BYGGFORSK
Norwegian Building Research Institute

Sivert Uvsløkk

Equipment for Measuring Thermal Transmissivity and Thermal Resistance

Intercalibration

NORDTEST Technical Report 249

78 Project report 1995

Norwegian Building Research Institute
Norges byggforskningsinstitutt

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Project report 178 – 1995

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ISSN 0801-6461
ISBN 82–536–0487–4
100 copies printed by
S. E. Thoresen as
Cyclus recycled paper
cover 200 g, content 100 g

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Keywords
Thermal insulation
Thermal conductivity
Thermal transmissivity measurement
Intercalibration

PREFACE

For many years there has been a good co-operation between the laboratories performing third party control of thermal insulation products in the Nordic countries. In 1987 the laboratories carried out a comparative testing of thermal properties of building materials.

The objectives of this new project were to find out whether the agreement within the Nordic countries as regards insulation materials was equally good now as in the previous investigation, and whether there had been any improvement with regard to materials with higher thermal transmissivity.

When the project started, agreement was reached with National Physical Laboratory, NPL, in England to perform measurements on the same specimens, thus enabling us to compare the Nordic level with other laboratories in Europe.

The following laboratories and persons have participated in the project:

NPL	National Physical Laboratory, Teddington, Middlesex responsible: D. Salomon & J.M. Corsan	England
NBI	Norwegian Building Research Institute, Trondheim Division responsible: P.Chr. Moe & S. Uvsløkk	Norway
DTI	Danish Institute of Technology, Tåstrup responsible: E. Petersen	Denmark
SP	Swedish National Testing and Research Institute, Borås responsible: B. Jonsson & P.I. Sandberg	Sweden
VTT	Technical Research Centre of Finland, Espoo responsible: E. Kokko & T. Mähönen	Finland

The results were reported to Nordtest in December 1992. This new report is a revised version translated into English. It also contains in an Annex results from measurements at NPL, Isover in France and National Research Council, NRC, in Canada, on specimens from the same batch of glass fibre insulation as the specimens used in this Nordtest project.

The project has been funded by Nordtest through NT Project No. 942-90 and 1086-93, supplemented by some resources from the participating laboratories themselves.

Trondheim, 09.05.1994

Sivert Uvsløkk

CONTENTS

SUMMARY

This report describes a comparison of measurements of thermal properties of insulation materials at four laboratories in the Nordic countries and one in England (NPL). A similar comparative testing at the four Nordic laboratories carried out in 1987 showed good agreement in the measurement of mineral wool and polystyrene specimens from all the laboratories, but agreement was not satisfactory for the rubber specimen.

Measurements have now been carried out on two specimens of each of three materials, expanded polystyrene, (EPS), glass fibre wool and rubber.

Measurements on EPS show a slightly larger deviation between the Nordic laboratories now than earlier. The difference between the highest and lowest values is now 3.6 % compared with 2.1 % in 1987. All values are within +/- 2 % of arithmetical mean. All Nordic values are lower than NPL values, except for the SP value which is slightly higher.

Measurements on glass fibre insulation show the same good agreement among the participating Nordic laboratories as in 1987. The difference between the highest and lowest values is now 1.0 % compared with 1.1 % in 1987. All values are within +/- 2 % of the arithmetic mean. All Nordic values are lower than NPL values.

Results from measurements at NPL, Isover in France and National Research Council, NRC, in Canada, on specimens from the same batch of glass fibre insulation as the specimens used in this Nordtest project, show good agreement with the Nordic laboratories.

Measurements on rubber specimens show improved agreement. The difference between the highest and lowest values is now 15.6 % compared with 29 % in 1987. All Nordic values are within +/- 2 % of the arithmetic mean. All Nordic values are lower than NPL values, except for the VTT value which is higher.

1. INTRODUCTION

This report describes the results from comparative testing carried out at four Nordic laboratories and a British one on thermal insulation materials. All five laboratories have measured the thermal transfer factors of specimens of, respectively, expanded polystyrene (EPS), glass fibre wool and rubber. A corresponding comparison in 1987 showed good agreement between all the laboratories as regards expanded polystyrene and glass fibre wool, whereas rubber sheets failed to show satisfactory agreement.

The objectives of this new project were to find out whether the agreement within the Nordic countries as regards insulation materials was equally good now, and whether there had been any improvement with regard to materials with higher thermal transmissivity.

When the project was starting, agreement was reached with National Physical Laboratory, NPL, in England to perform measurements on the same specimens to enable us to compare the Nordic level with other laboratories in Europe. At the same time NPL participated with Isover in France and National Research Council, NRC, in Canada in an intercalibration project on glass fibre insulation. The main results from their measurements are given in Annex A.
Reference specimens from the same batch of glass fibre insulation as the specimens measured at NPL, Isover and NCR were obtained for use in this Nordtest project.

