. **MTS Job No.:** 520274A

Specimen Preparation and Installation:

The three (3) nominally 72 by 22 by 3/8 inch Shutter panels were placed atop of support rods per standard and end to end on the furnace support ledge with the convex/grooved surface towards the chamber floor. The 24 foot length test specimen consisted of the three sections. Three (3) 24 by 96 inch and one (1) 24 by 12 inch flat, inorganic reinforced cement boards were placed end to end on top of the test specimen for furnace lid protection.

The samples were conditioned in a controlled laboratory at 70°F and 50% relative humidity a minimum of 72 hours prior to testing.

Test Procedure:

The flame spread distances, smoke obscuration percentages, and furnace temperatures were transmitted to an automated data acquisition system with a linear voltage transducer, a linear photometer system, and 18 gage, Type K thermocouples, respectively. The average flame front was observed and followed, with the linear voltage transducer, by a trained technician. Measurements were recorded over a 10 minute test time period.

Test Results:

The rounded test results as required by Section 9, "Interpretation of Results", are summarized on the following table. The unrounded test results, test data and graphical plots for flame spread, smoke, and temperature developed data are located in the Appendix.

Specimen Identification	Flame Spread Index (Unitless)	Smoke Index (Unitless)
ROLLAC A-200-H	25	400

Observations:

The shutter material continued to burn for over one minute after the test was completed.

Tested by: William M. Gwynn, Research Technologist

Approved by: Mark E. Hennis, Research Chemist

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FIRE TESTING LABORATORY REPORT
TEST METHOD ASTM D1929-96

March 2, 2000

Client: Rollac Shutter of Texas, Inc.
10800 Blackhawk Blvd.
Houston, TX 77089

MTS Job No.: 520536

Metro-Dade Notification No.: CAE 00006

Project: Ignition Properties of BASF P12041R/P1001U

Introduction:

This report presents the results of a fire test conducted on material submitted to our laboratory on January 19, 2000. Testing was completed on February 18, 2000.

Specimen Preparation:

Two small samples totaling 60 grams of dense foam plastic material were submitted by the client and identified as "BASF Elastopr® P12041 R (1.06 specific gravity) Resin and Elastopr® P1001 U (1.22 specific gravity) Isocyante", manufactured by BASF Corporation 1609 Biddle Ave., Wyandotte, MI 48192. Twelve (12) 3.0-gram samples were fabricated by cutting the supplied material into small one (1) inch squares and placing them into 1 inch diameter specimen cups. The samples were conditioned in a controlled laboratory at 75°F and 50% relative humidity a minimum of 48 hours prior to testing.

ASTM D1929-96 Test Method:

The following results were determined in accordance with the test method below.

ASTM D1929-96, "Standard Test Method for Ignition Properties of Plastics"

The plastic materials self-ignition and spontaneous-ignition temperatures were determined using a "Setchkin" hot-air ignition furnace. *This standard should be used to measure and describe the properties of materials, products, or assemblies in response to heat and flame under controlled laboratory conditions and should not be used to describe or appraise the fire hazard or fire risk of materials, products, or assemblies under actual fire conditions. However, results of this test may be used as elements of a fire risk assessment which takes into account all of the factors which are pertinent to an assessment of the fire hazard of a particular end use.*

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Celotex Corporation, #7823
10301 9th St. N.
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Date: 3-23-00

Client: Rollac Shutter of Texas, Inc. **MTS Job No.:** 520536

Summary of ASTM D1929-96 Test Results

	Flash-Ignition Temperature	Spontaneous-Ignition Temperature
BASF P12041R/P1001U	350°C [662°F]	530°C [986°F]

Observations:

Constant air velocities of 5 ft/min were maintained in the furnace test chamber as specified by Section 8.1.1 of the Standard Test Method. The sample material was flaming upon ignition and produced a black/olive colored sooty smoke during the flash and spontaneous ignition tests. Tabulated and graphical data are located in the Appendix.

These test results relate only to the behavior of test specimens under the particular conditions of the test. They are not intended to be used, and shall not be used, to assess the potential fire hazards of a material in use.

Tested by: William M. Gwynn
Research Technologist

Approved by: Mark E. Hennis
Research Chemist

R.G. Miller, #23335
Celotex Corporation, #7823
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Date: 3-23-00

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2. Airborne Sound Insulation Test (ASTM E966)

Report Prepared for:	ROLLAC Shutter of Texas, Inc. Houston, TX
Subject:	Field Measurement of Airborne Sound Insulation of Exterior Rolling Shutters
Report Prepared by:	Bernd Lorenz, Ph.D. Consulting Services Acoustical and Thermal Testing 10931 Sagewind Dr. Houston, TX 77089

16 June 2000

REPORT ON THE FIELD MEASUREMENT OF AIRBORNE SOUND INSULATION OF EXTERIOR ROLLING SHUTTERS (ASTM E966)

1. Introduction

In June 2000 acoustic measurements of the sound insulation (noise reduction) of the test object was performed in accordance with the ASTM test method E966-99: **Standard Guide for Field Measurements of Airborne Sound Insulation of Building Facades and Façade Elements.** The *Outdoor-Indoor Transmission Loss (OITL)*, the *Outdoor-Indoor Level Reduction (OILR)*, the *Outdoor-Indoor Transmission Class (OITC)* and other relevant parameters were estimated for the Exterior Rolling Shutter in combination with a single pane window. The improvement of noise insulation due to the Exterior Rolling Shutter is demonstrated in this report.

2. Sample Description

The test specimen was an Exterior Rolling Shutter installed over a single pane window. The technical specifications of the shutter are given below:

Manufacturer:	ROLLAC Shutter of Texas, Inc.
Type:	A 150 - Aluminum Foam-Insulated Slat
Color:	White
Slat-Description:	Double-walled roll formed aluminum (gauge: 0.017 inch / 0.43 mm), with regular-density polyurethane insulating foam core and ALCAN SP80 abrasive resistant paint finish (white). Slat size: 0.35” (9 mm) wide x 1.57” (40 mm) high.

3. Test site and receiving room

The measurements were taken in the field on Exterior Rolling Shutters installed on a large window of a house located at 10931 Sagewind Dr. in Houston, TX. The Facade of the house was made from brick on a wood frame construction. The area of the window and the shutter was 3.24 m^2 (36 ft^2) and 4.68 m^2 (52 ft^2), respectively. The receiving room was flanked by additional rooms on both sides (not a corner room). The volume of the room was 40 m^3 (≈ 1500 ft^3) and the interior surface area was 72 m^2 (800 ft^2). The room was equipped with several pieces of small furniture. The sound absorption characteristic of the receiving room was estimated using the reverberation method (Section 5.1).

