Celotex Corporation
Testing Services

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THERMAL TESTING LABORATORY REPORT

December 17, 1997

Client: Tenneco Packaging - AVI
1411 Pidco Drive
Plymouth, IN 46563

MTS Job No.: 258218C-1

Metro Dade Notification No.: CAE 97273

Project: Thermal Performance of an Astro-Foil Reflective Insulation
Insulated Simulated Concrete Block Wall Assembly

Introduction:

This report summarizes the results of thermal tests conducted on material submitted to our laboratory on August 26, 1997. Testing was completed on November 18, 1997. The scope of the work was limited to conducting the thermal test ASTM C 236-89, "Standard Test Method for Steady-State Thermal Performance of Building Assemblies by Means of a Guarded Hot Box" in the horizontal heat flow direction.

Sample Identification:

Two (2) 48 inch wide rolls of reflective insulation material were supplied by the client and identified as Astro-Foil foil/bubble/bubble/foil reflective insulation. The manufacture of the product was witnessed by J. Bridenstine on July 21, 1997 and documented in a P.E. sealed letter to R&D Services, Incorporated, dated July 23, 1997.

Sample Preparation:

An 8 by 8 foot simulated concrete block wall assembly was fabricated using 5/16 inch thick Astro-Foil reflective insulation, as per the client's request. A nominal 2 x 4 perimeter wood frame was constructed using 1.5 by 3.5 inch studs fastened together with wood screws. Two (2) 3/4 inch plywood sheets were horizontally fastened to the inside of the wood frame with screws to simulate a typical concrete block wall. Six (6) 0.75 by 1.5 inch wood furring strips placed 16 inches on center were attached to the plywood using wood screws. Reflective insulation sections were vertically installed flush with the hot side surface of the furring strip frame using staples to create a 3/4 inch reflective air space. A polystyrene baffle was installed to isolate the 6 by 6 foot metering area. The assembly was completed with two (2) 4 by 8 foot sheets of 1/2 inch gypsum board horizontally placed against the reflective insulation and fastened with wood screws. All butt and perimeter joints were sealed with caulk to prevent air infiltration.

Client: Tenneco Packaging - AVI MTS Job No.: 258218C-1

Test Program

Thirty (30), type T, 30 gauge, thermocouples were used to measure the temperature of the hot and cold side surfaces. Each were area weighted to account for both the wood furring strip frame and internal cavity areas.

The simulated concrete block wall assembly was tested at a 75°F ± 2°F mean specimen test temperature in controlled laboratory conditions of 70 °F and 50% relative humidity. The metering chamber was placed against the gypsum board surface.

Test Results

The following table summarizes the results of the thermal test performed on the Astro-Foil reflective insulation insulated simulated concrete block wall assembly in the horizontal heat flow direction. The systems surface to surface thermal resistance was determined to be 4.8 h ft² °F/Btu.

Reflective Insulation Simulated Concrete Block Wall Assembly Guarded Hot Box Test Results

	Horizontal Heat Flow
Hot Air Temperature, °F	100.7
Hot Surface Temperature, °F	95.1
Cold Surface Temperature, °F	54.6
Cold Air Temperature, °F	49.6
Mean Temperature, °F	74.9
Average Power, Watts	89.90
Hot Surface Coefficient, Btu/h ft² °F	15.21
Cold Surface Coefficient, Btu/h ft² °F	1.699
Thermal Conductance, Btu/h ft² °F	0.210
Thermal Resistance, h ft² °F/Btu	4.8

R Hmaller 2/19/97

Tested by: Russell Woltemar
Russell W. Woltemar

Approved by: Stanley D Gatland II
Stanley D. Gatland II

APPENDIX

MTS JOB NO. 258218C-1

CENTER FOR APPLIED ENGINEERING, INC.
ASTM C236 – Guarded Hot Box

Client: R & D Services
MTS Job No.: 258218
Test Date: 11–18–97 (Completion)

