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Johns Manville Technical Center
P.O. Box 625005
Littleton, CO 80162-5005
(303) 978-5200 FAX (303) 978-3123

JOHNS MANVILLE TECHNICAL CENTER
Thermal Testing Laboratory
September 6, 2013

Subject:

ASTM C1363 Hot Box Apparatus Testing of Sealed "N" Safe, LLC Metal Building Wall and Roof Systems

For:
Sealed "N" Safe
320 West 100 North
Ephraim, UT 84627

Submitted by:
Johns Manville Technical Center
PO Box 625005
Littleton, CO 80162-5005

Reported by:

Jeff Owens
Laboratory Lead
R&D Applied Technology

Approved by:

Amy Ferryman
Product Testing Laboratory Manager
R&D Applied Technology

Approved by:

Souvik Nandi
Product Development and Testing Leader
R&D Applied Technology

NVLAP ® NATIONAL VOLUNTARY LABORATORY ACCREDITATION PROGRAM FOR SELECTED TEST METHODS FOR THERMAL INSULATIONS

NVLAP LAB CODE 100425-0

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Introduction

Four calibrated hot box tests were conducted from July 30th, 2013 to August 20th, 2013 to measure the thermal performance of simulated metal building wall and roof assemblies using a Calibrated Hot Box Apparatus (CHBA) located at the Johns Manville Technical Center (JMTC) 10100 West Ute Ave, Littleton, Colorado 80127. These tests were performed for Craig Oberg of Sealed "N" Safe for the purpose of better understanding the heat flows, R-values and thermal performance of standard metal building wall and roof constructions using Sealed "N" Safe's proprietary polyisocyanurate thermal blocks. One cavity filled system was tested as a roof assembly (horizontal sample orientation, heat flow up) and three draped (continuous) systems were tested as wall constructions (wall systems tested vertically) installed in typical metal building configurations with the exception of the thermal blocks. The metal building assemblies were constructed using typical fastening methods utilizing common metal building components.

Sample Description

The following metal building insulation systems were tested:

Sample 1 (4" Top 6" Bottom) - The client provided a system consisting of two 8 inch purlins spaced 60 inches on center. Thermal blocks were fastened to the purlins and wood frame. R-13 metal building insulation was then placed over the top of purlins and the 1 inch thick polyisocyanurate thermal blocks. Fluted metal panels with corrugations spaced 12 inches on center were attached to the top of the insulation and thermal blocks. R-19 wide roll metal building insulation laminated to a white PSK facing with extended tabs was used to fill the cavities created by the purlins. The assembly was further supported by three 2 inch wide by ½ inch deep by 0.020 inch thick metal channels spaced 30 inches on center screwed to the bottom of the purlins and wooded frame. The entire assembly was installed within a 2 inch x 10 inch wood frame with exterior dimensions approximating the interior dimensions of the sample test frame. The product is identified as "Sample 1." See Figure 1 below.

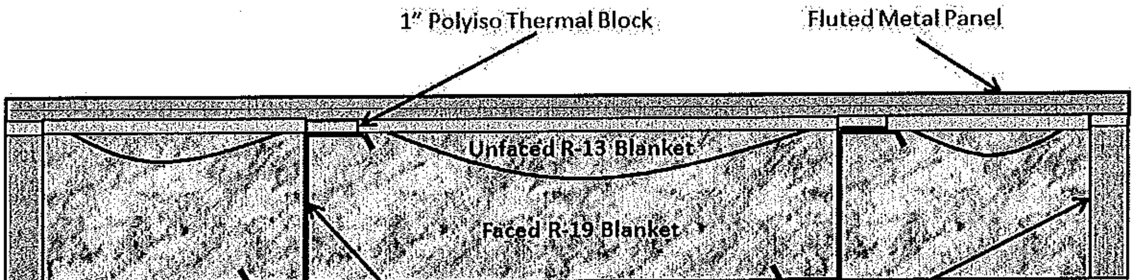

Figure 1

Sample Description (continued)

