Investigation of thermal isolation properties of polyisocyanurate (PIR) sandwich-panels at decreased mean temperatures.

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Introduction

Polyisocyanurate (PIR) panels are widely used in the construction industry as a thermal insulation with decreased flammability in contrast to conventional PUR foam. The improved fire behavior of PIR panels is a result of polyisocyanurate moieties presence in polymer matrix that can be formed in special conditions including polyol composition (Component A), considerable excess of isocyanate (Component B) and particular production line parameters.

Today polyurethane (PU) and its less flammable brother polyisocyanurate (PIR) are the most effective thermal insulation.

It should be noted that the thermal conductivity value (Lambda) is affected by several factors and the cell gas that originates from the use of a particular blowing agent has the highest impact [1]. Blowing agents can be devided into two groups: chemical (water, formic acid) and physical blowing agents (CFCs, HFCs, HCFCs, pentanes, methylal – inert organic substances with low boiling point). Chemical blowing agents react with isocyanates and one the products of such interaction is carbon dioxide. Cell gas formation in case of physical blowing agent is a result of boiling of a liquid during the exothermic reaction of A and B components.

The thermal conductivity of different materials is usually measured at mean temperature of 10ºC (Europe) or 23,9ºC (USA) [2], but the other values also used if required. The thermal conductivity of PU and PIR foams usually has linear dependence from the mean temperature.

Discussion

Recently, American Building Science Corporation (BSC) published the results of its research [3] that revealed unusual performance of polyisocyanurate (PIR) thermal insulation panels. According to the report, in contrast to the other investigated materials that showed linear dependence of thermal conductivity from the mean temperature, PIR panel Lambda has increased dramatically with the drop of mean temperature below +15ºC (Fig. 1) but no scientific proof was provided to explain the results.

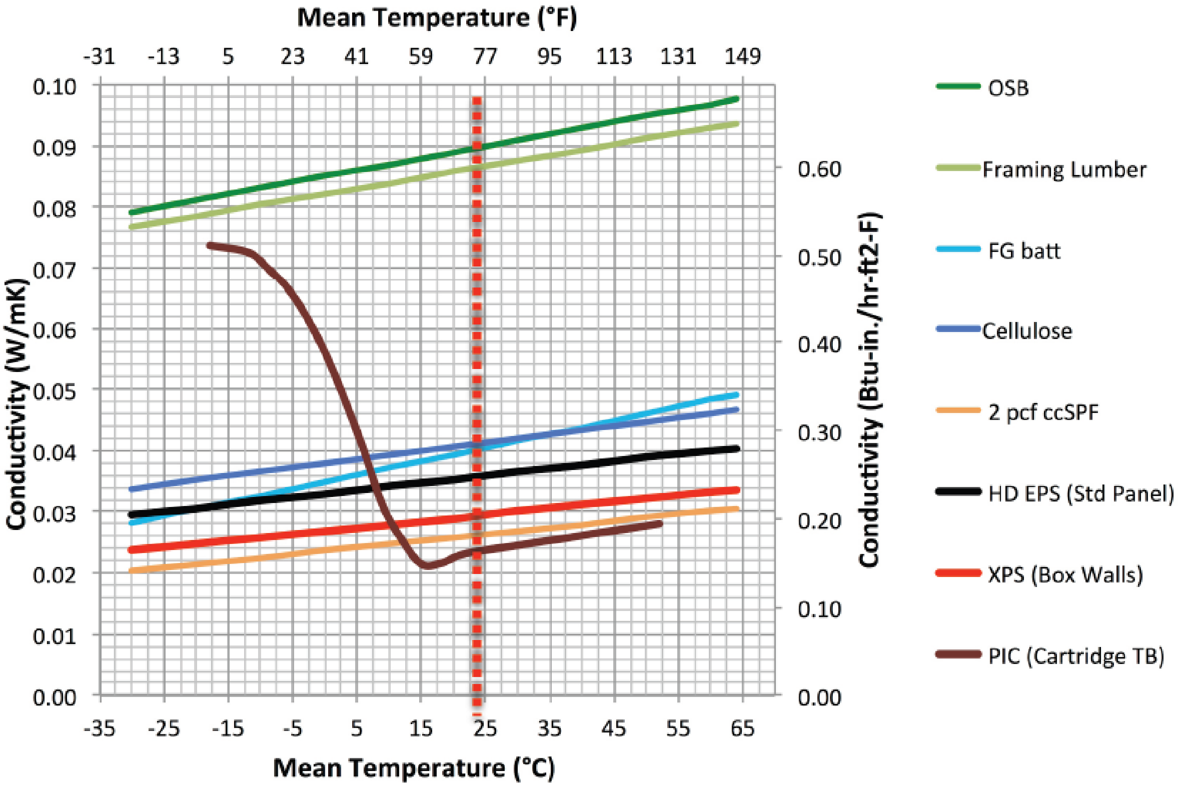

Fig. 1. Dramatic increase of Lambda of PIR panel with the drop of mean temperature below 15ºC, according to Building Science Corporation [3].