Average Test Results	Hot Chamber	Cold Chamber
Surface Temperature, Deg. F	95.1	54.6
Guard Surface Temperature, Deg. F	94.7	55.6
Air Temperature, Deg. F	100.7	49.6
Guard Air Temperature, Deg. F	98.4	50.2
Air Velocity, *mph*	< 0.5	< 0.5
Surface Coefficient, Btu/(h ft ^ 2 Deg. F)	1.521	1.699

Average Power Input = 89.90 Watts
306.72 Btu/hr

Mean Temperature = 74.9 Deg. F

Thermal Performance Results

Thermal Conductance, C =	0.210 Btu/(h ft ^ 2 Deg. F)
Thermal Resistance, R =	4.8 (h ft ^ 2 Deg. F)/Btu
Thermal Transmittance, U =	0.167 Btu/(h ft ^ 2 Deg. F)
Overall Thermal Resistance, Ru =	6.0 (h ft ^ 2 Deg. F)/Btu

Guarded Hot Box Dimensions: Metering Area = 6 ft. x 6 ft.
Guard Area Width = 1 ft.

Test Panel Construction Details:
Test 4

Client: R & D Services
MTS Job No.: 258218
Test Date: 11 – 18 – 97 (Completion)

	Time (Hr/Min)	Pcwer (Watts)	Tcs (F)	Tcsg (F)	Tca (F)	Tcag (F)	Ths (F)	Thsg (F)	Tha (F)	Tcsg (F)
1	1257	2.7050	54.7	55.7	49.7	50.3	95.2	94.8	100.8	98.4
2	1307	2.8180	54.6	55.6	49.6	50.3	95.2	94.8	100.8	98.3
3	1317	2.9290	54.6	55.6	49.6	50.1	95.2	94.8	100.7	98.2
4	1327	0.0690	54.7	55.6	49.7	50.4	95.2	94.8	100.8	98.3
5	1337	0.1795	54.7	55.7	49.7	50.4	95.2	94.7	100.8	98.3
6	1347	0.2900	54.7	55.7	49.8	50.3	95.2	94.8	100.8	98.7
7	1357	0.3935	54.7	55.7	49.6	50.4	95.2	94.8	100.7	98.6
8	1407	0.5045	54.7	55.7	49.7	50.3	95.2	94.8	100.8	98.4
9	1417	0.6170	54.7	55.7	49.6	50.3	95.1	94.7	100.8	98.2
10	1427	0.7285	54.7	55.7	49.7	50.2	95.2	94.8	100.8	98.2
11	1437	0.8400	54.7	55.7	49.6	50.3	95.2	94.8	100.8	98.2
12	1447	0.9485	54.6	55.7	49.5	50.2	95.1	94.8	100.7	98.6
13	1457	1.0590	54.6	55.6	49.6	50.4	95.1	94.8	100.8	98.3
14	1507	1.1665	54.6	55.6	49.5	50.2	95.2	94.8	100.8	98.3
15	1517	1.2770	54.6	55.6	49.5	50.1	95.2	94.8	100.8	98.2
16	1527	1.3875	54.6	55.6	49.5	50.2	95.2	94.8	100.8	98.3
17	1537	1.4995	54.6	55.6	49.5	50.1	95.2	94.8	100.7	98.8
18	1547	1.6090	54.6	55.5	49.6	50.2	95.1	94.8	100.8	98.4
19	1557	1.7180	54.6	55.6	49.4	50.3	95.1	94.8	100.7	98.4
20	1607	1.8275	54.5	55.6	49.5	50.2	95.1	94.8	100.7	98.3
21	1617	1.9360	54.5	55.6	49.6	50.2	95.2	94.8	100.7	98.3
22	1627	2.0450	54.5	55.5	49.5	50.1	95.1	94.7	100.8	98.3
23	1637	2.1565	54.5	55.5	49.5	50.2	95.1	94.7	100.7	98.2
24	1647	2.2695	54.5	55.5	49.5	50.1	95.1	94.7	100.7	98.3
25	1657	2.3795	54.5	55.5	49.6	50.3	95.1	94.7	100.7	98.2
		'82.65 (Uncorrected)	54.612	55.616	49.584	50.244	95.16	94.776	100.76	98.348