S. Uvsløkk at NBI has had overall responsibility for the project.

2. SPECIMENS

The specimens of expanded polystyrene, NT1 and NT2, were manufactured by Vartdal Plastindustri A/S, Norway, the natural rubber specimens, NT3 and NT4, were manufactured by Stavanger Gummiindustri A/S, Norway; and the glass fibre specimens, NL7 and NL9, came from NPL in England and were manufactured by Pilkington.

Densities and dimensions of the specimens are given in the tables of results.

3. PROCEDURE

Because the apparatus used at VTT is smaller than that at the other participating laboratories, the specimens had to be reduced in size to 400 mm x 400 mm prior to being measured at VTT. This could only be done in the case of the EPS and rubber specimens. The glass fibre specimens were therefore not measured at VTT.

The measurements were carried out in the period March to October 1992, except those on the glass fibre sheets at NPL which took place from August to October 1991.

Most measurements were made when the specimen had an approximate mean temperature of

10 °C. At DTI, the specimens were also measured at lower and higher average temperatures. Most measurements on the insulation materials were made when the temperature difference between the hot and the cold side of the specimen was about 20 °C, but at NPL and NBI measurements were also made when the temperature difference was about 10 °C. The specimens at NBI were measured in both a Guarded hot plate apparatus (GHP) and a Heat flow meter apparatus (HFM). Because of limitations in the heat flow capacity of the apparatus, the rubber sheets were measured at somewhat variable and lower temperature differences at the various laboratories.

The measurements were carried out in accordance with the ISO 8301 (HFM) or ISO 8302 (GHP) or national standards based on previous versions of these ISO standards.

4. APPARATUS

The most important information about the apparatus used is given in the table below.

Table 1 Information about the apparatus used

Institute	NPL	NBI	NBI	SP	DTI	VTT
Type of apparatus	GHP, single sided	GHP, double sided	HFM, heat flow meters on both sides of the specimen	HFM, heat flow meters on both sides of the specimen	GHP, double sided	HFM, one heat flow meter between two specimens
Heat flow direction	Upward	Vertical	Downward	Downward	Vertical	Horizontal
Overall size, mm	610	600	600	600	600	400
Metering section, mm	305	300	300	250	300	200

5. RESULTS AND MEASURING CONDITIONS

Even though the measurements were performed on the same specimens, the width, length and thickness measured vary slightly. The values measured and reported by the various laboratories and used in the calculations of density and transfer factor of the specimen are therefore given in the following tables along with the temperature conditions and the results. The transfer factor of a specimen is defined as density of heat flow rate divided by the temperature gradient through the specimen.

A check of the internal consistency of the data reported from the laboratories showed some minor irregularities. Some of the transfer factors given in the tables have therefore been recalculated on the basis of reported heat flow rate, temperature drop across the specimen and the thickness of the specimen during the measurement.

The values given for the EPS sheets may be up to 1 % lower than the thermal transmissivity of the material, owing to the effect of thickness. In the case of the glass fibre and rubber sheets, there are no effect of thickness and therefore the transfer factor equates with the thermal transmissivity of these materials. The terms "transfer factor" and "thermal transmissivity" are used as defined in ISO 9288. They characterises, respectively, an

insulating specimen and an insulating material in relation with the combined conduction and radiation heat transfer.
In the case of apparatus measuring two specimens simultaneously, the results are only given in the c tables which show mean values; the corresponding empty columns in the a and b tables are included to make the tables identical and easier to follow.

Table 2a Specimen: **Expanded polystyrene, NT1**

Institute	NPL	NPL	NBI	NBI	NBI	SP	DTI	DTI	DTI	VTT
Type of apparatus	GHP	GHP	GHP	HFM	HFM	HFM	GHP	GHP	GHP	HFM
Specimen width and length, mm	599	599		599	599	600				
Specimen thickness, mm	58.8	58.8		59.3	59.3	59.4				
Specimen density, kg/m³	25.5	25.5		25.3	253	25.1				
Ambient temperature, °C	20-23	20-23		10.4	10.4	10.1				
Specimen temperature drop, °C	10.38	20.26		10.16	19.26	19.5				
Mean specimen temperature, °C	10.43	10.67		9.90	10.05	10.1				
Density of heat flow rate, W/m²	5.91	11.52		5.54	10.49	11.0				
Transfer factor, mW/mK	33.48	33.43		32.31	32.29	33.51				

Table 2b Specimen: **Expanded polystyrene, NT2**

Specimen width and length, mm	599	599		599	599	600				
Specimen thickness, mm	58.25	58.25		59.3	59.3	59.4				
Specimen density, kg/m³	25.41	25.41		24.9	25.1	24.9				
Ambient temperature, °C	20-23	20-23		10.3	10.4	10.1				
Specimen temperature drop, °C	10.42	20.08		10.17	19.25	19.5				
Mean specimen temperature, °C	10.42	10.56		9.90	10.00	10.1				
Density of heat flow rate, W/m²	5.98	11.52		5.55	10.50	11.0				
Transfer factor, mW/mK	33.43	33.42		32.35	32.33	33.51				