It is interesting that the paper [4] citing the research of Building Science Corporation [3] suggests that the increasing of PIR Lambda can be the result of blowing agent condensation in the cells at decreased temperatures. Thus, according paper [4], the observed thermal insulation properties mostly depends on the type and quantity of blowing agent where the most critical is its boiling point.

Thus, the great disadvantage of BSC report [3] is not only providing the results without any scientific explanation but also the absence of data concerning the chemical composition of investigated polyurethane and polyisocyanurate panels (type and quantity of blowing agent) that makes the interpretation of observed results very difficult. In addition to the investigation of thermal conductivity of wall constructions [3], in order to establish the real reasons of the observed results it would have been logically to investigate the thermal conductivity of the insulation layer material but has not been done.

In the present work in order to check the reliability of BSC report data and establish the reasons of such unusual thermal insulation behavior of PIR panels at decreased temperatures we tried to perform the same experiment using own research equipment.

With this purpose we investigated the thermal conductivity of PIR panels produced by four Russian manufacturers.

The thermal conductivity measurement was performed using Taurus TCA 300 DTX (manufacturer: Taurus GmbH, Germany) consequentially at five different mean temperatures (2, 10, 15, 25, 50ºC) in one measurement cycle with a gradient of 5ºC (temperature difference 10ºC).

The samples for testing 300×300×25 mm were cut out from the core of sandwich-panel pieces with metal facers. The initial Lambda was measured at 10ºC mean temperature 24 hours after the sample preparation (Table 1). The thermal conductivity measurement at five mean temperatures 2, 10, 15, 25, 50ºC was performed 90 days after the sample preparation.

According to the graph published in BSC report [3] (Fig. 1) that shows the dependence of thermal conductivity value from the mean temperature of different materials it was logically to observe the same strong increase in Lambda from 0,021 up to 0,051 W/m*K during the decrease of the mean temperature from 15ºC to 2ºC. However, we didn't observe any increase of Lambda in our research (Fig. 2, Table 1).