		Time (Hr/Min)	Power (Watts)	Tcs (F)	Tcsg (F)	Tca (F)	Tcag (F)	Ths (F)	Thsg (F)	Tha (F)	Tcsg (F)
*	26	1657	2.3795	54.5	55.5	49.6	50.3	95.1	94.7	100.7	98.2
	27	1707	2.4895	54.5	55.5	49.5	50.2	95.1	94.7	100.8	98.2
	28	1717	2.6000	54.5	55.6	49.6	50.3	95.1	94.7	100.6	98.2
	29	1727	2.7075	54.6	55.6	49.5	50.2	95.1	94.7	100.6	98.1
	30	1737	2.8145	54.5	55.6	49.5	50.4	95.1	94.7	100.6	98.7
	31	1747	2.9260	54.6	55.6	49.5	50.3	95.0	94.7	100.6	98.1
	32	1757	0.0650	54.6	55.6	49.6	50.3	95.1	94.7	100.6	98.9
*	33	1807	0.1765	54.5	55.6	49.5	50.3	95.1	94.7	100.7	98.6
*	34	1817	0.2860	54.5	55.6	49.6	50.2	95.0	94.7	100.6	98.3
	35	1827	0.3945	54.5	55.6	49.5	50.2	95.1	94.6	100.7	98.2
	36	1837	0.5050	54.5	55.6	49.5	50.3	95.1	94.6	100.7	98.2
	37	1847	0.6150	54.6	55.6	49.6	50.2	95.0	94.7	100.7	98.1
	38	1857	0.7255	54.6	55.6	49.6	50.2	95.1	94.7	100.8	98.2
	39	1907	0.8385	54.5	55.5	49.5	50.0	95.1	94.6	100.7	98.7
	40	1917	0.9485	54.5	55.6	49.6	50.1	95.1	94.7	100.7	98.7
	41	1927	1.0550	54.6	55.6	49.5	50.2	95.0	94.7	100.8	98.3
	42	1937	1.1635	54.6	55.6	49.5	50.2	95.1	94.7	100.8	98.3
	43	1947	1.2735	54.6	55.6	49.6	50.1	95.1	94.7	100.7	98.3
	44	1957	1.3840	54.6	55.6	49.6	50.2	95.1	94.7	100.7	98.2
	45	2007	1.4960	54.5	55.6	49.6	50.3	95.1	94.6	100.6	98.1
	46	2017	1.6075	54.6	55.6	49.6	50.2	95.1	94.6	100.7	98.2
	47	2027	1.7175	54.6	55.6	49.5	50.3	95.1	94.7	100.7	98.9
	48	2037	1.8280	54.6	55.6	49.5	50.0	95.1	94.7	100.7	98.6
	49	2047	1.9355	54.5	55.6	49.5	50.2	95.1	94.7	100.7	98.4
*	50	2057	2.0460	54.5	55.6	49.5	50.2	95.1	94.7	100.7	98.4
			82.42 (Uncorrected)	54.5	55.6	49.5	50.2	95.1	94.7	100.7	98.4

	Power	Tcs	Tcsg	Tca	Tcag	Ths	Thsg	Tha	Tcsg
Average Results	82.53 (Uncorrected)	54.6	55.6	49.6	50.2	95.1	94.7	100.7	98.4

89.90 (Qc = Q*1.0661 + 1.9107)
(Corrected)

TENNESSEE TECH UNIVERSITY
Tennessee Technological University
College of Engineering . *Department of Chemical Engineering*
Box 5013 . Cookeville, TN 38505 . 615-372-3297

June 15, 1988

Innovative Energy, Inc.
1119 West 145th Avenue
Crown Point, IN 46307

Attention: Mr. Robert Wadsworth

Dear Mr. Wadsworth:

I have completed a set of calculations based on C 236 measurements reported by Sparrell Engineering Research Corporation Test Reports dated June 13, 1988. The measurements were made in a nominal 2 X 4 cavity. The methodology and factors used in the calculations were part of my April 25th, 1988 letter to you.