4. Test instruments

The instrumentation used for generating noise consisted of a function signal generator coupled to a 110 Watt amplifier and loudspeaker system. Sound was generated at one-third octave band frequencies from 125 to 8000 Hz. The incident noise level (A-weighting dezibel or dB (A)) was typically about 90 to 100 dB (A).

The A-weighting sound-pressure level was measured using a Type 2 sound level meter (in compliance with the standards: IEC 651-1979 Type 2; ANSI S1.4-1983 Type 2; JIS C 1502). For measuring the acoustic decay characteristics of the room the analog output of the sound level meter was read by a fast micro-voltmeter coupled to a computer system via standard IEEE interface for real-time data acquisition.

5. Test methods and procedures

1.1 Sound absorption of the receiving room

The receiving room absorption, *A*, is an important characteristic parameter for calculating the *Outdoor-Indoor Transmission Loss*. The value of *A* is derived from the rate of decay of the sound pressure level in the receiving room (Reverberation Method, ASTM Test Method C 423). The derivation of *A* uses the Sabin equation:

$$A = \frac{0.921 \; V \; d}{c} \qquad (1)$$

where:

V = volume of the receiving room

c = speed of sound in the receiving room

d = rate of decay of the reverberant sound in the room, dB/s

The speed of sound, c, is a function of temperature according to the equation

$$c = 343.23\ (K/293.15)^{1/2}\ \text{m/s}$$

K is the absolute temperature measured in Kelvin.

The rate of decay, d, was estimated in the receiving room at the one-third octave band frequencies from 125 Hz to 8000 Hz. Sound was generated inside the room. Five different locations as indicated in Fig. 1.1 (Appendix 1) were tested and the results were averaged over all five positions. The real time measurement of sound decay was achieved by reading the analog output of the sound level meter using a digital DMM (HP 3478A) with an IEEE 488 interface to a computer. A typical sound decay curve is shown in Fig. 1.2, Appendix 1. The decay rate, d, was estimated from the slope of the linear part (initial decay), as indicated in Fig. 1.2. An average decay rate of d=85 dB/s was estimated.

With the Sabin equation (1) the sound absorption of the receiving room is *A*=9.1 metric sabins. *A* does not exceed the value of $V^{2/3} = 11.7\ m^2$ (ASTM-Guide E966-99).

5.2 OILR and *OITL* measurements with a fixed source

All indoor measurements were performed 1.3 m above floor at the five positions marked in Fig. 1.1, Appendix 1. The sound pressure levels were averaged over the five positions and over five separate sets of measurement (i.e. a total of 25 measurements). The outdoor sound pressure data were taken at five locations in immediate neighborhood of the Exterior Rolling Shutter (Flush Outdoor Measurement Position). The five test points are indicated in Fig. 2.1 (Appendix 2). The measured values were averaged over the five test points for five independent sets of experiments.

The *OILR* and *OITL* were estimated for two basic configurations:

(i) Closed window – open shutter

(ii) Closed window – closed shutter

The *OILR* and *OITL* parameters for both configurations give an absolute estimate of the sound insulation for each case. The differences show the improvement in sound insulation to be expected by installing the Exterior Rolling Shutter.

5.2.1 Background noise

The background noise level was measured for the indoor and outdoor test positions in order to guarantee that the test data with activated source are at least 5 dB (preferentially 10 dB) higher than the background level. If the difference of the test signal and the background noise is between 5 and 10 dB, it has to be corrected according to the equation

$$L_s = 10 \log\left[10^{L_{sb}/10} - 10^{L_b/10}\right] \qquad (2)$$

where:

L_b = background noise level, dB

L_{sb} = signal and background level combined, dB

L_s = adjusted signal level, dB

The averaged background noise level was 32.5 dB inside the receiving room. The outdoor background level was 48.1 dB.

5.2.2 Method of measurement and calculation of *OILR* and *OITL*

The *Flush Outdoor Measurement Position* was chosen and the sound pressure was measured right at the surface of the window/shutter at the five positions shown in Fig. 2.1. The source of noise was located 2.1 m (7 ft) away from the test element and the sound was directed towards the center of the window/shutter. The angle of incidence, θ, was estimated as θ= 18 degree. This test configuration is shown in Fig. 2.2 (Appendix 2). The *OILR* and *OITL* were calculated according to

$$OILR = L_{surf} - L_{in} - 6\ \text{dB} \qquad (3a)$$

$$OITL = L_{surf} - L_{in} + 10 \log(S/A) + 10 \log(\cos\theta) \qquad (3b)$$

where:

L_{surf} = average sound pressure level measured at the surface of the window/shutter

L_{in} = average sound pressure level measured in the receiving room

S = area of the window/shutter

A = room absorption

6. Results and Conclusions

The detailed results of the test measurements are listed in Table 3.1 (Appendix 3). The average noise reduction of the Exterior Rolling Shutter in the frequency range from 500 Hz to 8000 Hz is estimated to be 13.3 dB. In terms of noise intensity the attenuation of 13.3 dB corresponds to a 95 % reduction of the incident intensity. According to the noise classification of various indoor areas the attenuation of 13.3 dB would convert a typical noisy office space environment (47 – 56 dBA) into a sleeping room quality (34 – 47 dBA). At low frequencies (< 500 Hz) the measured noise reduction effect is drastically reduced (Table 3.1). This is partially due to the fact that, at low frequencies, there is an appreciable amount of flanking transmission through the walls of the room. The window wall area is about the same as the shutter area and the brick facade without special sound insulation is quite transparent for low frequency sound. However, since the human ear is extremely insensitive to low frequency sound (the human recognition of sound at 125 Hz compared with 1000 Hz is decreased by 16 dB) the medium and high frequency (above 500 Hz) noise reduction effects are dominating unless the noise problem is due to a special low frequency source of noise.

The *Outdoor-Indoor Transmission Class* (*OITC*) represents a single number acoustical rating of sound transmission. The *OITC* is calculated according to ASTM Designation E 1332-90 (1998): **Standard Classification of Outdoor-Indoor Transmission Class** using the *OITL* data of Table 3.1 (*OITL* data at frequencies lower than 125 Hz are not taken into account). For the closed window – open shutter configuration the *Outdoor-Indoor Transmission Class* is *OITC*=26. If the shutter is closed the *OITC* increases to 32 indicating a remarkable improvement of the sound insulation. This rating is based on an average transportation noise source spectrum and an A-weighted sound level reduction, either of which may be inappropriate for some applications.

