HOLOMETRIX, INC.

Report on

THE THERMAL PERFORMANCE OF A CRAWL SPACE SYSTEM CONTAINING REFLECTIX REFLECTIVE INSULATION

Prepared for:

Reflectix inc.

P.O. Box 108
(317) 533-4332
1-800-879-3645
FAX (317) 533-2327

Holometrix Report Number REF-3-1

Work Performed Under Purchase Order No. 521S

Submitted by: Andre' Desjarlais
A. O. Desjarlais
Manager
Thermal Insulation Evaluation
Thermophysics Laboratory

January 1991

Report on

THE THERMAL PERFORMANCE OF A CRAWL SPACE SYSTEM CONTAINING REFLECTIX REFLECTIVE BATT INSULATION

Holometrix, Inc. was contracted by Reflectix, Inc. to measure the thermal performance of a crawl space system containing Reflectix reflective insulation in accordance with ASTM C 236-89, "Steady-State Thermal Performance of Building Assemblies by Means of a Guarded Hot Box" with vertical heat flow down.

The crawl space system was constructed by Holometrix personnel. It was comprised of 2 x 10 studs mounted 16 inches on center and sheathed on the interior hot side with 1/2 inch plywood. For the experiment, Reflectix staple tab reflective insulation was installed over the studs on the cold side. This reflective insulation was a 1/4 inch thick bubble product with foil on both sides. This product was also supplied in a 16 inch wide roll and had 1 inch wide staple tabs on each side.

Additional temperature instrumentation was attached to the interior side of the sheathing and reflective insulation for measuring the cavity temperature difference. Nine temperature sensors were mounted in an equal area array in the metering area of the central cavity. Three temperature sensors were embedded on each side of the central stud to measure its temperature difference. The measurements performed on this system were undertaken with a cavity mean temperature and temperature difference of 75 and 30°F, respectively.

Surface-to-surface and air-to-air thermal performance data for the insulation systems are reported in Tables 1 and 2, respectively. The cavity thermal resistance of the reflective insulation system was determined following the guidelines of the proposed ASTM Standard Specification for "Reflective Insulation for Building Applications." The cavity thermal resistance, R_{cav}, was calculated from

$$R_{cav} = (dT_{cav}) * A_{cav}/(Q_{total} - Q_{stud}) ,$$

where

dT_{cav} = temperature difference across cavity as measured by T/Cs mounted on the interior of the sheathing;

A_{cav} = the amount of cavity in the metering area of the panel;

Q_{total} = total metering box energy input; and

Q_{stud} = heat flow through studs calculated with the temperature measurements of the T/Cs in the studs and the R-values of the studs.

These results are presented in Table 3.

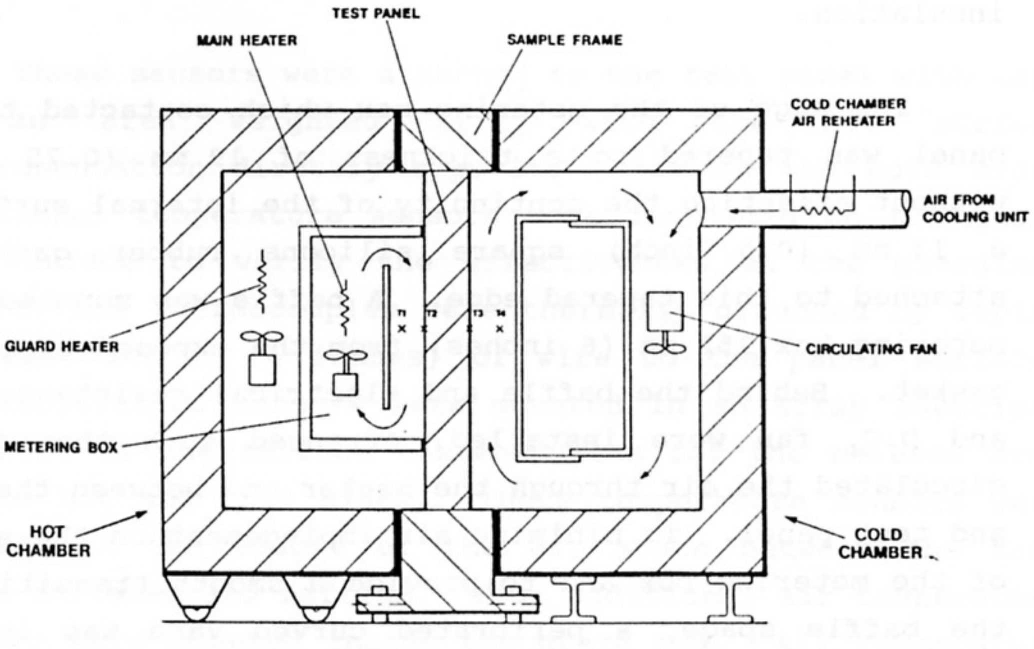
The calculated thermal transmittance and overall thermal resistance of the crawl space system are presented in Table 4. The surface-to-surface properties were combined with standard values for the airfilms extracted from the ASHRAE Handbook of Fundamentals. It was assumed that the air was still on both sides of the system.