Heat Flow Direction	Nominal ΔT °F	R-System $ft^2 \cdot hr \cdot °F/Btu$	R-Cavity(1)	R-Cavity(2)
Down	30	10.4	13.4	15.0
Down	45	9.91	12.5	13.8
Horizontal	30	6.52	7.12	7.31
Horizontal	45	5.55	5.79	5.89
Up	30	5.18	5.31	5.40
Up	45	4.95	5.06	5.10

The calculations that give the R-values in the above table are attached.

Sincerely,

David W. Yarbrough, Chairman
Department of Chemical Engineering

DWY/bh

Enclosures

SPARRELL ENGINEERING RESEARCH CORPORATION
POST OFFICE BOX 130, BRISTOL ROAD
DAMARISCOTTA, MAINE 04543
TEL: 207 563-3224

June 13, 1988

ASTRO VALCOUR INC.
11756 S. Austin Avenue
Alsip, IL 60482

Attention: Mr. Jark J. Mayronne

Reference: Purchase Order No. 24181

Gentlemen:

In accordance with your instructions, we have determined the thermal resistance of a sample of "Foil/Bubble/Bubble/Foil" reflective insulation installed in a studded wall. Tests were performed at two temperature gradients, and with three heat flow directions, horizontal, vertical up and vertical down. These tests were performed using the test method of ASTM C236 and conducted using personnel, procedures, and test equipment as approved under the U. S. Department of Commerce NVLAP Accreditation Program.

The sample was installed in a 36" X 36" test module whose dimensions correspond to the frontal dimensions of the meter box. This module consists of two 36" square, 1/2" thick plywood sheets separated by pine studs (2 X 4) located on 16" centers to simulate a standard studdedstudded wall. Two full cavities plus one partial one results. (see the enclosed sketch, Figure No. 1. The other module sides consist of 1 X 3 pine trim stock. The sample was installed midway between the two plywood faces and was stapled (from the hot side) using 1" strip tabs of the test material bent upwards.

The test module was installed in the aperture of a test frame whose outer dimension are 67" X 67" and correspond to the outer dimensions of the guard and cold boxes. The 36" X 36" aperture aligns in the instrument with the facial gasket of the meter box. The test frame itself is an insulated structure 5" thick, with 1 X 6 pine forming the outer edge and the edge towards the aperture. The faces of the test frame are 1/4" Luan and the inside if filled with fiberglass insulation.

The test frame containing the mounted test module is installed in the instrument as shown in the sketch of Figure No. 2. Thermocouples 5 distributed in each location, hot side air, hot side cavity (inside plywood), cold side cavity (inside plywood), and cold side air, are used to measure temperatures. Two additional thermocouples are attached to the exterior of the plywood, one centered over a cavity, and one centered over a stud. All thermocouples are 28 gauge type T.

The temperature of the refrigerated coolant supplied to the cold box, and the power supplied to the meter box were adjusted to provide the desired air temperature difference and the average temperature. For each test, at least 24 hours elapsed and then readings were taken at several hour intervals to insure thermal equilibrium test conditions.

From the power dissipated in the meter box and the temperatures as measured, the cavity and air to air thermal resistances were determined. These values as well as others determined are presented in the enclosed tables. It should be noted that these R values are for a system including the studs. The effect of the studs is to lower the true value for the reflective insulation alone.

We appreciate the opportunity to perform these measurements for you, and we look forward to being of service to you again in the future.