Tested by:

____

Bernd Lorenz, Ph.D.
Consulting Services
Acoustical and Thermal Testing
and
Research Associate Professor of Physics
at the University of Houston

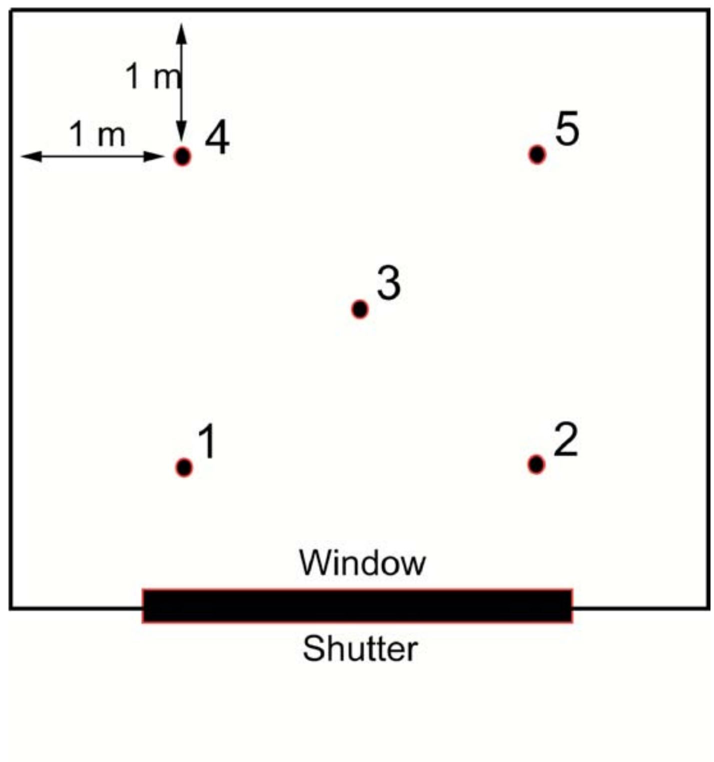

Fig. 1.1: Microphone positions 1 to 5 in the receiving room. All test points were 1.3 m above floor and the minimum distance to the walls was 1 m.

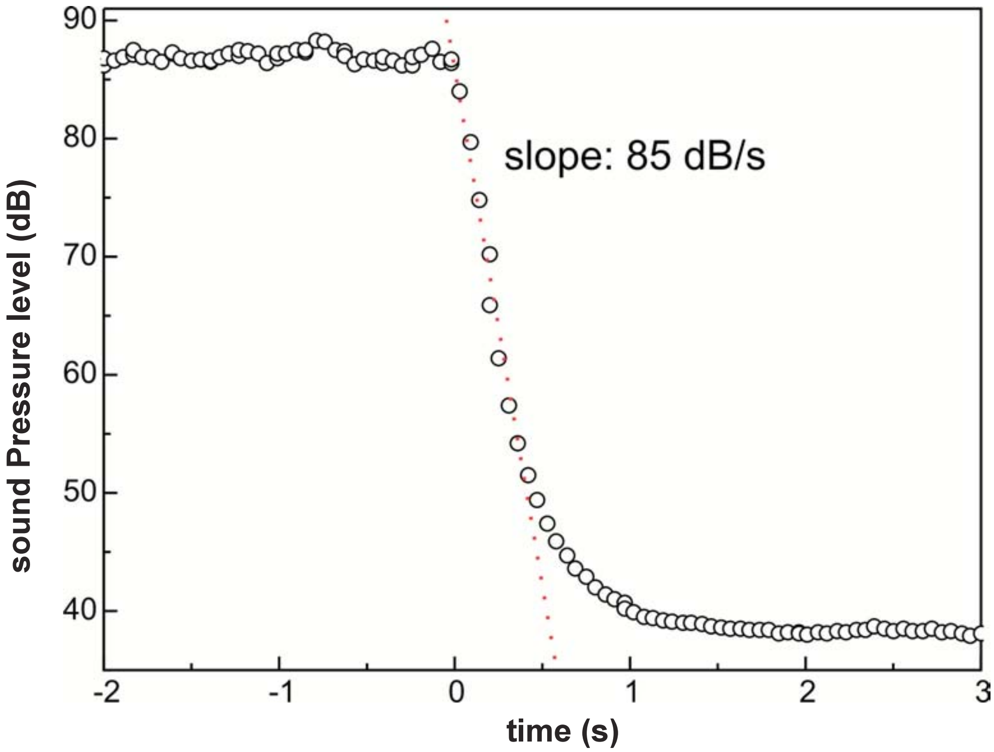

Fig. 1.2: Typical sound decay curve of the receiving room after switching off the source at time t=0. The slope of 85 dB/s is the characteristic quantity describing the receiving room absorption.