Experimental Procedure for Testing by C 236-89

The test panels were evaluated in accordance with ASTM C 236-89, "Steady-State Thermal Performance of Building Assemblies by Means of a Guarded Hot Box". A schematic diagram of the test facility is shown in Figure 1. The test panel was installed vertically in the center of a 2.4 by 2.4 by 2.4 m (96 by 96 by 96 inch) insulated chamber. The periphery of the test panel was insulated with an extruded polystyrene foam. The thickness of the peripheral foam insulation was equivalent to that of the test panel. Insertion of the test panel across the center of the chamber created two separate chambers whose temperatures could be independently controlled.

In the cold environmental chamber, a baffle was mounted 152 mm (6 inches) from the test panel. Temperature control in this chamber was accomplished by the insertion of a refrigeration system and an electrical resistance heater in series with an air blower. The refrigeration system was operated continuously and reheating of the air stream was monitored and controlled by temperature sensors in the discharge of the air circulation system. The arrangement of the equipment was such that the air was forced through the refrigerating coils, heater, and the space between the baffle and the test panel. The air velocity parallel to the cold surface of the test panel was controlled to 0.2 m sec^{-1} (0.4 mph).

In the center of the hot chamber a 1.22 by 1.22 by 0.61 m (48 by 48 by 24 inch) metering box was pressed against the test panel. The walls of the metering box were constructed of 50 mm (2 inch) thick aged extruded polystyrene foam having an approximate thermal resistance of $1.8 m^2 K W^{-1}$ (10 hr ft^2F Btu^{-1}) at 24°C (75°F). These walls



GUARDED HOT BOX FACILITY FOR LARGE-SCALE THERMAL PERFORMANCE TESTING

Heat flow through the test panel is determined by measuring the total electrical power input to the heaters inside the metering box. Heat flow across the walls of the metering box is prevented by careful control of the guard heaters in the hot chamber. The overall thermal resistance, R, of the test panel is calculated as follows:

$$R = \frac{S(T_2 - T_3)}{EI}$$

The thermal transmittance, U, is determined from the equation:

$$U = \frac{EI}{S(T_1 - T_4)}$$

Where

E = metering box heater voltage

I = metering box heater current

S = area of metering box opening

T_1 = air temperature, hot side

T_2 = surface temperature, hot side

T_3 = surface temperature, cold side

T_4 = air temperature, cold side

Figure 1.

SCHEMATIC OF GUARDED HOT BOX FACILITY

were reinforced with an aluminum frame on the interior and exterior surfaces with no physical connections through the insulation.

The edge of the metering box which contacted the test panel was tapered to a thickness of 19 mm (0.75 inches) without affecting the continuity of the internal surface and a 13 mm (0.5 inch) square silicone rubber gasket was attached to this tapered edge. A baffle was mounted in the metering box 152 mm (6 inches) from the exposed edge of the gasket. Behind the baffle and electrical resistance heater and D.C. fan were installed, arranged such that the fan circulated the air through the heater and between the baffle and test panel. To minimize air impingement on the surfaces of the metering box and to provide a smooth transition into the baffle space, a perforated curved vane was installed near the edge of the baffle.

A thirty-junction (fifteen pair) differential thermopile was applied on the interior and exterior walls of the metering box to sense the temperature imbalance between the metering and guard boxes. Each interior junction was mounted opposite a corresponding exterior junction with each junction located at the center of equivalent surface areas. Two heaters and fans were mounted in the guard box in opposing corners to supply heat and to circulate the air. The orientation of these units was chosen to prevent the heated air from directly impinging upon the metering box.

Temperature measurements were performed by utilizing Type T Copper/Constantan thermocouples calibrated to the special limits of error specified in ASTM E 230-83, "Temperature-Electromotive Force (EMF) Tables for Standardized Thermocouples". All thermocouple sensors were fabricated with No.30 AWG wire. Ten thermocouples were used for measuring the hot and cold test panel surface temperatures in the metering section.

These sensors were attached to the test panel with tape in an area weighted array with the hot surface instrumentation directly opposite those on the cold side. Additional temperature sensors were installed on the guard hot surface to verify the effectiveness of the guarding. All surface thermocouples were thermally grounded by taping at least 100 mm (4 inches) of wire to the panel surface. Air temperature sensors were mounted in an array identical to those of the surface thermocouples for the metered area on the hot and cold sides. These temperature sensors were mounted in the middle of the air space between the test panel surfaces and baffles. Four additional air temperature sensors were mounted inside the guard box. All temperature sensors were individually connected to a digital millivolt meter having a resolution of 1 microvolt.

