



Test Report

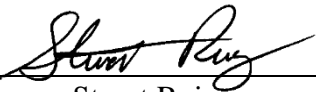
Selected Measurements According to ASTM C547 on IPB-680 Mineral Fiber V-Groove Pipe Insulation Supplied by Knauf Insulation (Slovenija)

Prepared For:

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R & D Services, Inc.
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Report: RD15648



Stuart Ruis
President

January 8, 2016

The test results in this report apply only to the specimens tested. The tests conform to the respective test methods except for the report requirements. The report includes summary data but a full complement of data is available upon request. This report shall not be reproduced, except in full, without written approval of R & D Services, Inc. This report must not be used by the client to claim product endorsement by R & D Services, Inc., IAS or any other organization.



January 8, 2016

R & D Services, Inc. has completed tests on “IPB 680” V-Groove Mineral Fiber Pipe Insulation provided by Knauf Insulation in Novi Marof, Croatia. R & D Services, Inc. received six pieces of material in pipe configuration and two packages of eight boards each (16 boards total) in flat configuration on September 28, 2015. Tests have been completed to verify that the product complies with ASTM C547 requirements for Type III-A insulation. The test results are summarized in Table 1 and 2.

Table 1

| MATERIAL PROPERTY | TEST STANDARD | RESULT | ASTM C547 REQUIREMENT PASS/FAIL |
|--------------------------------------|----------------|------------------------------------|---------------------------------|
| Density (kg/m ³) | ASTM C302 | 118.8 | NA |
| Dimensions (% of label) | ASTM C302 | Length – 100.0 Thickness – 99.5 | PASS PASS |
| Thermal Conductivity | ASTM C335 | See Table 2 | See Table 2 |
| Water Vapor Sorption (Mass %) | ASTM C1104 | 0.32 | PASS |
| Surface Burning Characteristics | ASTM E84 | FSI – 0 SDI – 0 | PASS |
| Maximum Use Temperature | ASTM C447/C411 | PASS | PASS |
| Exothermic Temperature Rise (°C) | ASTM C447/C411 | 0.0 | PASS |
| Sag Resistance (% thickness) | ASTM C411 | 0.8 | PASS |
| Linear Shrinkage (% change) | ASTM C356 | 0.28 | PASS |
| Corrosiveness | ASTM C795 | PASS | PASS |
| Non Fibrous Shot Content (% content) | ASTM C1335 | 12.4 | PASS |

The apparent thermal conductivity was measured according to ASTM C335 at mean temperatures specified in ASTM C547. One piece of IPB 680 with inner diameter of 75 mm and wall thickness of 50 mm was measured. Thermal conductivity data are summarized in Table 2.

Table 2

| MEAN TEMPERATURE (°C) | THERMAL CONDUCTIVITY (W/m·K) | ASTM C547 REQUIREMENT (W/m·K) | PASS/FAIL |
|-----------------------|------------------------------|-------------------------------|-----------|
| 38 | 0.036 | 0.036 | PASS |
| 93 | 0.044 | 0.045 | PASS |
| 149 | 0.053 | 0.053 | PASS |
| 204 | 0.062 | 0.065 | PASS |
| 260 | 0.072 | 0.078 | PASS |
| 316 | 0.083 | 0.094 | PASS |
| 371 | 0.096 | 0.111 | PASS |

Test results on the Knauf Insulation “IPB 680” V-Groove Mineral Fiber Pipe Insulation show that the product meets the requirements of ASTM C547 for Type III-A classification.



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Dimensions and Density of Preformed Pipe Insulation

Test Number: RD151963DB

Date of Test: October 20, 2015

Specimen Number: 1211150928-28

Date of Manufacture: September 11, 2015

Description of Test Specimen: IPB-680; Type III, Grade A Mineral Fiber V-Groove Pipe Insulation

Test Method: ASTM C547-12, "Standard Specification for Mineral Fiber Pipe Insulation" Section 11.1.1; ASTM C 302-13 "Standard Test Method for Density and Dimensions of Preformed Pipe-Covering-Type Thermal Insulation", Procedure A.