Sample 2 (4" Top 4" Bottom) - The client provided a system consisting of two 8 inch purlins spaced 60 inches on center. Thermal blocks were fastened to the purlins and wood frame. R-13 metal building insulation was then placed over the top of purlins and the 1 inch thick polyisocyanurate thermal blocks. Fluted metal panels with corrugations spaced 12 inches on center were attached to the top of the insulation and thermal blocks. R-13 wide roll metal building insulation laminated to a white PSK facing with extended tabs was used to fill the cavities created by the purlins. The entire assembly was installed within a 2 inch x 8 inch wood frame with exterior dimensions approximating the interior dimensions of the sample test frame. The product is identified as "Sample 2." See Figure 2 below.

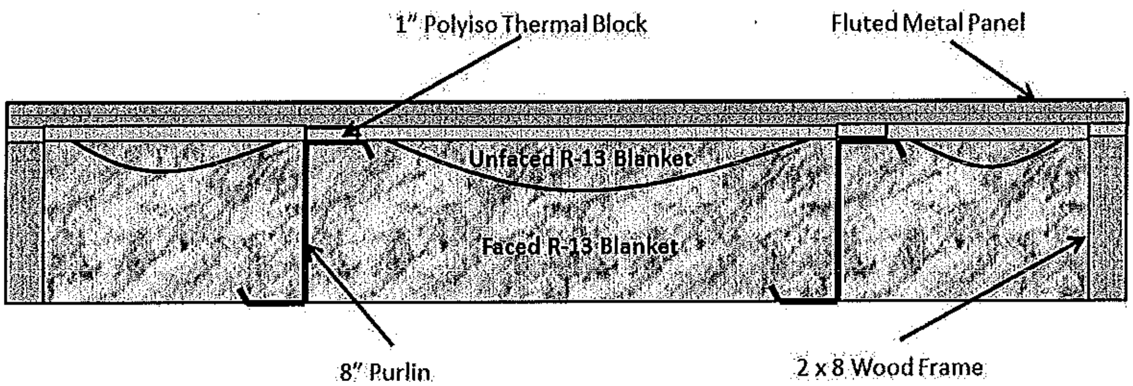

Figure 2

Sample 3 (4" Top) - The client provided a system consisting of two 8 inch purlins spaced 60 inches on center. R-13 wide roll metal building insulation laminated to a white PSK facing was installed over the purlins layered with 1 inch thick polyisocyanurate foam blocks. Fluted metal panels with corrugations spaced 12 inches on center were attached to the top of the insulation and thermal blocks. The entire assembly was installed within a 2 inch x 8 inch wood frame with exterior dimensions approximating the interior dimensions of the sample test frame. The product is identified as "Sample 3." See Figure 3 below.

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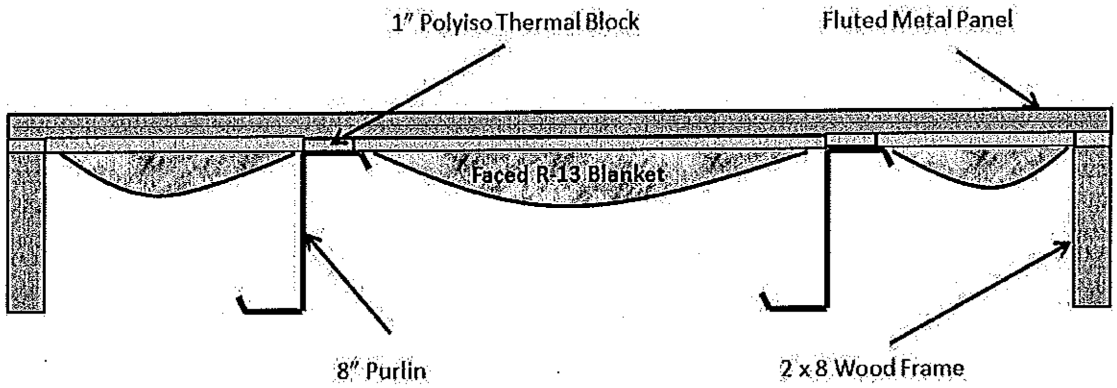