In operation, a controllable D.C. power supply was utilized to maintain the required hot surface temperature. A separate D.C. power supply was used to supply energy to the metering box fan. The air velocity in the metering box was controlled by adjustment of this energy input. The air velocity for this series of experiments was 0.3 m sec^{-1} (0.7 mph). The output of the differential thermopile was used to drive the heaters in the guard box by utilizing a differential controller. By this technique the temperature difference across the walls of the metering box could be minimized, thereby permitting negligible heat leaks into or out of the metering box. The temperature of the cold environmental chamber was set at the desired level. These conditions were maintained until temperatures and heat flows equilibrated. The heat flow generated by the heater and fan in the metering box was measured with precision resistor networks which had been previously calibrated with a NIST traceable voltage source. Once steady-state was achieved, the test period was continued until two consecutive four-hour periods produced results that varied by less than one percent. The data for each four-hour period was the average of hourly results for the period.

The thermal conductance was calculated by

$$C = \frac{q_H + q_F}{A(t_1 - t_2)} \quad ;$$

the thermal transmittance was calculated by

$$U = \frac{q_H + q_F}{A(t_H - t_C)} \quad ;$$

the thermal resistance was calculated by

$$R = \frac{A(t_1 - t_2)}{q_H + q_F} \quad ; \text{ and}$$

the overall thermal resistance was calculated by

$$R_u = \frac{A(t_H - t_C)}{q_H + q_F} \quad ;$$

where C = thermal conductance,
q_H = metering box heater power,
q_F = metering box fan power,
A = sample area,
t_1 = area weighted average hot surface temperature,
t_2 = area weighted average cold surface temperature,
U = thermal transmittance,

t_H = average hot air temperature,
t_C = average cold air temperature,
R = thermal resistance, and
R_u = overall thermal resistance.

The results are presented in the following tables.

An accuracy statement based on standard propagation of error techniques is not included because judgement is required in identifying all sources of error, and only estimates could be used in quantifying these errors. However, measurements have been undertaken on homogeneous test specimens from lots of material that have been evaluated by guarded hot plate instrumentation (ASTM C 177) previously verified utilizing the National Institute of Standards and Technology Transfer Standards. Results have been found to agree within the NIST's quoted uncertainty on the standards used. Holometrix also participated in the round-robin noted in the ASTM C 236 Standard Section 11.1. This series of tests indicated that results with a precision of better than thirteen percent may be achieved.

TABLE 1

THE THERMAL CONDUCTANCE AND THERMAL RESISTANCE OF A CRAWL SPACE CONTAINING REFLECTIX REFLECTIVE INSULATION MATERIAL

							Surface to Surface Properties			
Specimen	Surface Temperature, C			Surface Temperature, F			Thermal Conductance		Thermal Resistance	
	HS	CS	MEAN	HS	CS	MEAN	W/m^2 K	Btu/hr ft^2 F	m^2 K/W	hr ft^2 F/Btu
Reflectix	32.7	14.2	23.4	90.8	57.6	74.2	0.499	0.0880	2.00	11.36

TABLE 2

THE THERMAL TRANSMITTANCE AND OVERALL THERMAL RESISTANCE OF A CRAWL SPACE CONTAINING REFLECTIX REFLECTIVE INSULATION MATERIAL

							Air to Air Properties			
Specimen	Air Temperature, C			Air Temperature, F			Thermal Transmittance		Overall Thermal Resistance	
	HS	CS	MEAN	HS	CS	MEAN	W/m^2 K	Btu/hr ft^2 F	m^2 K/W	hr ft^2 F/Btu
Reflectix	34.0	11.1	22.5	93.1	52.0	72.6	0.404	0.0711	2.48	14.06

TABLE 3

THE CAVITY THERMAL CONDUCTANCE AND THERMAL RESISTANCE OF A CRAWL SPACE CONTAINING REFLECTIX REFLECTIVE INSULATION

Specimen	Cavity Surface Temperature, F			Stud Temperature, F			Cavity Thermal Conductance		Cavity Thermal Resistance	
	HS	CS	MEAN	HS	CS	MEAN	W/m^2 K	Btu/hr ft^2 F	m^2 K/W	hr ft^2 F/Btu
Reflectix	88.9	60.8	74.8	90.3	61.4	75.9	0.604	0.106	1.66	9.40

TABLE 4

THE CALCULATED THERMAL TRANSMITTANCE AND OVERALL THERMAL RESISTANCE OF A CRAWL SPACE CONTAINING REFLECTIX REFLECTIVE INSULATION MATERIAL

	Calculated Air to Air Properties			
Specimen	Thermal Transmittance		Overall Thermal Resistance	
	W/m^2 K	Btu/hr ft^2 F	m^2 K/W	hr ft^2 F/Btu
Reflectix	0.337	0.0594	2.97	16.84