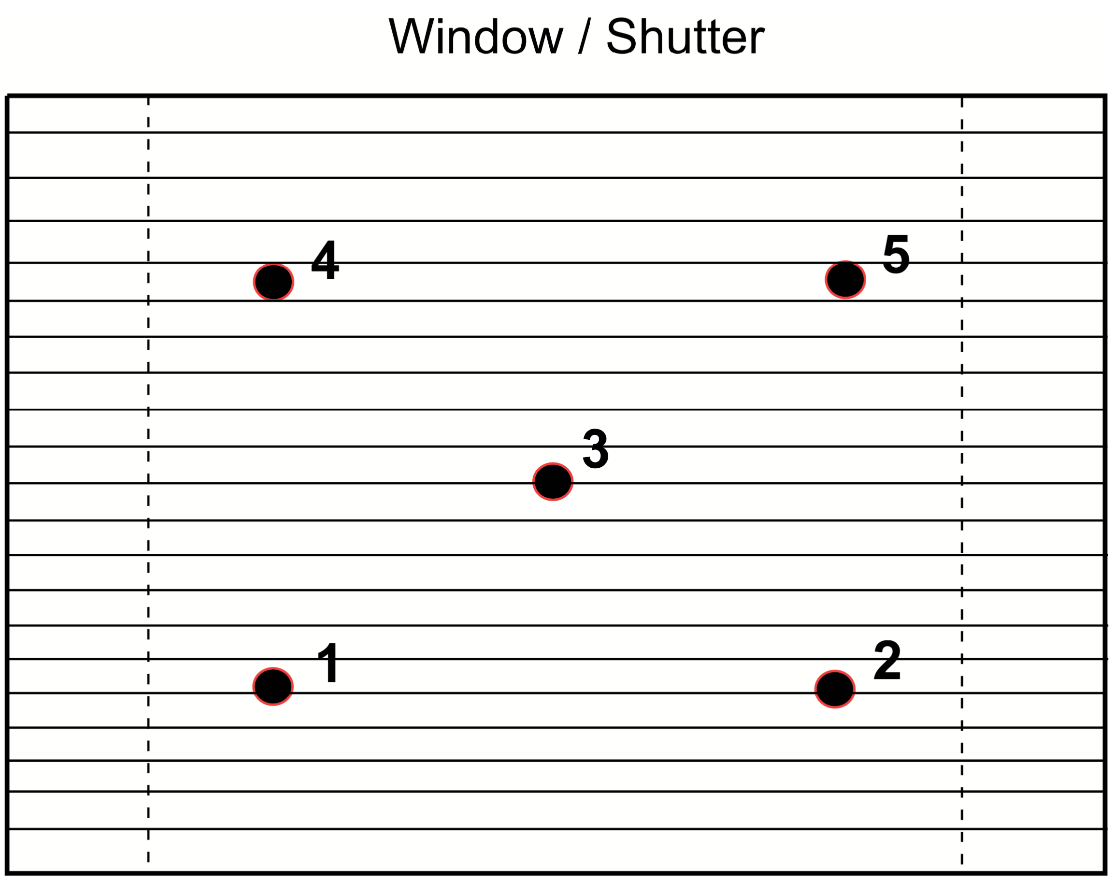

Fig. 2.1 Sketch of the test element window/shutter. The test points 1 to 5 indicate the positions of the microphone at the surface of the window or the shutter (*Flush Outdoor Measurement Position*) where the incident sound pressure level was measured.

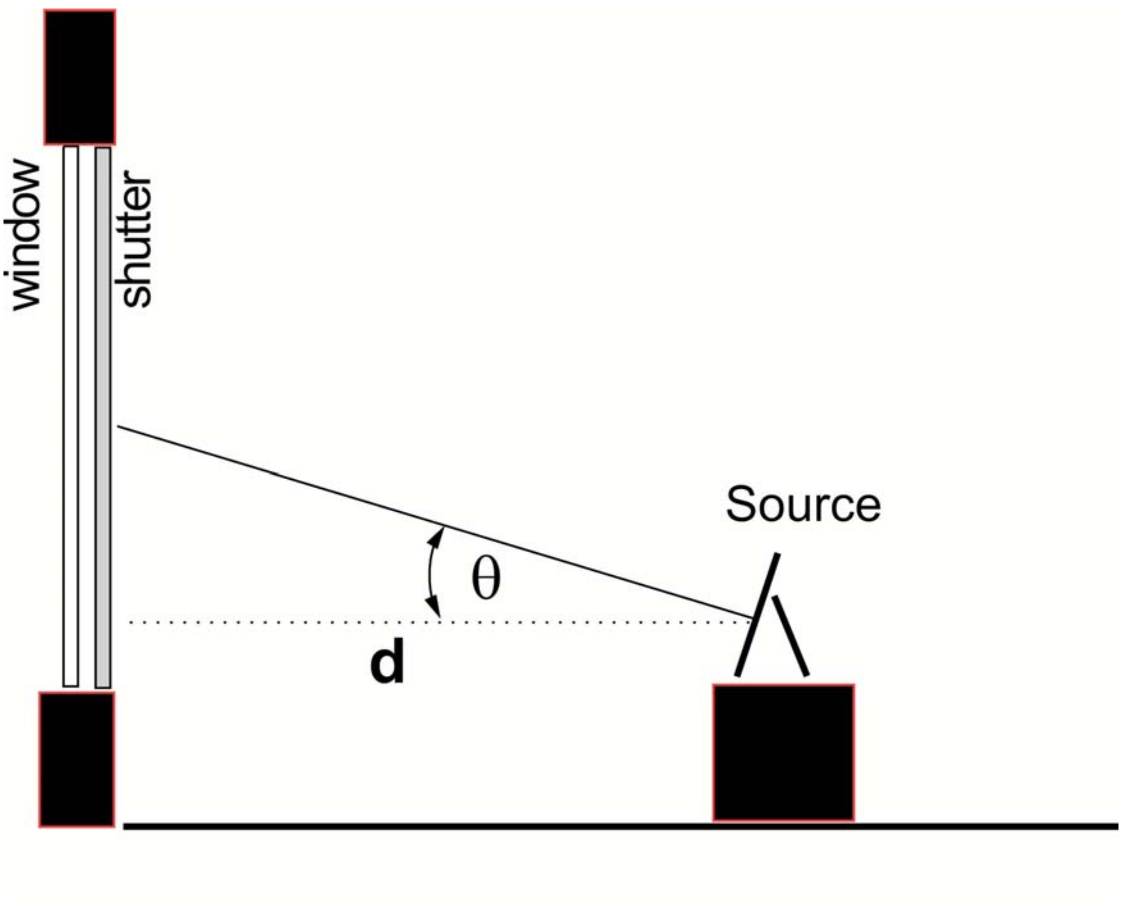

Fig. 2.2: Schematic view of the outdoor configuration. The distance of the source from the shutter was d = 2.1 m and the angle of incidence was = 18 degree.

The test results are presented in table 3.1. The sound level intensities are averaged values as described in Section 3.

Table 3.1: Test results for the Exterior Rolling Shutter, Type A 150

	window only				window plus shutter				
FrequencyHz	L_{surf} dB	L_{in} dB	OILR dB	OITL dB	L_{surf} dB	L_{in} dB	OILR dB	OITL dB	Noise reduction of shutter in dB
125	82.1	57.2	18.9	21.9	83.2	56.1	21.1	24.1	2.2
160	85.2	59.7	19.5	22.5	81.5	53.3	22.2	25.2	2.7
200	83.7	58.3	19.4	22.4	85.1	54.5	21.0	24.0	1.6
250	86.2	58.2	22.0	25.0	80.0	48.5	25.5	28.5	3.5
315	89.3	61.5	21.8	24.8	83.4	52.4	25.0	28.0	3.2
400	90.2	61.3	22.9	25.9	85.9	51.1	28.8	31.8	5.9
500	88.0	58.2	23.8	26.8	87.0	47.5	33.5	36.5	9.7
630	91.1	61.1	24.0	27.0	92.3	50.1	36.2	39.2	12.2
800	91.7	61.5	24.2	27.2	89.9	45.4	38.5	41.5	14.3
1000	90.4	60.4	24.0	27.0	91.1	47.1	38.0	41.0	14.0
1250	92.6	62.8	23.8	26.8	94.4	49.9	38.5	41.5	14.7
1600	94.2	64.1	24.1	27.1	95.1	51.2	37.9	40.9	13.8
2000	93.5	64.2	23.3	26.3	92.2	48.1	38.1	41.1	14.8
2500	90.8	61.0	23.8	26.8	93.7	49.7	38.0	41.0	14.2
3150	92.8	63.8	23.0	26.0	91.6	49.2	36.4	39.4	13.4
4000	94.0	64.1	23.9	26.9	93.0	50.1	36.9	39.9	13.0
5000	92.5	63.3	23.2	26.2	91.8	49.1	36.7	39.7	13.5
6300	90.3	61.4	22.9	25.9	92.1	50.4	35.7	38.7	12.8
8000	94.0	65.2	22.8	25.8	90.1	48.3	35.8	38.8	13.0