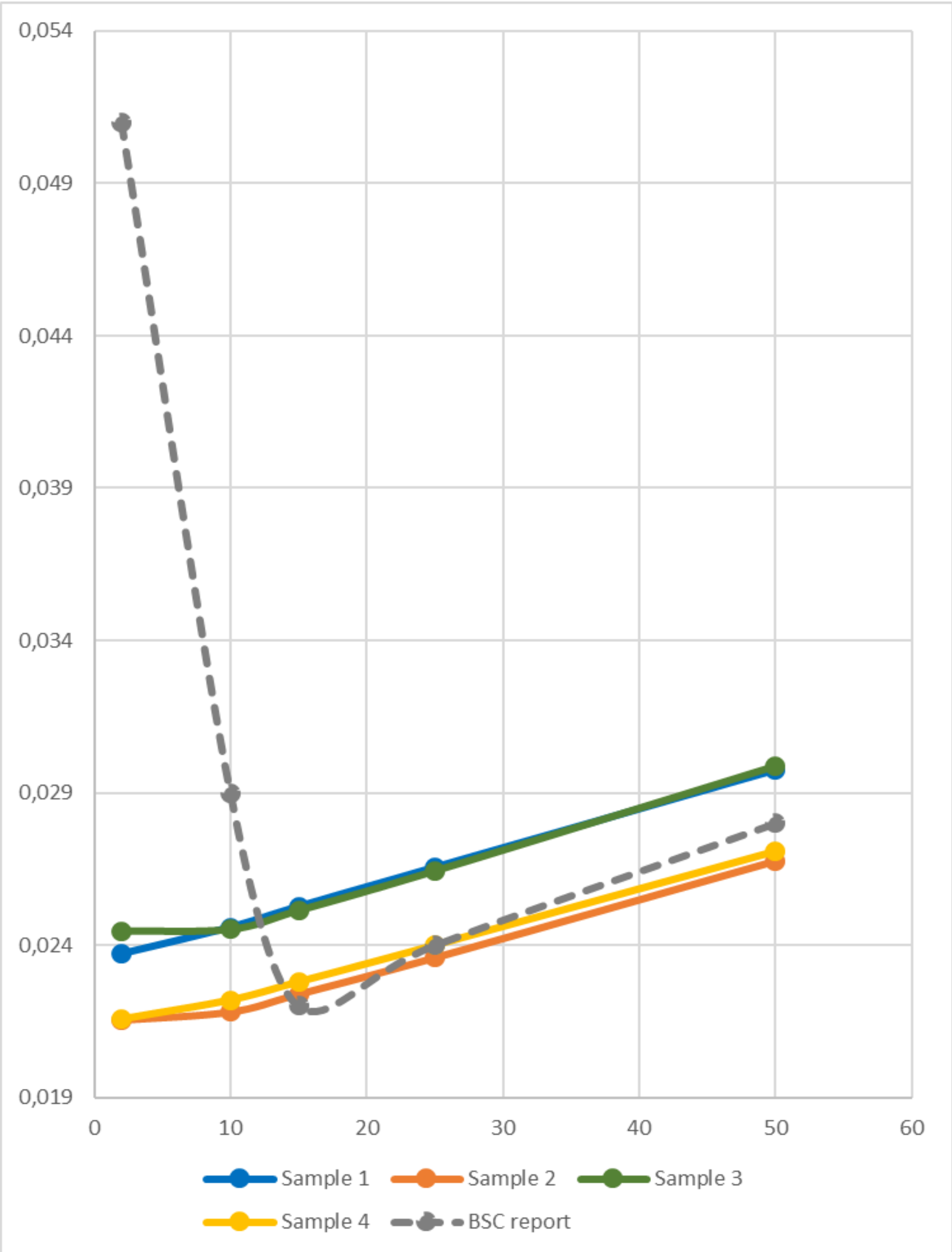

Fig. 2. The thermal conductivity of PIR sandwich-panels produced by four manufacturers in the mean temperature range from 2 to 50ºC ninety days after the sample preparation in contrast to published data by Building Science Corporation [3] (dotted line).

Table 1. The results of thermal conductivity measurement of PIR sandwich-panels produced by five manufacturers in the mean temperature range from 2 to 50ºC					
Mean temperature, ºC	**Sample 1**	**Sample 2**	**Sample 3**	**Sample 4**	**BSC report [3] (approximate values)**
Initial Lambda, W/m*K					
10	0,01998	0,01978	0,02068	0,01994	
Lambda 90 days after the sample preparation, W/m*K					
2	0,02371	0,02153	0,02446	0,02157	0,051
10	0,02459	0,0218	0,02452	0,0222	0,029
15	0,02527	0,02238	0,02514	0,02279	0,022
25	0,02656	0,02358	0,02644	0,02399	0,024
50	0,02977	0,02675	0,02989	0,02706	0,028

As can be seen in Fig. 2 and Table 1, the Initial Lambda of almost all testing samples corresponds to the usually declared value of 0,022 W/m*K. The increase of Lambda 90 days after the preparation of the samples is the result of diffusion of the cell gas and air. It is considered to be normal for PUR or PIR without facers and material having crushed cells of the upper surface layer.

The samples 2 and 3 have a small difference in Lambda values at mean temperatures 2 and 10ºC and its curves take more horizontal orientation in this range. It should be noted that for all tested samples Lambda has linear dependence from the mean temperature as for the other materials listed in BSC report [3].

Conclusion

Thus, our investigation of PIR sandwich-panels produced by different Russian manufacturers showed that no Lambda increase exist at the mean temperature below 15ºC and the data provided by Building Science Corporation [3] are not reliable and doubtful. At least, it can't be applied for Russian PIR producers as they use mainly n-pentane or its mixtures with iso-pentane in different ratio (80:20, 70:30) in contrast to the American industry which also use cyclopentane that has higher boiling point and, hence, more likely to condense in the foam cells at decreased temperatures.

References:

1. Leppkes R. Polyurethans A versatile specialty plastic. Sixth edition. Verlag Moderne Industrie. 2012. 70 P
2. Randall D., Lee S. The polyurethanes book. John Wiley & Sons, LTD. 2002. 477 P.
3. Building Science Corporation RR-0002: The Thermal Metric Project - Summary Report: https://buildingscience.com/documents/special/thermal-metric-documents/thermal-metric-summary-report
4. Owens Corning Technical Bulletin Capturing the Thermal Performance of FOAMULAR® Extruded Polystyrene (XPS) vs. Polyisocyanurate: http://www.owenscorning.com/NetworkShare/EIS/10019949-FOAMULAR-XPS-vs-Polyiso-Tech-Bulletin.pdf