Figure 3

Sample 4 (3" Top) - The client provided a system consisting of two 8 inch purlins spaced 60 inches on center. R-10 wide roll metal building insulation laminated to a white PSK facing was installed over the purlins layered with 1 inch thick polyisocyanurate foam blocks. Fluted metal panels with corrugations spaced 12 inches on center were attached to the top of the insulation and thermal blocks. The entire assembly was installed within a 2 inch x 8 inch wood frame with exterior dimensions approximating the interior dimensions of the sample test frame. The product is identified as "Sample 4." See Figure 4 below.

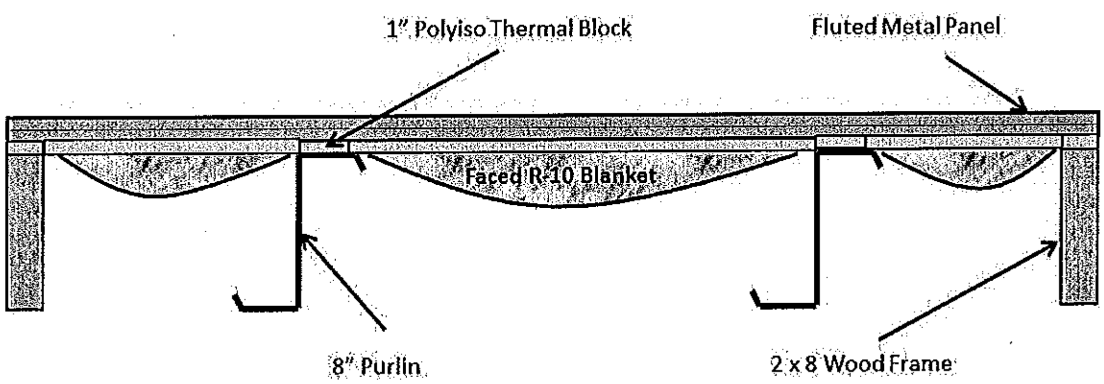

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Figure 4
Test Methods

ASTM C1363: Standard Test Method for the Thermal Performance of Building Assemblies by Means of a Hot Box Apparatus. This test method covers the laboratory measurement of heat transfer through a specimen under controlled air temperature, air velocity, and thermal radiation conditions established in a metering chamber on one side and in a climatic chamber on the other side. Under steady state conditions, power inputs and chamber temperatures were measured and then used to calculate the test results.

The test samples were preconditioned at laboratory conditions prior to the testing of the panel assemblies. The materials were then assembled within a wood frame that was installed within the Hot Box Apparatus (HBA) frame with a total metering area of 80 square feet (10 feet long by 8 feet high). The last calibration check of the system was conducted on May 8, 2013.

The inside and outside surfaces of the test assemblies, exposed to both hot metering chamber and cold environmental chamber conditions, were each instrumented with 24 thermocouples (TCs) to allow for surface temperature measurement. The 24 thermocouples (TCs) were also used to measure the air temperature on each side of the sample. A combination of foam, fiberglass insulation, and duct tape was used to seal all gaps surrounding the frame to minimize heat loss due to air infiltration. Sample 1 was tested in a horizontal orientation as a roof with upward heat flow. Samples 2, 3, & 4 were tested in a vertical orientation as a wall with horizontal heat flow.