3. Thermal Resistance and Transmission Test (R/U Value)

Report Prepared for: ROLLAC Shutter of Texas, Inc.
Houston, TX

Subject: Measurement of Steady-State Thermal Performance of Exterior Rolling Shutters

Report Prepared by: Bernd Lorenz, Ph.D.
Consulting Services
Acoustical and Thermal Testing
10931 Sagewind Dr.
Houston, TX 77089

18 October 2000

REPORT ON THE MEASUREMENT OF STEADY-STATE THERMAL PERFORMANCE (THERMAL RESISTANCE AND TRANSMITTANCE) OF EXTERIOR ROLLING SHUTTERS

1. Introduction

In September/October 2000 the Thermal Resistance (R-value) and Transmittance (U-value) of the test objects were measured in accordance with the ASTM test method C 236: **Standard Test Method for Steady-State Thermal Performance of Building Assemblies by Means of a Guarded Hot Box.** The thermal resistance values of the hot surface, the cold surface, and the shutter were measured for four different types and materials used for construction of the Exterior Rolling Shutters. The total thermal resistance and transmittance were estimated for a combination of the shutter with a standard single pane window.

2. Sample Description

The test specimens were four different types of Exterior Rolling Shutters. The technical specifications are given below:

(i) Exterior Rolling Shutter type **A 150**

Manufacturer: ROLLAC Shutter of Texas, Inc.
Type: A 150 – Aluminum Foam-Insulated Slat
Color: White
Slat-Description: Double-walled roll formed aluminum (gauge: 0.017 inch / 0.43 mm), with regular-density polyurethane insulating foam core and ALCAN SP80 abrasive resistant paint finish (white).
Slat size: 0.35” (9 mm) wide x 1.57” (40 mm) high.

(ii) Exterior Rolling Shutter type **A 200**

Manufacturer:	ROLLAC Shutter of Texas, Inc.
Type:	A 200 – Aluminum Foam-Insulated Slat
Color:	White
Slat-Description:	Double-walled roll formed aluminum (gauge: 0.02 inch / 0.49 mm), with regular-density polyurethane insulating foam core and ALCAN SP80 abrasive resistant paint finish (white). Slat size: 0.55” (14 mm) wide x 2.16” (55 mm) high.

(iii) Exterior Rolling Shutter type **GULF**

Manufacturer:	ROLLAC Shutter of Texas, Inc.
Type:	GULF – PVC Slat
Color:	White
Slat-Description:	Double-walled stiffened cavity extruded mini PVC profile (light gauge: 0.031 inch / 0.80 mm), white. Slat size: 0.31” (8 mm) wide x 1.57” (40 mm) high.

(iv) Exterior Rolling Shutter type **ELITE**

Manufacturer:	ROLLAC Shutter of Texas, Inc.
Type:	ELITE – PVC Slat
Color:	White
Slat-Description:	Double-walled impact resistant extruded maxi PVC profile (heavy gauge: 0.044 inch / 1.13 mm), white. Slat size: 0.55” (14 mm) wide x 2.01” (51 mm) high.

For the thermal tests all shutters were completely closed and framed in aluminum rails.

3. Test Facilities

The thermal performance of the test specimens was measured by means of a guarded hot box (GHB) according to ASTM Designation C 236. The construction of the GHB follows closely the guidelines given in C 236. A Metering Box was placed completely inside a Guard Box. The size of the Metering Box was 18 ft^3 (0.49 m^3), i.e. 3 ft x 3 ft x 2 ft (0.9 m x 0.9 m x 0.6 m). The size of the Guard Box was 44 ft^3 (1.19 m^3), i.e. 4 ft x 4 ft x 2.75 ft (1.2 m x 1.2 m x 0.83 m) leaving a minimum distance of ½ ft (150 mm) between the walls of the Metering and the Guard Box.. The test specimens were mounted to the open front sides of Metering and Guard Box. The edge of the Metering Box in contact with the panel was sealed with a ½ inch (13 mm) wide rubber foam gasket. All other walls of the Metering and Guard Boxes were thermally insulated to reduce heat flow from the Guard Box to the outside area and between the two boxes.

Both, the Metering and the Guard Box, were equipped with an externally regulated heater and fan for distributing the heated air inside the boxes. A baffle parallel to the panel inside the Metering Box supports a homogeneous distribution of the stream of hot air across the metering area of the test panel. Additional slat type baffles in the Metering Box and in the Guard Box improve the homogeneity of the hot air circulation.

To accurately measure the heat flow through the five walls of the Metering Box into the Guard Box a system of forty (twenty pairs) of differential thermocouples was installed on both sides of the walls. Each pair of thermocouples senses the temperature at the same wall position inside and outside the Metering Box. There were four differential pairs of thermocouples distributed evenly over each wall. The thermocouple wire was flushed and in good thermal contact with the wall for at least 4 inch (100 mm) distance from each junction. All thermocouples were welded together differentially to form a thermopile. The measured emf of the thermopile was used to reduce the total heat flow through the walls of the Metering Box to zero (for the thermopile emf and heat flow relationship see ASTM Designation C 236, Appendix).

Air and panel surface temperatures were measured inside (hot space) and outside (cold space) the Metering Box. Nine different positions evenly distributed over the metering area of the specimen (as indicated in Fig. 1, Appendix 1) were tested. The temperatures at the panel surface were measured using thermocouples attached on both sides to the cold and hot surfaces. Starting from the junction, at least 4 inch (100 mm) of the thermocouple wire was in good thermal contact with the surface. Air temperature of the hot side (inside the Metering Box) was measured by another set of nine thermocouples placed exactly at the same positions, opposite to the hot surface thermocouples, midway between the hot surface and the baffle (the distance to the hot surface was larger than 3 inch / 75 mm). Similarly, the cold space air temperature was measured at nine positions in front of the cold surface of the test specimen. The thermocouples were placed opposite to the cold surface thermocouples in a distance of 3 inch (75 mm) from the panel.

The total of 36 temperatures were measured using a HH506R digital thermometer with RS232C optical interface. The interface to a computer allows the monitoring of the change of temperatures over long time and to determine precisely the time when temperature stability and stationary equilibrium was achieved.