Supplementary Data

ElastoKaM
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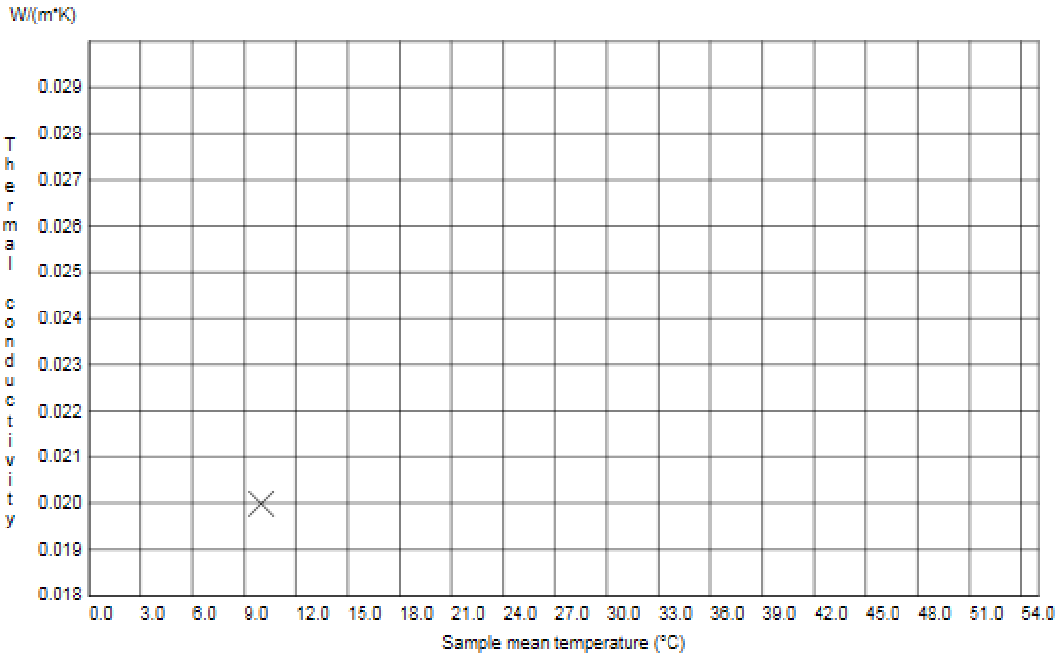
INN 1651 027 131

MEASURING THERMAL CONDUCTIFITY

Report No.:

Sample Thickness :	25.88 mm
Specimen Dimension	Sample 1 initial Lambda 300mm*300mm*height mm
Comment	with heatflowmeter
Test device	TCA 300 DTX
Date of measurement	02.11.2016
Operator	Dr. Evgeny Stukan
Remarks	

Measuring No.	Heat flow (W/m²)	Temperature cold sample surface (°C)	Temperature warm sample surface (°C)	Temperature-difference on sample (K)	Sample mean temperature (°C)	Thermal conductivity (W/m*K)
1	7.970	4.8	15.2	10.3	10.0	0.01998



Lambda (10.0°C) = 0.0200 W/(m*K)
Result +/- expanded uncertainty (factor 2)

Vsevolozhsk, 13.02.2017

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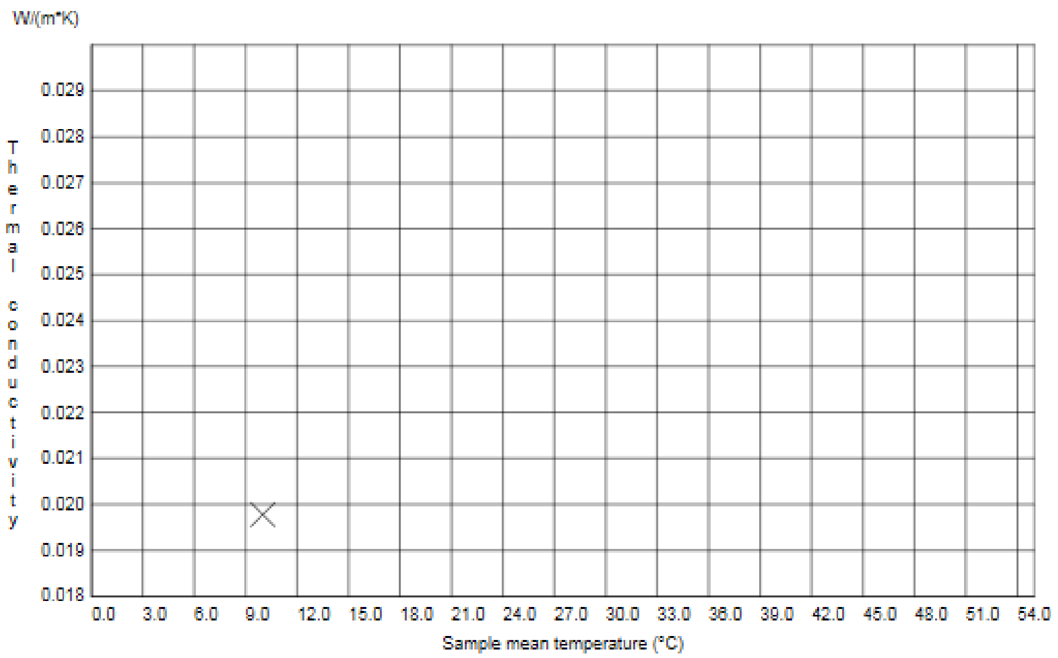
MEASURING THERMAL CONDUCTIFITY

Report No.:

Sample Thickness :	25.96 mm
Specimen Dimension	Sample 2 initial Lambda 300mm*300mm*height mm
Comment	with heatflowmeter
Test device	TCA 300 DTX
Date of measurement	02.11.2016
Operator	Dr. Evgeny Stukan
Remarks	

Measuring No.	Heat flow (W/m²)	Temperature cold sample surface (°C)	Temperature warm sample surface (°C)	Temperature-difference on sample (K)	Sample mean temperature (°C)	Thermal conductivity (W/m*K)
1	7.864	4.8	15.2	10.3	10.0	0.01978