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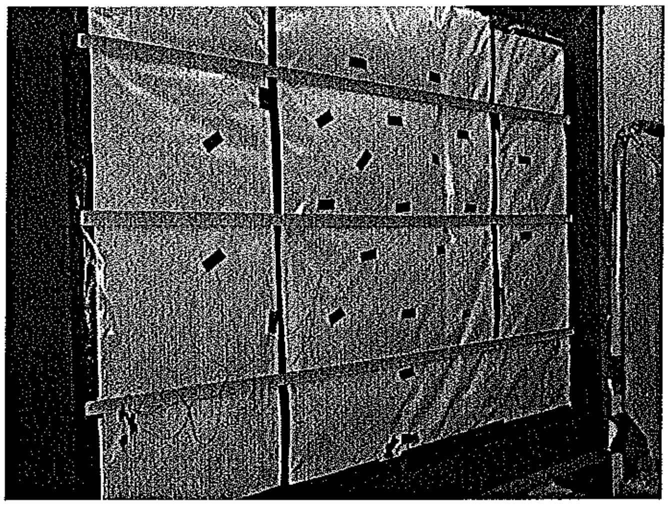
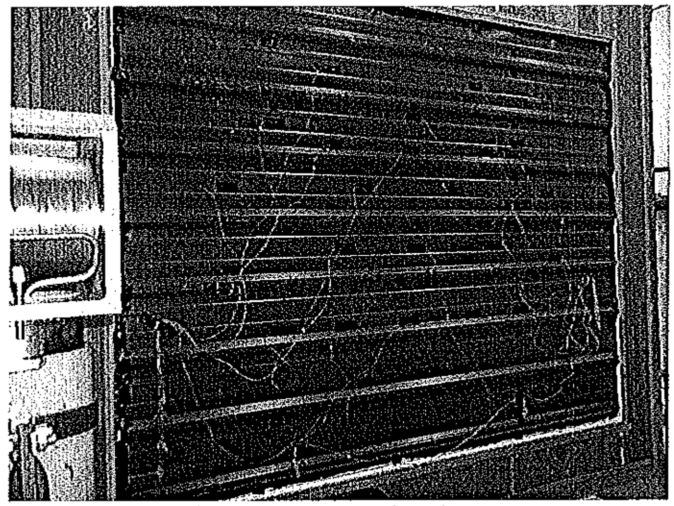
Sample Pictures



Warm Side Thermocouple Placement



Cold Side Thermocouple Placement

All sample configurations were tested with the same thermocouple orientation.

Results

The summarized results for each test are listed below. Details of the testing can be found in Appendix I. The uncompiled results of this test series are kept on record within the laboratory. The test specimen R-value and U-value results were corrected to remove the influence of the wood framing by use of the framing correction methodology listed at the end of Appendix I. Specimen thickness for configurations 3 and 4 were determined by averaged measurements taken in three cavity areas (A, B, and C), see Figure 5 below.

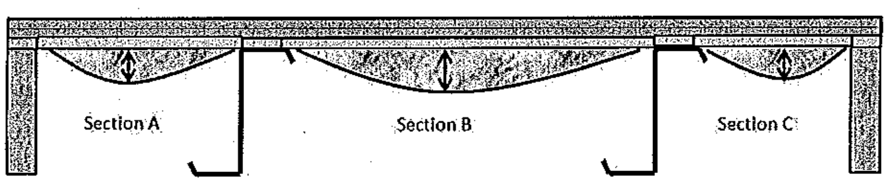


Figure 5

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Sample 1- Roof Configuration (Vertical heat flow up from facing to the steel panel)
Test Date: July 30, 2013 – August 1, 2013
Perimeter Thickness: 10.25" (26.0 cm)
Specimen Thickness: 10.25" (26.0 cm)
Air Mean Temperature: 74.9°F (23.8°C, 297.0°K)
Air Temperature Difference: 50.3°F (10.2°C, 283.3°K)

English Units

Configuration: Corrugated steel panel, unfaced R-13 fiber glass, 1" thick thermal block, 8" Z-purlin/girt 60" on center, PSK faced R-19 fiber glass cavity insulation	C1363 R-Value/U-Value: Air-to-Air (hr•ft²•°F/Btu) / (Btu/hr•ft²•°F)	C1363 R-Value/U-Value: Surface-to-Surface (hr•ft²•°F/Btu) / (Btu/hr•ft²•°F)
Vertical Heat Flow Up	R-24.69 / U-0.041	R-23.70/ U-0.042