Report Prepared For: Knauf Insulation (Slovenija) / Mr. Markus Mentz

Background

ASTM C302, Procedure A is a procedure for determining the density of preformed pipe insulation from a measurement of mass and volume. The volume is the product of the length, circumference, and wall thickness of the specimen. The mass is measured using a digital scale. The density is calculated as the mass divided by the volume. Conversion factors $1.0 \text{ kg} = 2.205 \text{ lb}_m$ and $1.0 \text{ m}^3 = 35.314 \text{ ft}^3$ are used in this report.

Three one-piece sections of pipe insulation approximately 1200 mm long, with inner diameter of 76 mm and wall thickness of 100 mm (47 by 3.0 by 4 inches) were used for this determination. Specimens were conditioned for a minimum of 48 hours at $70 \pm 3^\circ \text{ F}$ and $50 \pm 2 \% \text{ RH}$. Three specimens were prepared and measured.

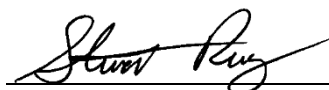
Test Results

| Specimen Number | Measured Length (mm) | Measured Circumference (mm) | Measured Wall Thickness (mm) |
|-----------------|----------------------|-----------------------------|------------------------------|
| 1211150928-28 | 1000.3 | 918.2 | 99.5 |

| Specimen Number | Volume | | Mass | | Density | |
|--------------------|----------------|-----------------|-------|-----------------|-------------------|----------------------------------|
| | m ³ | ft ³ | kg | lb _m | kg/m ³ | lb _m /ft ³ |
| 1211150928-28 | 0.0603 | 2.13 | 7.160 | 15.79 | 118.8 | 7.42 |
| Average | | | | | 118.8 | 7.42 |
| Standard Deviation | | | | | 0.0 | 0.00 |

Conclusion

The average density for the insulation that was tested is 118.8 kg/m^3 ($7.42 \text{ lb}_m/\text{ft}^3$).



Reviewed by:

1/8/16

Date:



**Apparent Thermal Conductivity for Pipe Insulation Supplied by Knauf Insulation
 manufactured in Novi Marof, Croatia as Determined in Accordance with ASTM
 C335**

A specimen of IPB 680 mineral fiber V-Groove pipe insulation supplied by Knauf Insulation has been tested in accordance with ASTM C335 “Standard Test Method for Steady-State Heat Transfer Properties of Pipe Insulation” to determine the apparent thermal conductivity, λ_a , over the temperature range 37.8 to 371.1 °C. The nominal 50 mm thick pipe insulation was produced for use on nominal 76 mm OD pipe. A copy of the laboratory test report is attached.

The measured physical properties of the pipe insulation specimen that was tested are listed in Table 1 while the thermal data are summarized in Table 2. The smoothed data in Table 2 were obtained in accordance with ASTM C1045 “Standard Practice for Calculating Thermal Transmission Properties Under Steady-State Conditions”. The equation for $\lambda(T)$ is:

$$\lambda(T) = 0.303177 \text{ E-1} + 0.146713 \text{ E-3} (T) + 0.212636 \text{ E-11} (T)^3$$

Table 1. Measured Physical Properties of Tested Specimen

| | |
|-----------------------------|-----------------------|
| Inside diameter of specimen | 76 mm |
| Thickness of specimen | 51 mm |
| Density of specimen | 126 kg/m ³ |

Table 2. Apparent Thermal Conductivity of Test Specimen

| <u>T (°C)</u> | <u>λ_a (W/m·K)</u> |
|---------------|---------------------------------------|
| 38 | 0.036 |
| 93 | 0.044 |
| 149 | 0.053 |
| 204 | 0.062 |
| 260 | 0.072 |
| 316 | 0.083 |
| 371 | 0.096 |

David W. Yarbrough, PhD, PE
 January 8, 2016



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Water Vapor Sorption Test Report

Test Number: RD151962WV

Date of Test: October 23 – 27, 2015

Specimen Number: 1211150928-28,29

Date of Manufacture: September 11, 2015

Description of Test Specimen: IPB-680; Type III, Grade A Mineral Fiber V-Groove Pipe Insulation

Test Method: ASTM C547-12, “Standard Specification for Mineral Fiber Pipe Insulation” Section 11.1.4 and ASTM C 1104/C 1104M-13a, “Standard Test Method for Determining the Water Vapor Sorption of Unfaced Mineral Fiber Insulation”.