4. Sampling and Test Procedure

The test specimens (Exterior Rolling Shutters, closed) were framed and adapted to the size of the Guard Box, 4 ft x 4 ft (1.2 m x 1.2 m). The metered area was 3 ft x 3 ft (0.9 m x 0.9 m). The edges of the shutter/frame were sealed and thermally insulated to reduce any lateral heat flow. Rubber foam was used to achieve a tight seal of the metered area and the edge of the Metering Box.

The Guarded Hot Box can be used in vertical and horizontal sample position. Both configurations were employed for testing each specimen and the results are identical. The horizontal sample configuration results in a more homogeneous temperature distribution across the metered sample area whereas in the vertical position a small temperature gradient was observed. The measured thermal parameters, however, are averaged over the metering area and the same results are obtained in horizontal and vertical positions within the error limits.

Steady state conditions, characterized by zero heat flow between the Metering and Guard Boxes, stable air and sample surface temperatures, and stable power input, were obtained after a typical time period of four to six ours. After achieving stationary equilibrium data were taken within two four our periods. The average of the data were used to calculate the thermal resistance and transmittance of the samples under test.

The following data were determined:

- Q: the total net energy or average power through the specimen (metered area) including meter box heater and fan, W
- t_1: area weighted average temperature of hot surface, K
- t_2: area weighted average temperature of cold surface, K
- t_h: average air temperature inside the Metering Box (75 mm from hot surface), K
- t_c: average air temperature of cold space (75 mm from cold surface), K
- A: metering area normal to the heat flow

The following parameters were estimated:

- $R=(t_1-t_2)*A/Q$: thermal resistance of the specimen, Km^2/W
- $r_h=(t_h-t_1)*A/Q$: hot surface resistance, Km^2/W
- $r_c=(t_2-t_c)*A/Q$: cold surface resistance, Km^2/W
- $R_u=(t_h-t_c)*A/Q$: overall thermal resistance, Km^2/W
- $U=Q/A(t_h-t_c)$: thermal transmittance, W/Km^2
- $C=Q/A(t_1-t_2)$: thermal conductance of specimen
- R_{total} : estimated thermal resistance of the shutter in combination with a single pane window
- U_{total} : estimated thermal transmittance of the shutter in combination with a single pane window

5. Test Results

The detailed test results are listed in Appendix 2. This section gives a summary and the most important parameters for the specimens under test. An estimate of the thermal parameters of the Exterior Rolling Shutters in combination with a single pane window and an assumed air gap between shutter and window of 1.5 inch (38 mm) is given by using standard values for the thermal resistance of the air space (R_{air}), the window glass (R_{glass}), and the inner surface resistance of the window (R_i):

R_{air} = 0.157 Km^2/W = 0.890 F $ft^2/(Btu/h)$

Note: this value is for cool air (winter conditions),
for warm air (summer conditions) R_{air} is slightly lower

R_{glass} = 0.0053 Km^2/W = 0.030 F $ft^2/(Btu/h)$

R_i = 0.120 Km^2/W = 0.680 F $ft^2/(Btu/h)$

The total thermal resistance, R_{total}, and transmittance, U_{total}, for the shutter-window combination were estimated according to the formulas:

$$R_{total} = r_h + R + R_{air} + R_{glass} + R_i \qquad U_{total} = 1/R_{total}$$

(i) Exterior Rolling Shutter type **A 150**

	SI units (K, m, W)	US units (F, ft, Btu)
Measured values for shutter		
Hot surface resistance, r_h Km^2/W, F $ft^2/(Btu/h)$	0.0365	0.207
Cold surface resistance, r_c Km^2/W, F $ft^2/(Btu/h)$	0.0355	0.202
Specimen resistance, R Km^2/W, F $ft^2/(Btu/h)$	0.0324	0.184
Overall resistance, R_u Km^2/W, F $ft^2/(Btu/h)$	0.105	0.592
Thermal conductance, C W/Km^2, $(Btu/h)/F\ ft^2$	30.9	5.43
Thermal transmittance, U W/Km^2, $(Btu/h)/F\ ft^2$	9.52	1.69
Estimated values for shutter and single pane window		
Overall resistance, R_{total} (shutter + window) Km^2/W, F $ft^2/(Btu/h)$	0.351	1.99
Thermal transmittance, U_{total} (shutter + window) W/Km^2, $(Btu/h)/F\ ft^2$	2.85	0.502

(ii) Exterior Rolling Shutter type **A 200**

	SI units (K, m, W)	US units (F, ft, Btu)
Measured values for shutter		
Hot surface resistance, r_h Km^2/W, F $ft^2/(Btu/h)$	0.0402	0.229
Cold surface resistance, r_c Km^2/W, F $ft^2/(Btu/h)$	0.0394	0.224
Specimen resistance, R Km^2/W, F $ft^2/(Btu/h)$	0.0324	0.184
Overall resistance, R_u Km^2/W, F $ft^2/(Btu/h)$	0.112	0.634
Thermal conductance, CW/Km^2, $(Btu/h)/F\ ft^2$	30.9	5.43
Thermal transmittance, U W/Km^2, $(Btu/h)/F\ ft^2$	8.93	1.58
Estimated values for shutter and single pane window		
Overall resistance, R_{total}(shutter + window) Km^2/W, F $ft^2/(Btu/h)$	0.355	2.01
Thermal transmittance, U_{total} (shutter + window) W/Km^2, $(Btu/h)/F\ ft^2$	2.82	0.497

(iii) Exterior Rolling Shutter type **GULF**

	SI units (K, m, W)	US units (F, ft, Btu)
Measured values for shutter		
Hot surface resistance, r_h Km^2/W, F $ft^2/(Btu/h)$	0.0448	0.254
Cold surface resistance, r_c Km^2/W, F $ft^2/(Btu/h)$	0.0478	0.272
Specimen resistance, R Km^2/W, F $ft^2/(Btu/h)$	0.0686	0.390
Overall resistance, R_u Km^2/W, F $ft^2/(Btu/h)$	0.161	0.916
Thermal conductance, C W/Km^2, $(Btu/h)/F\ ft^2$	14.6	2.56
Thermal transmittance, U W/Km^2, $(Btu/h)/F\ ft^2$	6.21	1.09
Estimated values for shutter and single pane window		
Overall resistance, R_{total}(shutter + window) Km^2/W, F $ft^2/(Btu/h)$	0.395	2.25
Thermal transmittance, U_{total} (shutter + window) W/Km^2, $(Btu/h)/F\ ft^2$	2.53	0.445

(iv) Exterior Rolling Shutter type **ELITE**

	SI units (K, m, W)	US units (F, ft, Btu)
Measured values for shutter		
Hot surface resistance, r_h Km^2/W, $F\ ft^2/(Btu/h)$	0.0478	0.272
Cold surface resistance, r_c Km^2/W, $F\ ft^2/(Btu/h)$	0.0516	0.293
Specimen resistance, R Km^2/W, $F\ ft^2/(Btu/h)$	0.0979	0.556
Overall resistance, R_u Km^2/W, $F\ ft^2/(Btu/h)$	0.198	1.12
Thermal conductance, C W/Km^2, $(Btu/h)/F\ ft^2$	10.2	1.80
Thermal transmittance, U W/Km^2, $(Btu/h)/F\ ft^2$	5.05	0.893
Estimated values for shutter and single pane window		
Overall resistance, R_{total} (shutter + window) Km^2/W, $F\ ft^2/(Btu/h)$	0.428	2.43
Thermal transmittance, U_{total} (shutter + window) W/Km^2, $(Btu/h)/F\ ft^2$	2.34	0.411

The comparison of the thermal parameters of the different types of Exterior Rolling Shutters reveals some interesting properties.