Metric Units

Configuration: Corrugated steel panel, unfaced R-2.3 fiber glass, 25.4 mm thick thermal block, 203 mm Z-purlin/girt 1524 mm on center, R-3.3 fiber glass cavity insulation	C1363 R-Value/U-Value: Air-to-Air (m²•K/W) / (W/m²•K)	C1363 R-Value/U-Value: Surface-to-Surface (m²•K/W) / (W/m²•K)
Vertical Heat Flow Up	R-4.35 / U-0.230	R-4.17 / U-0.240

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Results (continued)

Sample 2- Wall Configuration (Horizontal heat flow from facing to the steel panel)
Test Date: August 6, 2013 – August 8, 2013
Perimeter Thickness: 9.5" (24.1 cm)
Specimen Thickness: 9.5" (24.1 cm) average insulation thickness.
Air Mean Temperature: 75.3°F (24.1°C, 297.2°K)
Air Temperature Difference: 50.5°F (10.3°C, 283.4°K)

English Units

Configuration: Corrugated steel panel, unfaced R-13 fiber glass, 1" thick thermal block, 8" Z-purlin/girt 60" on center, PSK faced R-13 fiber glass cavity insulation	C1363 R-Value/U-Value: Air-to-Air (hr•ft²•°F/Btu) / (Btu/hr•ft²•°F)	C1363 R-Value/U-Value: Surface-to-Surface (hr•ft²•°F/Btu) / (Btu/hr•ft²•°F)
Horizontal Heat Flow	R-20.83 / U-0.048	R-19.89/ U-0.050

Metric Units

Configuration: Corrugated steel panel, unfaced R-2.3 fiber glass, 25.4 mm thick thermal block, 203 mm Z-purlin/girt 1524 mm on center, PSK faced R-2.3 fiber glass cavity insulation	C1363 R-Value/U-Value: Air-to-Air (m²•K/W) / (W/m²•K)	C1363 R-Value/U-Value: Surface-to-Surface (m²•K/W) / (W/m²•K)
Horizontal Heat Flow	R-3.66 / U-0.273	R-3.50/ U-0.286

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Results (continued)

Sample 3- Wall Configuration (Horizontal heat flow from facing to the steel panel)

Test Date: August 9, 2013 – August 11, 2013
Perimeter Thickness: 9.0" (22.9 cm)
Specimen Thickness: 4.8" (12.2 cm) average insulation thickness.
Air Mean Temperature: 75.1°F (23.9°C, 297.1°K)
Air Temperature Difference: 49.9°F (9.9°C, 283.1°K)

English Units

Configuration: Corrugated steel panel, PSK faced R-13 fiber glass, 1" thick thermal block, 8.0" Z-purlin/girt 60" on center.	C1363 R-Value/U-Value: Air-to-Air (hr•ft²•°F/Btu) / (Btu/hr•ft²•°F)	C1363 R-Value/U-Value: Surface-to-Surface (hr•ft²•°F/Btu) / (Btu/hr•ft²•°F)
Horizontal Heat Flow	R-7.73 / U-0.129	R-7.24/ U-0.138

Metric Units

Configuration: Corrugated steel panel, PSK faced R-2.3 fiber glass, 25.4 mm thermal block, 203 mm Z-purlin/girt 1524 mm on center.	C1363 R-Value/U-Value: Air-to-Air (m²•K/W) / (W/m²•K)	C1363 R-Value/U-Value: Surface-to-Surface (m²•K/W) / (W/m²•K)
Horizontal Heat Flow	R-1.36 / U-0.735	R-1.28/ U-0.784

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Results (continued)

Sample 4- Wall Configuration (Horizontal heat flow from PSK facing to the steel panel)

Test Date: August 18, 2013 – August 20, 2013
Perimeter Thickness: 9.0" (20.96 cm)
Specimen Thickness: 5.1" (12.8 cm) average insulation thickness.
Air Mean Temperature: 75.2°F (24.0°C, 297.2°K)
Air Temperature Difference: 50.2°F (10.1°C, 283.35°K)