Very truly yours,
SPARRELL ENGINEERING RESEARCH CORPORATION

James K. Sparrell
President

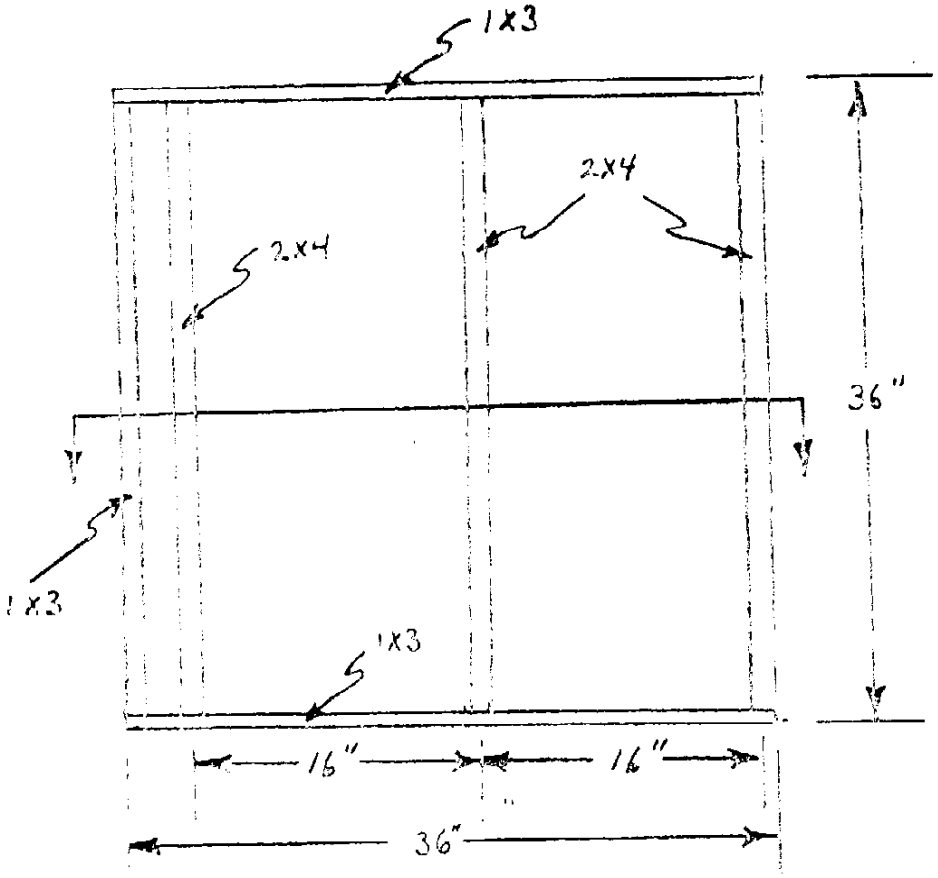
JKS/eos

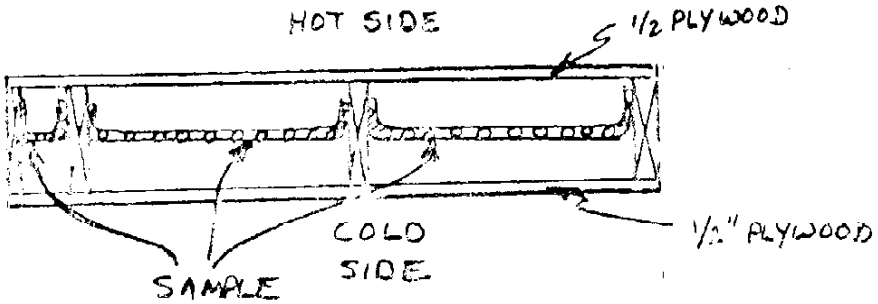
cc: Robert Wadsworth, Innovative Energy

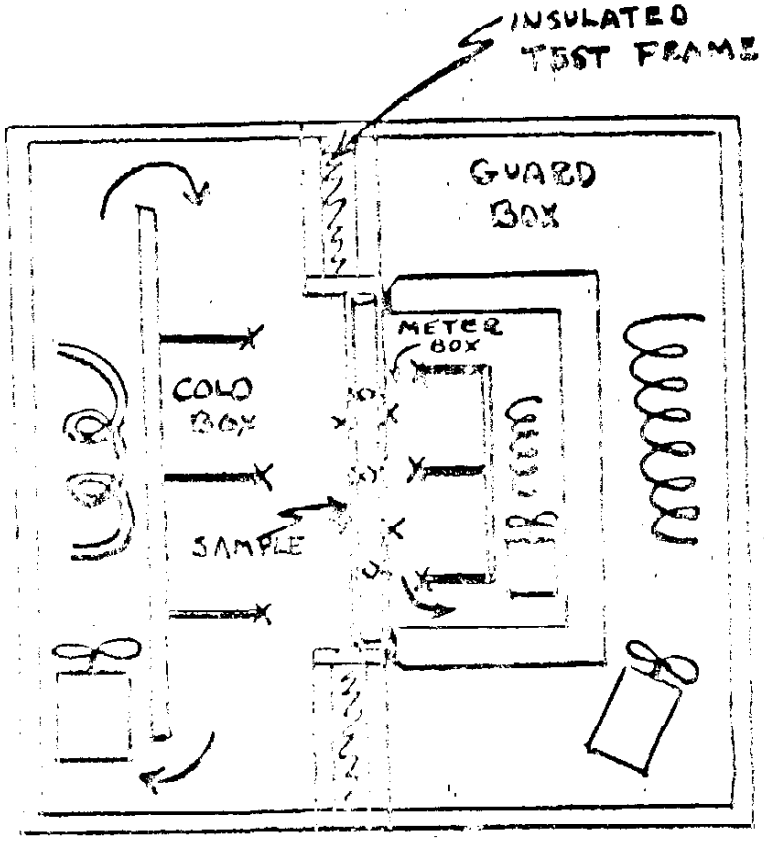
The name of our firm may not be used in any published sales literature without our written permission. Reference to NVLAP may not be made in any published literature.

FIGURE NO. 1

TEST MODULE WITH SAMPLE INSTALLED







X DENOTES THERMOCOUPLE LOCATIONS

← DENOTES AIR FLOW

ASTM C236 GUARDED HOT BOX

FIGURE 2

TEST REPORT

ASTRO VALCOUR INC.
11756 S. Austin Avenue
Alsip, IL 60482

June 13, 1988

Attention: Mr. Mark J. Mayronne

Reference: Purchase Order No. 24181

Subject: Thermal Resistance Tests on "Foil/Bubble/Bubble/Foil"

Test Method: ASTM C236

Sample orientation	Vertical	
Heat flow direction	Horizontal	
Nominal air temperature difference, °F	30	45
Hot side air temperature, °F	87.39	95.78