Lambda (10.0°C) = 0.0198 W/(m*K)

Result +/- expanded uncertainty (factor 2)

Vsevolozhsk, 13.02.2017

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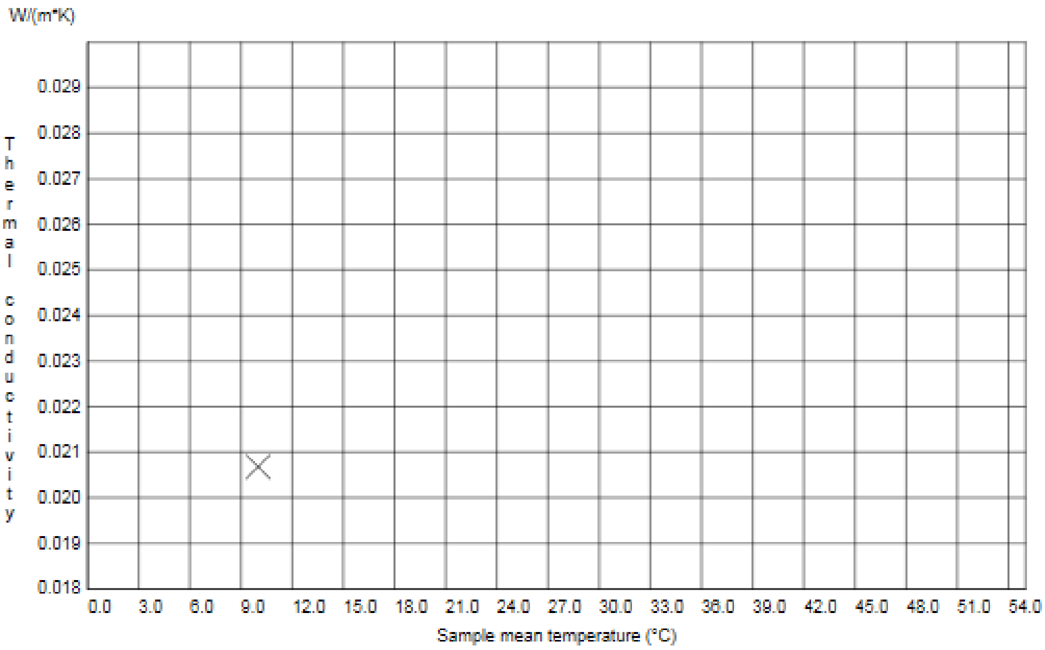
MEASURING THERMAL CONDUCTIFITY

Report No.:

Sample Thickness :	25.11 mm
Specimen Dimension	Sample 3 initial Lambda 300mm*300mm*height mm
Comment	with heatflowmeter
Test device	TCA 300 DTX
Date of measurement	02.11.2016
Operator	Dr. Evgeny Stukan
Remarks	

Measuring No.	Heat flow (W/m²)	Temperature cold sample surface (°C)	Temperature warm sample surface (°C)	Temperature-difference on sample (K)	Sample mean temperature (°C)	Thermal conductivity (W/m*K)
1	8.494	4.8	15.2	10.3	10.0	0.02068



Lambda (10.0°C) = 0.0207 W/(m*K)

Result +/- expanded uncertainty (factor 2)

Vsevolozhsk, 13.02.2017

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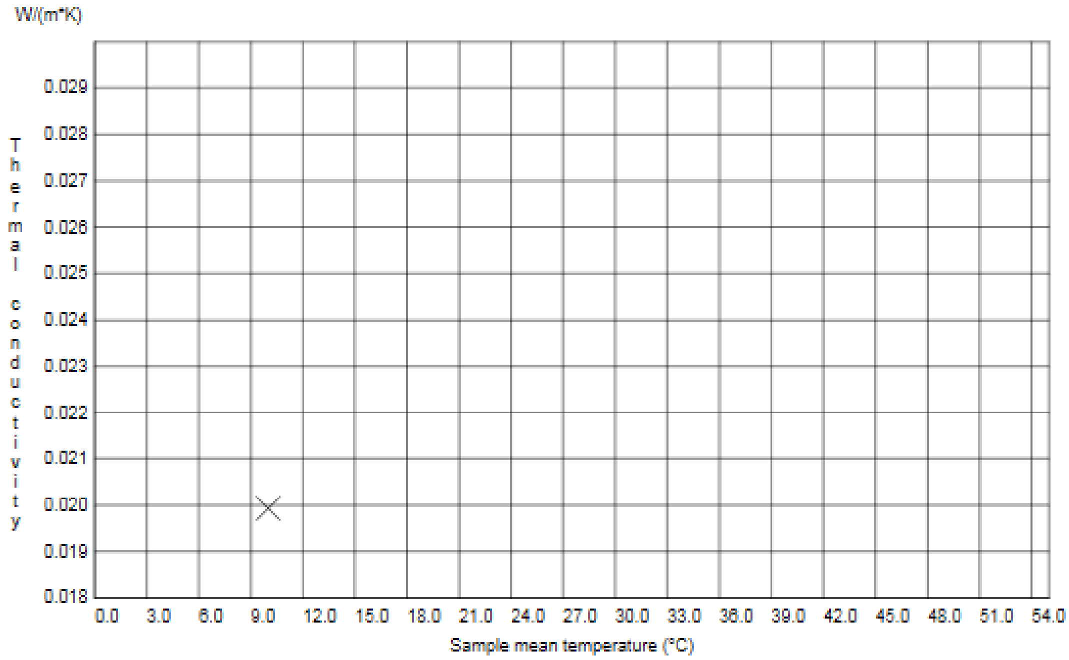
INN 1651 027 131