English Units

Configuration: Corrugated steel panel, PSK faced R-10 fiber glass, 1" thick thermal block, 8.0" Z-purlin/girt 60" on center.	C1363 R-Value/U-Value: Air-to-Air (hr•ft²•°F/Btu) / (Btu/hr•ft²•°F)	C1363 R-Value/U-Value: Surface-to-Surface (hr•ft²•°F/Btu) / (Btu/hr•ft²•°F)
Horizontal Heat Flow	R-7.03 / U-0.142	R-6.43/ U-0.156

Metric Units

Configuration: Corrugated steel panel, PSK faced R-1.8 fiber glass, 25.4 mm thermal block, 203 mm Z-purlin/girt 1524 mm on center.	C1363 R-Value/U-Value: Air-to-Air (m²•K/W) / (W/m²•K)	C1363 R-Value/U-Value: Surface-to-Surface (m²•K/W) / (W/m²•K)
Horizontal Heat Flow	R-1.24 / U-0.808	R-1.13/ U-0.883

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Appendix 1
Summarized Data - Calculation Inputs

	Sample 1	Sample 2	Sample 3	Sample 4
Input:	Roof	Wall	Wall	Wall
Metering Chamber (MC) Temperatures				
Avg. MC Air Temperature, F	100.1	100.6	100	100.3
Avg. MC Specimen Surface, F	98.7	99	97.9	97.3
Average Differential Inside MC Surface, F	100.0	100.4	100.0	100.3
Average Differential Outside MC Surface, F	101.2	102.6	102.5	101.9
Climatic Chamber (CC) Temperatures				
Avg. CC Specimen Surface, F	50.2	50.5	51.0	51.2
Avg. CC Air Temperature, F	49.8	50.0	50.1	50.1
Surround Room Temperature				
Avg. Hot Box Surround Room Temperature, F	100.3	101.9	101.8	100.8
Metering Chamber Power Input				
Fan Voltage, volts	12.678	12.678	12.728	12.743
Fan Current, volts (amps = volts/0.10Ω)	0.058	0.058	0.059	0.059
Heater Voltage, volts	14.955	17.165	25.448	27.702
Heater Current, volts (amps = volts/0.10Ω)	0.346	0.397	0.585	0.638
Velocity Sensor Voltage, volts	10.898	10.9	10.901	10.902
Velocity Sensor Current, volts (amps = volts/0.1765Ω)	0.001	0.001	0.001	0.001
Test Assembly (Specimen)				
Frame Test Area (Heat Flow Metering Area), ft2	80.489	80.375	80.489	80.489
Framing Area Perpendicular to Heat Flow, ft2	4.417	4.417	4.417	4.417
Cavity Area Perpendicular to Heat Flow, ft2	76.072	75.958	76.072	76.072
Percent Framing Area, %	5.487	5.495	5.487	5.487
Percent Cavity Area, %	94.513	94.505	94.513	94.513
Test Specimen Thickness, inches	10.25	9.50	9	9.00

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Appendix (continued)