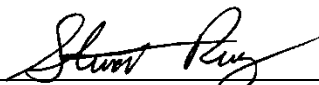
Report Prepared For: Knauf Insulation (Slovenija) / Mr. Markus Mente

The procedure used to test blanket, board, or pipe insulation products is contained in Section 8 of ASTM C 1104/C 1104M-13a. The procedure is carried out for three specimens of the product. The volume of each test specimen is determined from measurements of the length, width, and thickness. The dry weight of the test specimens is determined after drying to steady state in a 102 to 121 °C environment. The test specimens are brought to a uniform temperature of 60°C before being transferred to an environmental chamber maintained at 49 ± 2 °C and 95 ± 3 % relative humidity. The test specimens remain in the environmental chamber for 96 ± 4 hours. At the end of the 96 hour exposure the specimens are sealed in a water impermeable bag and allowed to cool before final weighing. The increase in mass due to the exposure is used to calculate mass % and volume % water sorption relative to the moisture-free material.

Results:

| Specimen: | 1 | 2 | 3 |
|---------------------------------|--------------|----------|----------|
| Volume (cm ³): | 367.60 | 369.66 | 370.11 |
| Moisture-free Mass (g): | 42.31 | 42.32 | 43.96 |
| Mass after test (g): | 42.40 | 42.49 | 44.11 |
| Mass % sorbed: | 0.21 | 0.40 | 0.34 |
| Volume % sorbed: | 0.024 | 0.046 | 0.041 |
| Average Mass % sorbed: | 0.32 | | |
| Average Volume % sorbed: | 0.037 | | |

The precision of C1104/C1104M-13a has been determined to be 0.02 volume % at the 95 % reproducibility limit for light-density mineral fiber.


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Hot Surface Performance of High-Temperature Thermal Insulation

Test Number: RD152055HS Date of Manufacture: Unknown

Specimen Number: 1211150928-49,50 Date of Test: November 2015

Description of Test Specimen: “IPB 680”; Type III, Grade A Mineral Fiber V-Groove Pipe Insulation.

Report Prepared For: Knauf Insulation (Slovenia)

Contact Person: Mr. Markus Mente

Test Methods: ASTM C411, “Standard Test Method for Hot-Surface Performance of High-Temperature Thermal Insulation”.

ASTM C547, “Standard Specification for Mineral Fiber Pipe Insulation”.

Description of Test

ASTM C 411 tests the performance of a thermal insulation intended for high temperature applications when the insulation is in continuous contact with a hot surface at a controlled temperature for a period of 96 hours. Visible signs of flaming, glowing, smoldering, or smoking results in termination of the test. The electrical power to the heater is turned off at the end of 96 hours and the test specimen was allowed to cool to room temperature. After cooling the test specimen was removed from the pipe for evaluation.

The test pipe diameter was nominal 80 mm (nominal 3 inch). The hot surface temperature of the pipe was measured at four (4) locations. The temperature of the insulation was measured at 25 mm intervals through the thickness beginning at the heated surface to the surface of the insulation. The temperatures were recorded every 15 seconds the first 10 hours and every 60 seconds for the remainder of the test.

One piece of insulation was prepared and installed on the pipe. The temperature of the specimen was measured in 25 mm increments from the hot surface to the exterior side exposed to the room. The material was held in place with ½ inch steel bands. Photographs were taken before and after completing the test. The sample was installed on the pipe and the apparatus was heated to the test temperature as quickly as possible.



Conditions and Observations

1. The product was identified as “IPB 680”; Type III, Grade A Mineral Fiber V-Groove Pipe Insulation. The material was supplied by Knauf Insulation at the Novi Marof, Croatia manufacturing plant.
2. The specimen was placed on the test pipe apparatus and the apparatus was heated up to the test temperature as quickly as possible.
3. The test temperature was 650 +/- 15 °C. The average pipe temperature during the test was 650.4 °C.
4. There was no warpage observed after the 96 hour exposure.
5. There was no flexibility change observed.
6. No cracking was observed.
7. There was no evidence of flaming, glowing, smoldering or melting during the 96 hour test. There was no evidence of melting or fiber degradation.
8. No smoking was observed. A minor odor was detected at the beginning of the test.
9. Slight discoloration was observed on the face exposed to the pipe.
10. There was no exothermic reaction observed.
11. Figure 1 is a photograph of the inside surface of the specimen prior to testing. Figure 2 is a photograph of the inside surface of the specimen after testing. Figure 3 is the temperature profile for the duration of the test.
12. The Table 1 contains the mass before and after testing. Table 2 contains sag measurements before and after testing. Table 3 contains the maximum recorded temperatures

