R&D Services, Inc.
209 Tennessee Blvd.
Watertown, Tennessee 37184

Thermal Resistance of Duct Insulation According to ASTM C335

"Standard Test Method for Steady-State Heat Transfer Properties of Pipe Insulation"

PRODUCT IDENTIFICATION: "Polynum™ FR Double Bubble One 1200"
Reflective Thermal Insulation

REPORT ISSUED TO:

Polynum Insulation Ltd.
Rome 5 St.
Sderot
Israel

REPORT NUMBER: RD231277

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IAS ACCREDITED Testing Laboratory

Stuart Ruis
President

ISO/IEC 17025:2017
Testing Laboratory TL-566

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TEST REPORT PREPARED FOR
Polynum Insulation Ltd.
DATE OF TEST
October 11 – 18, 2023
R&D SERVICES WORK ORDER NUMBER
2178W230911-020
R&D SERVICES PRODUCT NUMBER
230915-007
MANUFACTURE DATE OF SPECIMENS
Unknown

SAMPLE IDENTIFICATION

Reflective thermal insulation identified as "Polynum™ FR Double One 1200; Foil / Double Bubble / White Construction; Method 1 Test Assembly."

SAMPLING INFORMATION

The material was received by R&D Services, Inc. in Watertown, TN on September 15, 2023. No evidence of sampling was provided.

TEST METHODS

ASTM C335/C335M-17, "Standard Test Method for Steady-State Heat Transfer Properties of Pipe Insulation"

ASTM C518-21, "Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus"

SAMPLE CONDITIONING

The specimen was conditioned for a minimum of 48 hours at 73 ± 4 °F (23 ± 2 °C) and 50 ± 5 % relative humidity.

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TEST METHOD PROCEDURE

The resistance of externally applied air-handling duct insulation is determined using a calibrated end apparatus operated in accordance with ASTM C335 with analysis in accordance with ASTM C1668, Section 10.8. The calibrated end apparatus is discussed in Section 5.4 of the test method. The test apparatus is an 84-inch (2134 mm) long section of 8 by 12-inch (203 by 305 mm) rectangular steel duct. An electrical resistance heater is mounted horizontally along the centerline of the duct. Fans at each end of the duct provide internal air circulation.

Five Type-K thermocouples were permanently attached to the interior surface of the duct to provide a hot-side temperature. Five thermocouples were attached to the outside surface of installed duct insulation to provide a cold-side temperature. Thermocouples were attached to rectangular end caps of known thermal resistance in order to determine heat loss from the ends of the apparatus. Two thermocouples were placed 4-inch (102 mm) from the exterior side of the duct insulation to measure the temperature of the air adjacent to the insulated duct. The entire apparatus was in a conditioned space maintained at 70 ± 2 ˚F (21 ± 2 ˚C) and 50 ± 5 %RH.

R-value for the duct insulation was obtained from Equation (1) where the heat flow through the insulation is determined from Equation (2). The heat flow through the end caps is calculated from Equation (3) where the R-value for the end caps is obtained as a function of temperature using a heat-flow meter apparatus operated in accordance with ASTM C518.

where:

$$R = A \cdot \Delta T / Q \quad (1)$$

A	=	Surface area of insulated duct, ft^2
ΔT	=	Average temperature difference, ˚F
ΔT	=	T inside Surface – T outside Surface for $R_{\text{Sur-to-Sur}}$
ΔT	=	T inside Surface – T air for $R_{\text{Sur-to-Air}}$
Q	=	Heat flow through the insulation, Btu/h
R	=	R-value, $ft^2 \cdot h \cdot ˚F/Btu$

$$Q = Q_{heater} + Q_{fan} - Q_{ends} \quad (2)$$

$$Q_{ends} = A_{ends} \cdot \Delta T_{ends} / R_{ends} \quad (3)$$

A_{ends}	=	Cross sectional area of Ends, ft^2
ΔT_{ends}	=	Average temperature difference, ˚F
R_{ends}	=	R-value at the average temperature of the end caps, $ft^2 \cdot h \cdot ˚F/Btu$

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TEST ASSEMBLY

Two 44-inch (111.76 cm) sections of material were installed to encompass the entire length of the duct in a single layer by tightly wrapping the duct in the clockwise direction starting on the top edge of the duct assembly with a 1-inch (2.54 cm) overlap. The white surface of the material was oriented to the duct surface.