MEASURING THERMAL CONDUCTIFITY

Report No.:

Sample Thickness :	25.88 mm
Specimen Dimension	Sample 4 initial Lambda 300mm*300mm*height mm
Comment	with heatflowmeter
Test device	TCA 300 DTX
Date of measurement	02.11.2016
Operator	Dr. Evgeny Stukan
Remarks	

Measuring No.	Heat flow (W/m²)	Temperature cold sample surface (°C)	Temperature warm sample surface (°C)	Temperature-difference on sample (K)	Sample mean temperature (°C)	Thermal conductivity (W/m*K)
1	7.951	4.8	15.2	10.3	10.0	0.01994



Lambda (10.0°C) = 0.0199 W/(m*K)

Result +/- expanded uncertainty (factor 2)

Vsevolozhsk, 13.02.2017

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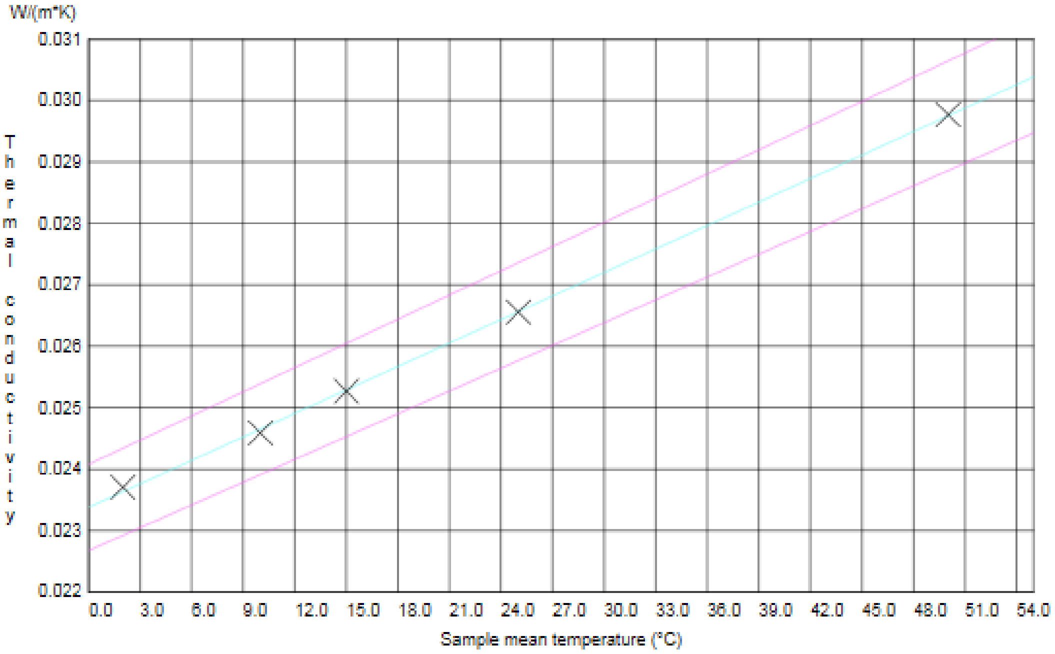
MEASURING THERMAL CONDUCTIFITY

Report No.:

Sample Thickness :	25.52 mm
Specimen	Sample 1
Dimension	300mm*300mm*height mm
Comment	with heatflowmeter
Test device	TCA 300 DTX
Date of measurement	02.02.2017
Operator	Dr. Evgeny Stukan
Remarks	

Measuring No.	Heat flow (W/m²)	Temperature cold sample surface (°C)	Temperature warm sample surface (°C)	Temperature-difference on sample (K)	Sample mean temperature (°C)	Thermal conductivity (W/m*K)
1	9.565	-3.2	7.1	10.3	2.0	0.02371
2	9.921	4.9	15.1	10.3	10.0	0.02459
3	10.192	9.9	20.1	10.3	15.0	0.02527
4	10.711	19.9	30.1	10.3	25.0	0.02656
5	11.997	44.9	55.2	10.3	50.0	0.02977



Lambda (10°C) = (0.0247 +/-0.0007) W/(m*K)
Result +/- expanded uncertainty (factor 2)