Conclusion

The “IPB 680”; Type III, Grade A Mineral Fiber V-Groove Pipe Insulation manufactured by Knauf Insulation at the Novi Marof, Croatia plant meets the requirements of ASTM C547-15, “Standard Specification for Mineral Fiber Pipe Insulation” when tested according to ASTM C411-11, “Standard Test Method for Hot-Surface Performance of High-Temperature Thermal Insulation at a surface temperature of 650°C.

| Knauf Insulation IPB 680 Mass Loss During Test | | | |
|---|--------|-------|-----------------|
| | Before | After | Weight Loss (%) |
| Mass (grams) | 1344 | 1258 | 6.4 |

Table 1 – Mass Before and After Testing

| Knauf Insulation IPB 680 Sag Measurements | |
|--|-----------|
| | Thickness |
| Before heating | 153.8 |
| After cooling | 152.6 |

Table 2 – Sag Measurements Before and After Testing

The average change in thickness was -0.8% which is within the 5% allowed by ASTM C547.

| Knauf Insulation IPB 680 Exothermic Temperature Data | | |
|---|--------------------------|--------------------------|
| Location of Temperature Measurement | Maximum Temperature (°C) | Average Temperature (°C) |
| Pipe | 676.1 | 650.4 |
| 25 mm | 634.6 | 513.3 |
| 50 mm | 612.9 | 436.5 |
| 75 mm | 591.2 | 359.6 |
| 100 mm | 580.7 | 262.2 |
| 125 mm | 529.8 | 153.2 |
| Surface | 265.0 | 63.9 |

Table 3 – Maximum Internal Temperature and Average Temperature

There was no exothermic reaction observed which meets the requirements of ASTM C547.



Figure 1. Typical Specimen Before Testing



Figure 2. Layer 1 After Testing

Hot Surface Performance

ASTM C411 SI Units

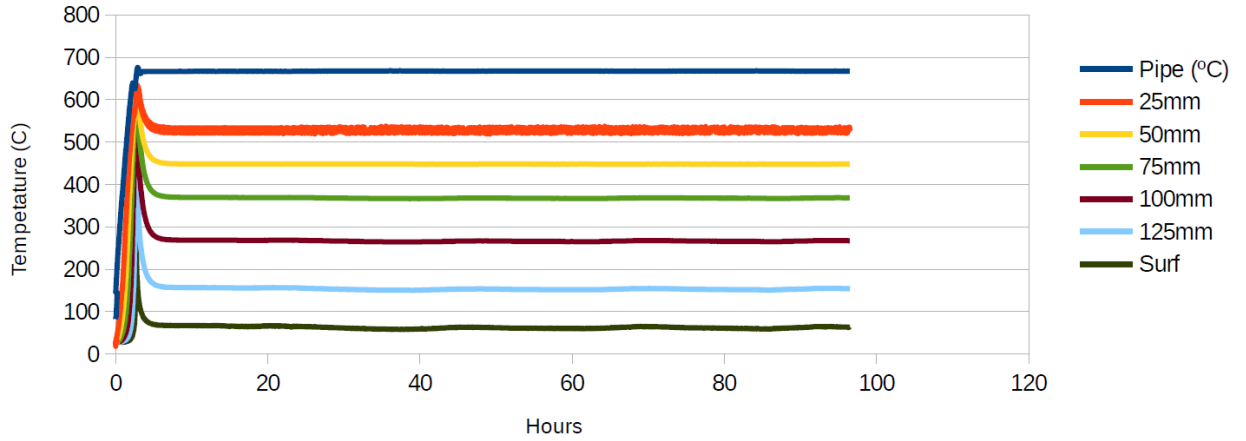


Figure 5- Temperature Profile for the Duration of Testing



Linear Shrinkage of Thermal Insulation Report

Test Number: RD151964LS

Date of Test: October 13 – 15, 2015

Specimen Number: 1211150928-29

Date of Manufacture: September 11, 2015

Description of Test Specimen: IPB-680; Type III, Grade A Mineral Fiber V-Groove Pipe Insulation

Test Method: ASTM C547-12, "Standard Specification for Mineral Fiber Pipe Insulation" Section 11.1.8 and ASTM C356, "Standard Test Method for Linear Shrinkage of Preformed High-Temperature Thermal Insulation Subjected to Soaking Heat"

Report Prepared For: Knauf Insulation (Slovenija) / Mr. Markus Mente

Background

The linear shrinkage of mineral fiber insulation due to exposure to short-term high temperature has been determined. The specimens are conditioned and exposed to high temperature conditions for 24 hours. The average linear shrinkage of four specimens is measured and used to calculate the linear shrinkage percent of the samples expressed as a percentage of the length measured before exposure.