The material was approximately 1/8-inch (3.56 mm) thick. Air spaces at the end of the duct assembly were blocked to prevent unintended air circulation.

TEST RESULTS

The thermal resistance for the surface of the duct to the outside surface of the insulation, the surface of the duct to the surrounding air, and the average assembly temperatures have been reported.

Table 1: Measured Thermal Resistances

Average Temperature (˚F)	$R_{Sur\text{-}to\text{-}Sur}$ (ft²·h·˚F/Btu)	Uncertainty $_{Sur\text{-}to\text{-}Sur}$ (%)	$R_{Sur\text{-}to\text{-}Air}$ (ft²·h·˚F/Btu)	Uncertainty $_{Sur\text{-}to\text{-}Air}$ (%)
80.1	1.85	11.56	3.40	10.60
84.5	1.82	9.68	3.42	8.17
90.5	1.76	7.75	3.25	6.95
94.4	1.73	7.49	3.14	6.52
97.0	1.65	7.88	3.04	6.45
102.5	1.59	6.37	3.12	5.76
106.2	1.54	6.17	3.02	5.50

The measured thermal resistances contained in Table 1 and the Method of Least Squares were used to obtain Equation (4) for the duct surface to outside insulation surface R-value ($R_{Sur\text{-}to\text{-}Sur}$). Equation (5) is for the thermal resistance between the duct surface and the air surrounding the insulated duct ($R_{Sur\text{-}to\text{-}Air}$). The data and the equations that describe the data are shown in Figure 1.

$$R_{Sur\text{-}to\text{-}Sur} = -0.0124x + 2.8622 \cdot T_{ave} \qquad (4)$$

$$R_{Sur\text{-}to\text{-}Air} = -0.0160x + 4.6928 \cdot T_{ave} \qquad (5)$$

(T_{avg}) is the average temperature (˚F) of the insulation assembly. Equations (4) and (5) were used to calculate the R-values results below.

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Table 2: R-value Calculations

Temperature (˚F)	$R_{Sur\text{-}to\text{-}Sur}$ ($ft^2 \cdot h \cdot ˚F/Btu$)	$R_{Sur\text{-}to\text{-}Air}$ ($ft^2 \cdot h \cdot ˚F/Btu$)
75	1.94	3.49
80	1.87	3.41
90	1.75	3.25
100	1.63	3.10
110	1.50	2.94
120	1.38	2.78
130	1.26	2.62