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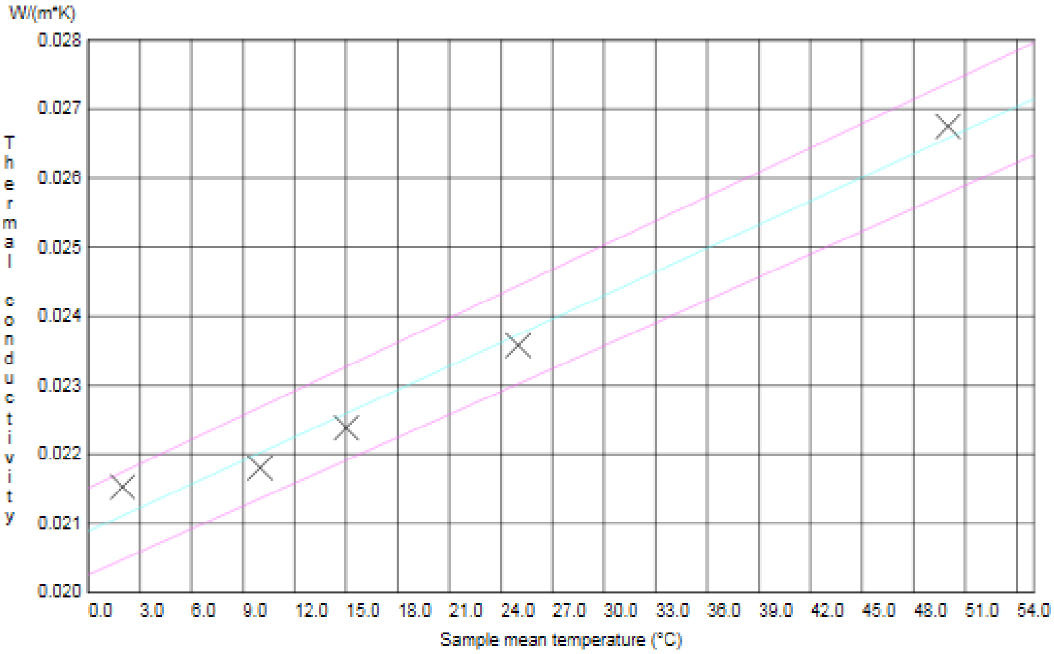
MEASURING THERMAL CONDUCTIFITY

Report No.:

Sample Thickness :	25.52 mm
Specimen	Sample 2
Dimension	300mm*300mm*height mm
Comment	with heatflowmeter
Test device	TCA 300 DTX
Date of measurement	02.02.2017
Operator	Dr. Evgeny Stukan
Remarks	

Measuring No.	Heat flow (W/m²)	Temperature cold sample surface (°C)	Temperature warm sample surface (°C)	Temperature-difference on sample (K)	Sample mean temperature (°C)	Thermal conductivity (W/m*K)
1	8.705	-3.2	7.2	10.3	2.0	0.02153
2	8.812	4.8	15.2	10.3	10.0	0.02180
3	9.044	9.8	20.2	10.3	15.0	0.02238
4	9.521	19.9	30.2	10.3	25.0	0.02358
5	10.790	44.9	55.2	10.3	50.0	0.02675



Lambda (10°C) = (0.0220 +/-0.0007) W/(m*K)

Result +/- expanded uncertainty (factor 2)

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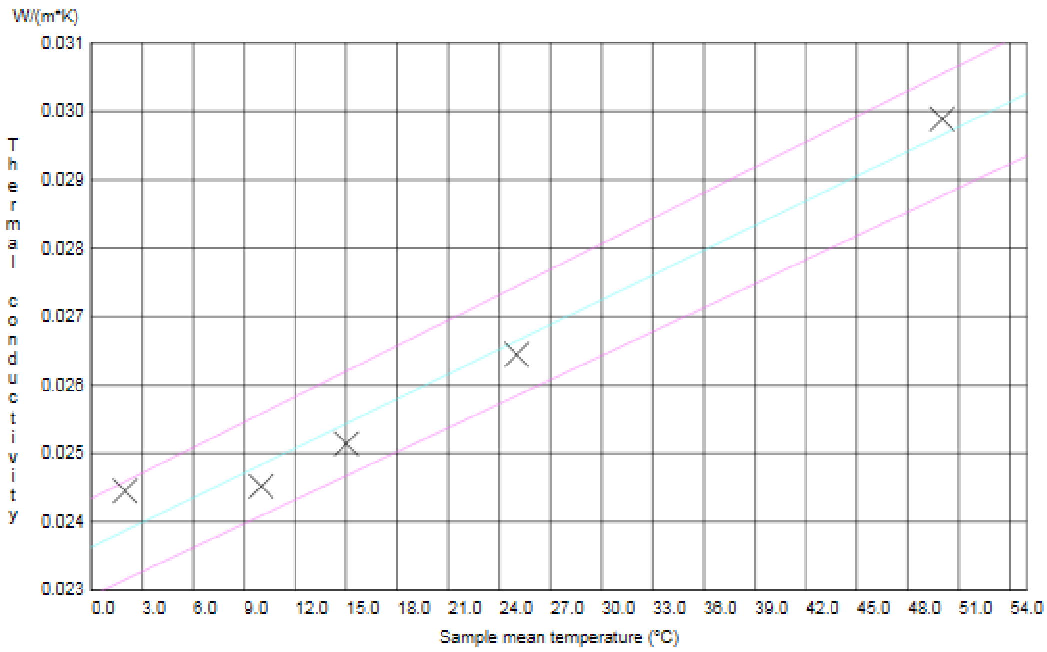
MEASURING THERMAL CONDUCTIFITY