First of all, the thermal performance of the PVC shutters is far better than the aluminum shutters. This is not surprising because aluminum is one of the best heat conducting materials. The different slat size of type A 150 and type A 200 has almost no influence on the thermal conductance indicating that the major thermal conductor is the aluminum shell of the slats. Type A 200 has a slightly higher surface resistance resulting in a 7 % lower thermal transmittance (U-value). It can be concluded that the effect of the foam core on improving the thermal insulation is very marginal.

A major enhancement of thermal insulation is obtained by replacing the aluminum by PVC. The thermal conductance of the PVC shutters type GULF and type ELITE is reduced by 50 % and 67 %, respectively, if compared with the thermal conductance of the aluminum slats. A clear decrease of thermal conductance is also observed with increasing PVC slat size (GULF to ELITE). The lower thermal conduction results in a decrease of the U-value (thermal transmittance) from about 9 W/Km^2 (A150, A200) to 6.2 W/Km^2 (GULF) and 5 W/Km^2 (ELITE).

Tested by: ____________________

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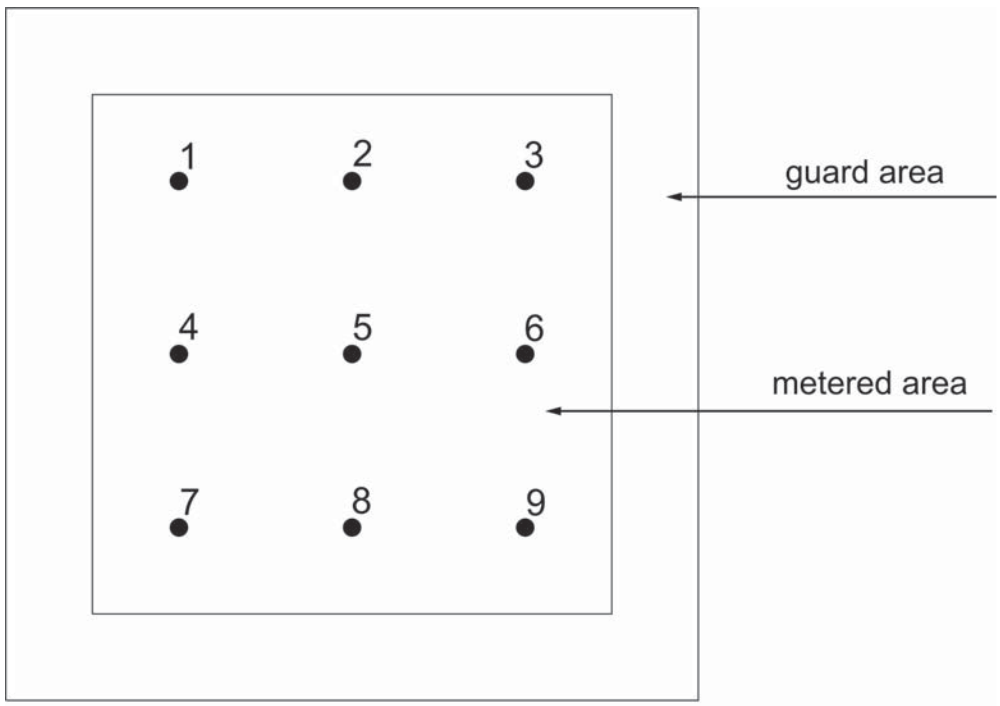
Appendix 1

Position of the temperature sensors at the surface of the test specimen. The numbers 1 to 9 refer to the data given in Appendix 2.



Appendix 2

Detailed presentation of the measured data for the test panels (i) to (iv). The average temperatures numbered from 1 to 9 refer to the positions indicated in Fig. 1. The metered area for all tests is 9 ft^2 (0.81 m^2). All temperatures are given in ^oC

Panel (i):

Exterior Rolling Shutter Type A 150
Horizontal position

test point	hot air	hot surface	cold surface	cold air
1	83.2	66.9	51.9	36.5
2	84.0	67.8	53.0	37.1
3	83.9	67.5	52.8	37.1
4	84.7	67.9	52.6	36.4
5	84.0	67.3	52.0	37.1
6	84.4	67.6	52.0	36.7
7	85.0	68.0	53.4	36.6
8	84.0	67.1	52.6	36.5
9	84.6	67.4	53.1	36.5
Average temp.	84.2	67.5	52.6	36.7
Total power input (heater + fan), W			368	

$r_h = 0.0368\ Km^2/W = 0.209\ F\ ft^2/(Btu/h)$

$r_c = 0.0350\ Km^2/W = 0.199\ F\ ft^2/(Btu/h)$

$R = 0.0328\ Km^2/W = 0.186\ F\ ft^2/(Btu/h)$

$R_u = 0.105\ Km^2/W = 0.594\ F\ ft^2/(Btu/h)$

$U = 9.52\ W/Km^2 = 1.68\ (Btu/h)/F\ ft^2$

Exterior Rolling Shutter Type A 150
Vertical position

test point	hot air	hot surface	cold surface	cold air
1	74.1	58.9	46.5	30.9
2	72.5	58.2	46.0	30.7
3	73.3	59.0	46.1	31.0
4	73.5	58.7	45.4	30.6
5	72.0	58.6	45.7	30.5
6	73.7	58.8	45.9	30.9
7	71.5	56.3	44.0	31.2
8	70.9	56.2	43.8	30.5
9	71.4	57.0	43.8	30.7
Average temp.	72.5	58.0	45.2	30.8
Total power input (heater + fan), W			325	

r_h = 0.0361 Km^2/W = 0.205 F ft^2/(Btu/h)

r_c = 0.0359 Km^2/W = 0.204 F ft^2/(Btu/h)

R = 0.0319 Km^2/W = 0.181 F ft^2/(Btu/h)