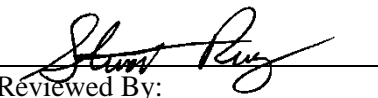
Four samples approximately 153 by 52 by 40 mm were used. The test was conducted at 650 °C.

Test Results

| | Specimen 1 | Specimen 2 | Specimen 3 | Specimen 4 |
|-------------------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Initial Length (mm) | 153.0 | 152.7 | 153.0 | 153.3 |
| Initial Width (mm) | 53.0 | 52.7 | 52.7 | 52.3 |
| Initial Thickness (mm) | 40.00 | 40.00 | 40.00 | 39.33 |
| Final Length (mm) | 152.7 | 152.30 | 153.0 | 152.3 |
| Final Width (mm) | 52.7 | 52.3 | 52.3 | 52.0 |
| Final Thickness (mm) | 41.00 | 41.00 | 41.33 | 40.67 |
| Change in Length (mm) | 0.3 | 0.4 | 0.0 | 1.0 |
| Linear Shrinkage (%) | -0.20 | -0.26 | 0.00 | -0.65 |

Result:

The average observed linear shrinkage of the test specimens was -0.28 %. This satisfies the physical requirements of ASTM C547, Table 1.

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Non-Fibrous Content Test Report

Test Number: RD151961NF Date of Test: October 28, 2015
 Specimen Number: 1211150928-28,29 Date of Manufacture: September 11, 2015
 Description of Test Specimen: IPB-680; Type III, Grade A Mineral Fiber V-Groove Pipe Insulation
 Test Method: ASTM C547-12, "Standard Specification for Mineral Fiber Pipe Insulation" Section 11.1.8; ASTM C1335-12, "Standard Test Method for Measuring Non-Fibrous Content of Man-Made Rock and Slag Mineral Fiber Insulation".
 Report Prepared For: Knauf Insulation (Slovenija) / Mr. Markus Mente

Background

This test procedure determines the non-fibrous content (shot) of man-made rock and slag mineral fiber insulation. The procedure involves a dry sieve analysis method to distinguish between fiberized and non-fiberized (shot) portions of a specimen of man-made rock and slag mineral fiber insulation.

Three 10 gram specimens are prepared. Test specimens are conditioned at high temperature for 15 minutes and allowed to cool to room temperature. The specimens are placed into a nest of three sieves and shaken for 20 minutes using a Tyler model RX-24 portable sieve shaker. The non-fibrous (shot) content remaining in each sieve is weighed. The percentage of non-fibrous content is calculated using the equation in Section 8 of ASTM C1335.

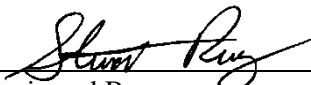
Test Results

Conditioning Temperature: 593 °C
 Type of Sieves Used: Number 20, 50 and 100; brass

| | Specimen 1 | Specimen 2 | Specimen 3 |
|---|------------|------------|------------|
| Initial Mass of Specimen (g) | 10.7656 | 10.5286 | 10.6638 |
| Mass of Specimen After Conditioning (g) | 10.4178 | 10.1871 | 10.3155 |
| Mass of Non-Fibrous Material in No. 20 Sieve (g) | 0.0098 | 0.0097 | 0.0066 |
| Mass of Non-Fibrous Material in No. 50 Sieve (g) | 0.1251 | 0.1737 | 0.1515 |
| Mass of Non-Fibrous Material in No. 100 Sieve (g) | 0.9641 | 1.2035 | 1.1909 |
| Total Mass of Non-Fibrous Material (g) | 1.099 | 1.387 | 1.349 |
| Non-Fibrous Content (%) | 10.6 | 13.6 | 13.1 |

Result:

The average observed non-fibrous content of the test specimens was 12.4 %. This satisfies the physical requirements of Section 6.3 in ASTM C547.


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