Report No.:

Sample Thickness :	25.05 mm
Specimen	Sample 3
Dimension	300mm*300mm*height mm
Comment	with heatflowmeter
Test device	TCA 300 DTX
Date of measurement	02.02.2017
Operator	Dr. Evgeny Stukan
Remarks	

Measuring No.	Heat flow (W/m²)	Temperature cold sample surface (°C)	Temperature warm sample surface (°C)	Temperature-difference on sample (K)	Sample mean temperature (°C)	Thermal conductivity (W/m*K)
1	10.063	-3.2	7.1	10.3	2.0	0.02446
2	10.081	4.9	15.1	10.3	10.0	0.02452
3	10.338	9.8	20.1	10.3	15.0	0.02514
4	10.867	19.9	30.2	10.3	25.0	0.02644
5	12.269	44.9	55.2	10.3	50.0	0.02989



Lambda (10°C) = (0.0248 +/-0.0007) W/(m*K)

Result +/- expanded uncertainty (factor 2)

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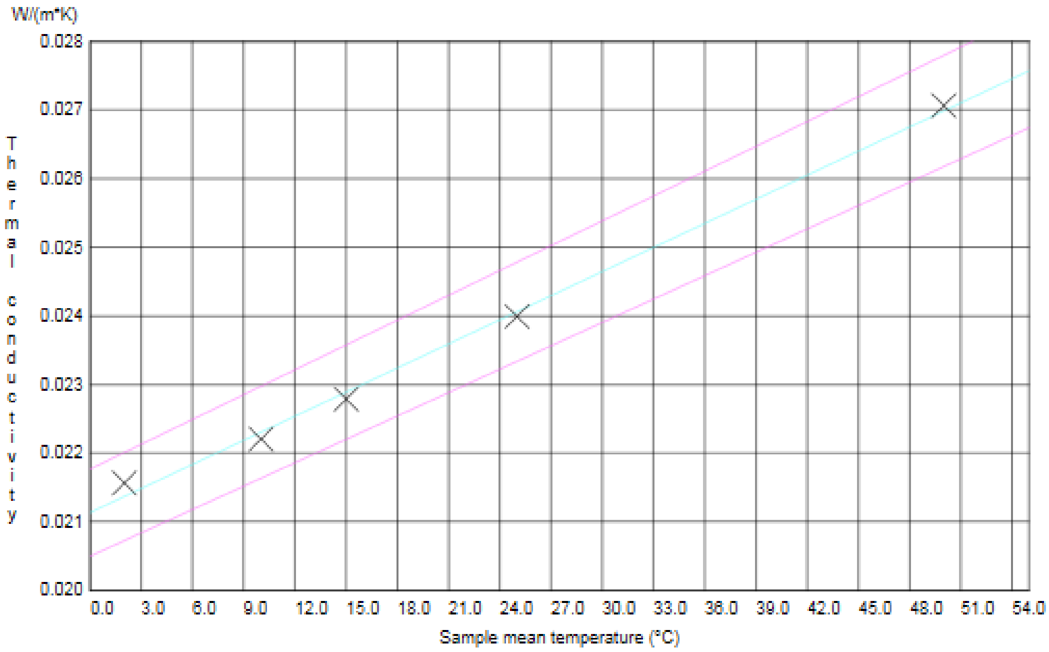
MEASURING THERMAL CONDUCTIFITY

Report No.:

Sample Thickness :	25.85 mm
Specimen	Sample 4
Dimension	300mm*300mm*height mm
Comment	with heatflowmeter
Test device	TCA 300 DTX
Date of measurement	03.02.2017
Operator	Dr. Evgeny Stukan
Remarks	

Measuring No.	Heat flow (W/m²)	Temperature cold sample surface (°C)	Temperature warm sample surface (°C)	Temperature-difference on sample (K)	Sample mean temperature (°C)	Thermal conductivity (W/m*K)
1	8.596	-3.1	7.2	10.3	2.0	0.02157
2	8.856	4.9	15.2	10.3	10.0	0.02220
3	9.088	9.8	20.2	10.3	15.0	0.02279
4	9.567	19.9	30.2	10.3	25.0	0.02399
5	10.782	44.9	55.2	10.3	50.0	0.02706



Lambda (10°C) = (0.0223 +/-0.0007) W/(m*K)

Result +/- expanded uncertainty (factor 2)

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