R_u = 0.104 Km^2/W = 0.590 F ft^2/(Btu/h)

U = 9.62 W/Km^2 = 1.69 (Btu/h)/F ft^2

Panel (ii)

Exterior Rolling Shutter Type A 200
Horizontal position

test point	hot air	hot surface	cold surface	cold air
1	83.9	68.1	53.5	36.9
2	83.2	67.5	53.2	37.1
3	84.0	67.4	53.6	36.6
4	84.5	66.8	52.9	36.2
5	83.9	65.7	53.2	35.8
6	83.9	65.9	52.8	36.1
7	84.9	66.0	53.0	36.3
8	82.3	66.2	53.5	35.9
9	83.2	67.0	53.1	36.0
Average temp.	83.7	66.7	53.2	36.3
Total power input (heater + fan), W			345	

r_h = 0.0399 Km^2/W = 0.227 F $ft^2/(Btu/h)$
r_c = 0.0397 Km^2/W = 0.225 F $ft^2/(Btu/h)$
R = 0.0317 Km^2/W = 0.180 F $ft^2/(Btu/h)$
R_u = 0.111 Km^2/W = 0.632 F $ft^2/(Btu/h)$
U = 8.99 W/Km^2 = 1.58 (Btu/h)/F ft^2

Exterior Rolling Shutter Type A 200
Vertical Position

test point	hot air	hot surface	cold surface	cold air
1	76.2	61.0	48.1	32.8
2	76.5	61.3	48.3	32.4
3	76.0	60.5	47.7	32.7
4	75.9	61.0	47.6	31.9
5	76.3	61.4	48.3	31.8
6	76.7	60.6	47.8	32.3
7	74.5	59.0	46.3	32.6
8	75.0	58.7	46.1	32.0
9	74.9	58.5	46.6	31.9
Average temp.	75.8	60.2	47.4	32.3
Total power input (heater + fan), W			313	

r_h = 0.0405 Km^2/W = 0.230 F $ft^2/(Btu/h)$

r_c = 0.0391 Km^2/W = 0.222 F $ft^2/(Btu/h)$

R = 0.0330 Km^2/W = 0.187 F $ft^2/(Btu/h)$

R_u = 0.113 Km^2/W = 0.639 F $ft^2/(Btu/h)$

U = 8.85 W/Km^2 = 1.56 (Btu/h)/F ft^2

Panel (iii):

Exterior Rolling Shutter Type GULF
Horizontal Position

test point	hot air	hot surface	cold surface	cold air
1	82.8	67.9	46.2	31.0
2	81.7	68.7	46.8	31.3
3	83.0	68.4	46.2	31.1
4	82.2	67.9	45.9	30.8
5	81.0	68.0	45.7	30.8
6	82.4	67.8	46.3	30.3
7	82.1	67.5	46.1	31.1
8	81.7	68.0	46.8	31.8
9	82.0	67.7	46.4	31.1
Average temp.	82.1	68.0	46.3	31.0
Total power input (heater + fan), W			258	

r_h = 0.0443 Km^2/W = 0.251 F $ft^2/(Btu/h)$

r_c = 0.0480 Km^2/W = 0.273 F $ft^2/(Btu/h)$

R = 0.0681 Km^2/W = 0.387 F $ft^2/(Btu/h)$

R_u = 0.160 Km^2/W = 0.911 F $ft^2/(Btu/h)$

U = 6.25 W/Km^2 = 1.10 $(Btu/h)/F\ ft^2$

Exterior Rolling Shutter type GULF

Vertical position

test point	hot air	hot surface	cold surface	cold air
1	79.9	66.4	45.8	31.4
2	79.5	66.0	46.0	30.9
3	79.6	66.3	46.1	31.1
4	79.3	65.9	45.7	31.5
5	78.9	66.2	46.0	31.2
6	79.0	65.9	45.2	30.9
7	78.1	64.6	44.1	31.2
8	77.9	64.5	44.0	31.4
9	78.2	64.7	44.2	30.9
Average temp.	78.9	65.6	45.2	31.2
Total power input (heater + fan), W			239	

r_h = 0.0452 Km^2/W = 0.257 F ft^2/(Btu/h)

r_c = 0.0475 Km^2/W = 0.270 F ft^2/(Btu/h)

R = 0.0690 Km^2/W = 0.392 F ft^2/(Btu/h)

R_u = 0.162 Km^2/W = 0.920 F ft^2/(Btu/h)

U = 6.17 W/Km^2 = 1.09 (Btu/h)/F ft^2

Panel (iv):

Exterior Rolling Shutter type ELITE
Horizontal position

test point	hot air	hot surface	cold surface	cold air
1	79.0	65.6	38.2	23.2
2	78.4	65.5	37.8	23.6
3	78.6	65.9	38.0	22.9
4	78.9	64.9	37.6	23.2
5	78.4	64.7	37.9	23.2
6	79.0	65.1	37.7	22.8
7	79.1	64.8	38.1	23.0
8	78.3	65.6	37.7	22.7
9	78.5	65.5	37.6	23.0
Average temp.	78.7	65.3	37.8	23.1
Total power input (heater + fan), W			229	

$r_h = 0.0474\ Km^2/W = 0.269\ F\ ft^2/(Btu/h)$

$r_c = 0.0520\ Km^2/W = 0.295\ F\ ft^2/(Btu/h)$

$R = 0.0973\ Km^2/W = 0.552\ F\ ft^2/(Btu/h)$

$R_u = 0.197\ Km^2/W = 1.12\ F\ ft^2/(Btu/h)$

$U = 5.08\ W/Km^2 = 0.895\ (Btu/h)/F\ ft^2$

Exterior Rolling Shutter type ELITE
Vertical position

test point	hot air	hot surface	cold surface	cold air
1	80.9	67.4	40.2	26.3
2	81.2	67.6	39.8	26.2
3	81.3	67.3	40.1	25.9
4	81.0	67.2	39.9	26.2
5	80.7	66.9	39.7	25.9
6	80.2	67.3	40.1	26.0
7	78.8	66.0	38.9	24.7
8	78.3	65.7	38.6	24.2
9	78.6	65.8	38.8	23.9
Average temp.	80.1	66.8	39.6	25.5
Total power input (heater + fan), W			224	

r_h = 0.0482 Km^2/W = 0.274 F ft^2/(Btu/h)

r_c = 0.0511 Km^2/W = 0.290 F ft^2/(Btu/h)

R = 0.0985 Km^2/W = 0.559 F ft^2/(Btu/h)

R_u = 0.198 Km^2/W = 1.12 F ft^2/(Btu/h)

U = 5.06 W/Km^2 = 0.889 (Btu/h)/F ft^2