Hot side plywood surface temperature, °F	86.81	94.57
(center of cavity), °F	(86.91)	(94.74)
(stud), °F	(86.70)	(94.39)
Hot side cavity surface temperature, °F	84.27	90.74
Cold side cavity surface temperature, °F	62.27	57.82
Cold side plywood surface temperature, °F	60.45	54.77
(center of cavity), °F	(60.43)	(54.77)
(stud), °F	(60.48)	(54.77)
Cold side air temperature, °F	58.91	52.36
Heat flux, Btu/hr-ft^2-°F	3.375	5.933
Temperature difference, air to air, °F	28.48	43.42
Average temperature, air to air, °F	73.17	74.28
Conductance, air to air, U, Btu/hr-ft^2-°F	0.119	0.137
Resistance, air to air, R, Hr-ft^2-°F/Btu	8.43	7.31
Temperature difference, cavity, °F	22.00	32.92
Average temperature, cavity, °F	73.27	74.28
Conductance, cavity, C, Btu/hr-ft^2-°F	0.153	0.180
Resistance, cavity, R, Hr-ft^2-°F/Btu	6.52	5.54
Hot side air coefficient, h, Btu/hr-ft^2-°F	5.8	4.9
Cold side air coefficient, h, Btu/hr-ft^2-°F	2.2	2.5
Hot side air velocity, ft/sec	0.4	0.6
Cold side air velocity, ft/sec	1.1	1.1