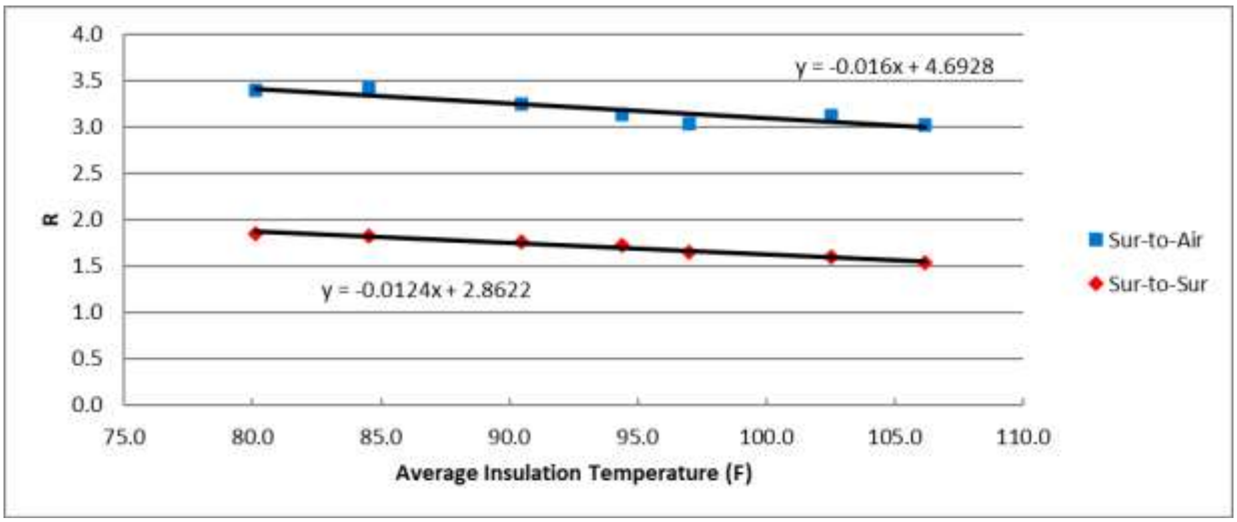

Figure 1. R-Value Of Duct Insulation Versus Average Insulation Temperature

CONCLUSION

The thermal resistance between the duct surface and the exterior insulation surface (the insulation material) was 1.9 $ft^2 \cdot h \cdot ˚F/Btu$ at an average insulation assembly temperature of 75 ˚F (24 ˚C).

The thermal resistance between the duct surface and the air surrounding the duct (the insulation material plus air-film resistance) was 3.5 $ft^2 \cdot h \cdot ˚F/Btu$ at an average insulation assembly temperature of 75 ˚F (24 ˚C).

The maximum measurement uncertainty associated with the R-values in this report is estimated to be 11.56 % for the 75 ˚F (24 ˚C) results.

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Completed By:	Carla King	**Reviewed By:**	Stuart Ruis
TITLE	Reporting Manger	**TITLE**	President
Signature	Carla King	**Signature**	Stuart Ruis
Date	11/28/23	**Date**	11/28/23

REVISION LOG

Revision Number	Date	Page(s)	Revision
0	11/28/23		Initial Report

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APPENDIX
A1. U-VALUE CALCULATIONS
A2. SURFACE-TO-AIR SI CONVERSION

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A1. U-VALUE CALCULATIONS

A1.1 Calculated U-values[1] for $R_{Sur\text{-}to\text{-}Sur}$ and $R_{Sur\text{-}to\text{-}Air}$ are shown in Table 3.

Table 3: Calculated U-values

Average Temperature (˚F)	$R_{Sur\text{-}to\text{-}Sur}$ (ft²·h·˚F/Btu)	$U_{Sur\text{-}to\text{-}Sur}$ (BTU/ft²·h·°F)	$R_{Sur\text{-}to\text{-}Air}$ (ft²·h·˚F/Btu)	$U_{Sur\text{-}to\text{-}Air}$ (BTU/ft²·h·°F)
75	1.94	0.515	3.49	0.287
80	1.87	0.535	3.41	0.293
90	1.75	0.571	3.25	0.308
100	1.63	0.613	3.10	0.323
110	1.50	0.667	2.94	0.340
120	1.38	0.725	2.78	0.360
130	1.26	0.794	2.62	0.382

[1] *U-values were calculated using equation: U-value (BTU/ft²·h·°F) = 1 / R-value (ft²·h·˚F/Btu)*

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A2. SURFACE-TO-AIR SI CONVERSION

A2.1 Calculated RSI values[2] for $R_{Sur\text{-}to\text{-}Sur}$ and $R_{Sur\text{-}to\text{-}Air}$ are shown in Table 4.

Table 4: Calculated RSI Values

Average Temperature (˚F)	$R_{Sur\text{-}to\text{-}Sur}$ ($ft^2 \cdot h \cdot ˚F/Btu$)	$RSI_{Sur\text{-}to\text{-}Sur}$ ($m^2 \cdot K/W$)	$R_{Sur\text{-}to\text{-}Air}$ ($ft^2 \cdot h \cdot ˚F/Btu$)	$RSI_{Sur\text{-}to\text{-}Air}$ ($m^2 \cdot K/W$)
75	1.94	0.342	3.49	0.615
80	1.87	0.329	3.41	0.601
90	1.75	0.308	3.25	0.572
100	1.63	0.287	3.10	0.546
110	1.50	0.264	2.94	0.518
120	1.38	0.243	2.78	0.490
130	1.26	0.819	2.62	0.461

[2] *RSI values were calculated using equation: RSI ($m^2 \cdot K/W$) = R-value ($ft^2 \cdot h \cdot ˚F/Btu$) / 5.678*