Summarized Data – Calculated Results

CALCULATIONS:				
Area Weighted Surface Temperatures				
MC Surface Temperature, F	98.7	99	97.9	97.3
CC Surface Temperature, F	50.2	50.5	51	51.2
MC Power Input (Qpow)				
Fan Power, Watts	7.37	7.37	7.45	7.49
Heater Power, Watts	51.69	68.18	148.94	176.87
Velocity Sensor Power, Watts	0.07	0.08	0.07	0.07
Total MC Power Input, Watts	59.14	75.62	156.46	184.43
Total MC Power Input, Btu/hr	201.77	258.02	533.85	629.26
MC Wall Heat Flow (Qmcw)				
MC Wall Temperature Difference, F	1.22	2.14	2.53	1.59
MC Wall Heat Flow, Btu/hr	4.62	8.13	9.61	6.02
Infiltration Heat Flow (Qinf)				
Test Specimen Pressure Difference, Pa	1.3	1.3	1.3	1.3
Volumetric Flow Rate of Infiltrated Air, ft3/hr	33.3	70	31.4	83.0
Mass Flow Rate of Infiltrated Air, lb/hr	2.1	4.5	2	5.3
Infiltration Rate, ACH (based on 120 ft3 MC volume)	0.3	0.6	0.3	0.7
Infiltration Heat Flow, Btu/hr	26.73	55.23	24.31	63.73
Flanking Loss Heat Flow (Qfl)				
Flanking Loss Thru Frame Perimeter, Btu/hr	8.37	9.00	9.46	9.47
Net Heat Flow (Qnet=Qpow+Qmcw)				
Net Heat Flow, Btu/hr	206.39	266.15	543.46	635.28
Surface Air Films (Boundary Layers)				
MC Fan Setting	3.0	3	3	3.0
MC Air Film Velocity, fps	0.64	0.62	0.09	0.20
MC Convection Coefficient (hmc), Btu/hr-ft2-F	1.53	1.55	2.96	2.29
CC Fan Setting	9.0	9.0	9	9.0
CC Air Film Velocity, fps	4.54	4.54	4.29	4.37
CC Convection Coefficient (hcc), Btu/hr-ft2-F	4.97	5.45	7.17	6.53
Effective Convection Coefficient (sqrt. heff)	0.795	0.813	1.047	0.950
Specimen Heat Flow (Qsp=Qnet-(Qinf+Qfl)				
Specimen Heat Flow, Btu/hr	171.29	201.92	509.69	562.09
Test Specimen R-value (Rsp):				
Specimen Temperature Difference, F	48.5	48.5	46.8	46.1
Mean Specimen Temperature, F	74.5	74.7	74.5	74.2
Rsp, hr-ft2-F/Btu	22.79	19.29	7.40	6.60

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Appendix (continued)

Summarized Data – Calculated Results

Air to Air R-value (Rair/air):				
Air Temperature Difference, F	50.3	50.5	49.9	50.2
Mean Air Temperature, F	74.9	75.3	75.1	75.2
Rair/air, hr-ft2-F/Btu	23.64	20.12	7.88	7.19
Overall Transmittance (U-value), Btu/hr-ft2-F	**0.042**	**0.05**	**0.127**	**0.1391**
Air Film R-value	**0.86**	**0.83**	**0.48**	**0.59**
Specimen R (Rair to air - Air Film R)	22.8	19.3	7.4	6.60
Specimen Heat Flow With Infiltration, Btu/hr	198.02	257.15	534	625.82
Adjusted Specimen R-value	19.71	15.15	7.06	5.93
Wood Surround Frame Adjustment:				
% Wood surround framing area	5.49	5.50	5.487	5.487
% Sample area	94.513	94.505	94.513	94.513
Framing Resistivity (R/inch)	1.25	1.25	1.25	1.25
Framing Depth, in	10.250	9.5	9	9.000
Framing R-value	12.8125	11.85	11.25	11.25
Air Film R-values	0.86	0.83	0.48	0.59
Total Framing R-value	13.669	12.702	11.727	11.840
Framing U-value	0.0732	0.0787	0.0853	0.0845
Total air to air Tested U-value	**0.4230**	**0.0497**	**0.127**	**0.1391**
Adjusted Sample U-value	**0.0405**	**0.048**	**0.1294**	**0.1423**
Air to Air R-value	**24.69**	**20.83**	**7.73**	**7.03**

Framing Correction Methodology:
Qtot = Qfr + Qsample (parallel path heat flows)
Qtot = UtotAtot(DT)
Qfr = UfrAft(DT)
Qs = UsAs(DT)
hence,
UtotAtot(DT) = UfrAfr(DT) + UsAs(DT)
Utot = Ufr(Afr/Atot) + Us(As/Atot)
Utot = Ufr(% framing) + Us(% specimen)
Utot - Ufr(% framing) = Us(% speciman)
Us = (Utot - Ufr(% framing))/(%sample)