SPARRELL ENGINEERING RESEARCH CORPORATION

James K. Sparrell
President

TEST REPORT

ASTRO VALCOUR INC.
11756 S. Austin Avenue
Alsip, IL 60482

June 13, 1988

Attention: Mr. Mark J. Mayronne

Reference: Purchase Order No. 24181

Subject: Thermal Resistance Tests on "Foil/Bubble/Bubble/Foil"

Test Method: ASTM C236

Sample orientation	Horizontal	
Heat flow direction	Down	
Nominal air temperature difference, °F	30	45
Hot side air temperature, °F	89.48	99.00
Hot side plywood surface temperature, °F	88.24	98.11
(center of cavity), °F	(88.26)	(98.22)
(stud), °F	(88.22)	(98.00)
Hot side cavity surface temperature, °F	87.39	95.87
Cold side cavity surface temperature, °F	61.32	56.95
Cold side plywood surface temperature, °F	60.09	55.00
(center of cavity), °F	(60.09)	(55.00)
(stud), °F	(60.09)	(55.00)
Cold side air temperature, °F	58.95	53.14
Heat flux, Btu/hr-ft^2-°F	2.502	3.928
Temperature difference, air to air, °F	30.53	45.86
Average temperature, air to air, °F	74.22	76.07
Conductance, air to air, U, Btu/hr-ft^2-°F	0.0820	0.0857
Resistance, air to air, R, Hr-ft^2-°F/Btu	12.2	11.7
Temperature difference, cavity, °F	26.07	38.92
Average temperature, cavity, °F	74.36	76.41
Conductance, cavity, C, Btu/hr-ft^2-°F	0.0961	0.1006
Resistance, cavity, R, Hr-ft^2-°F/Btu	10.4	9.94
Hot side air coefficient, h, Btu/hr-ft^2-°F	2.0	3.9
Cold side air coefficient, h, Btu/hr-ft^2-°F	2.2	2.1
Hot side air velocity, ft/sec	0.3	0.4
Cold side air velocity, ft/sec	1.1	1.1

SPARRELL ENGINEERING RESEARCH CORPORATION

James K. Sparrell
President

TEST REPORT

ASTRO VALCOUR INC.
11756 S. Austin Avenue
Alsip, IL 60482

June 13, 1988

Attention: Mr. Mark J. Mayronne

Reference: Purchase Order No. 24181

Subject: Thermal Resistance Tests on "Foil/Bubble/Bubble/Foil"

Test Method: ASTM C236

Sample orientation	Horizontal	
Heat flow direction	UP	
Nominal air temperature difference, °F	30	45
Hot side air temperature, °F	90.35	96.30
Hot side plywood surface temperature, °F	89.09	94.61
(center of cavity), °F	(89.30)	(94.91)
(stud), °F	(88.87)	(94.30)
Hot side cavity surface temperature, °F	86.39	90.48
Cold side cavity surface temperature, °F	64.73	59.32
Cold side plywood surface temperature, °F	62.32	55.47
(center of cavity), °F	(62.09)	(55.35)
(stud), °F	(62.55)	(55.59)
Cold side air temperature, °F	60.17	52.14
Heat flux, Btu/hr-ft^2-°F	4.188	6.289
Temperature difference, air to air, °F	30.18	44.16
Average temperature, air to air, °F	75.26	74.22
Conductance, air to air, U, Btu/hr-ft^2-°F	0.139	0.142
Resistance, air to air, R, Hr-ft^2-°F/Btu	7.21	7.02
Temperature difference, cavity, °F	21.66	31.16
Average temperature, cavity, °F	75.56	74.90
Conductance, cavity, C, Btu/hr-ft^2-°F	0.193	0.202
Resistance, cavity, R, Hr-ft^2-°F/Btu	5.17	4.95
Hot side air coefficient, h, Btu/hr-ft^2-°F	3.3	3.7
Cold side air coefficient, h, Btu/hr-ft^2-°F	1.9	1.9
Hot side air velocity, ft/sec	0.5	0.7
Cold side air velocity, ft/sec	1.1	1.1

SPARRELL ENGINEERING RESEARCH CORPORATION

James K. Sparrell
President