Table 2c Specimen: **Expanded polystyrene, NT1 and NT2, average values**

Specimen width and length, mm	599.0	599.0	599	599.0	599.0	600.0	600	600	600	400
Specimen thickness, mm	58.5	58.5	59.3	59.3	59.3	59.4	59.07	59.07	59.07	59.45
Specimen density, kg/m³	25.5	25.5	25.1	25.1	25.1	25.0	25.1	25.1	25.1	24.8
Ambient temperature, °C	20-23	20-23	9.7	10.3	10.4	10.1	11	11	11	
Specimen temperature drop, °C	10.4	20.17	19.77	10.17	19.26	19.50	23.01	25.48	19.09	15.8
Mean specimen temperature, °C	10.42	10.62	9.84	9.9	10.03	10.1	7.29	10.02	15.06	10.3
Density of heat flow rate, W/m²	5.94	11.52	11.02	5.545	10.49	11.00	12.63	14.12	10.72	8.74
Transfer factor, mW/mK	33.45	33.43	33.06	32.33	32.31	33.51	32.42	32.73	33.17	32.89

Table 3a Specimen: **Glass fibre, LA7**

Institute	NPL	NPL	NBI	NBI	NBI	SP	DTI	DTI	DTI
Type of apparatus	GHP	GHP	GHP	HFM	HFM	HFM	GHP	GHP	GHP
Specimen width and length, mm	611 596	611 596		610 597	610 597	611 599			
Specimen thickness, mm	75.0	75.0		75.0	75.0	75.0			
Specimen density, kg/m³	54.3	54.3		54.3	54.3	54.6			
Ambient temperature, °C	20-23	20-23		10.3	10.3	9.5			
Specimen temperature drop, °C	10.46	20.6		10.12	19.54	19.6			
Mean specimen temperature, °C	10.41	10.73		9.9	9.9	10.0			
Density of heat flow rate, W/m²				4.05	7.82	7.88			
Transfer factor, mW/mK	30.97	30.85		30.01	30.01	30.15			

Tabel 3b Specimen: **Glass fibre, LA9**

Specimen width and length, mm	613 598	613 598		612 599	612 599	611 599			
Specimen thickness, mm	75.0	75.0		75.0	75.0	75.0			
Specimen density, kg/m³	53.3	53.3		53.4	53.4	54.1			
Ambient temperature, °C	20-23	20-23		10.1	10.1	9.5			
Specimen temperature drop, °C	10.29	20.58		10.30	19.52	19.6			
Mean specimen temperature, °C	10.31	10.69		10.0	9.95	10.0			
Density of heat flow rate, W/m²				4.14	7.91	7.86			
Transfer factor, mW/mK	31.04	30.94		30.14	30.40	30.08			

Table 3c Specimen: **Glass fibre, LA7 and LA9, average values**

Specimen width and length, mm	613 598	613 598	611 598	611 598	611 598	611 599	600 600	600 600	600 600
Specimen thickness, mm	75.0	75.0	75.0	75.0	75.0	75.0	74.7	74.7	74.7
Specimen density, kg/m³	53.8	53.8	53.9	53.9	53.9	54.4	53.4	53.4	53.4
Ambient temperature, °C	20-23	20-23	9,9	10.2	10.2	9.5	11	11	11
Specimen temperature drop, °C	10.38	20.59	20.11	10.21	19.53	19.60	24.91	25.97	22.64
Mean specimen temperature, °C	10.36	10.71	10.03	9.95	9.93	10.00	6.36	9.83	13.34
Density of heat flow rate, W/m²			8.06	4.09	7.87	7.87	9.82	10.39	9.19
Transfer factor, mW/mK	31.01	30.90	30.06	30.08	30.20	30.11	29.45	29.89	30.32

Table 4a Specimen: **Rubber, NT3**

Institute	NPL	NPL	NBI	NBI	NBI	SP	DTI	DTI	DTI	VTT
Type of apparatus	GHP	GHP	GHP	HFM	HFM	HFM	GHP	GHP	GHP	HFM
Specimen width and length, mm	640	640		640	640	640				
Specimen thickness, mm	42.4	42.4		42.5	42.5	42.6				
Specimen density, kg/m³	1253	1253		1227	1227	1230				
Ambient temperature, °C	20-23	20-23		10.3	10.3	9.9				
Specimen temperature drop, °C	8.90	5.39		7.14	13.62	4.2				
Mean specimen temperature, °C	10.58	9.79		10.45	10.05	10.1				
Density of heat flow rate, W/m²	59.29	36.01		42.87	81.32	26.5				
Transfer factor, mW/mK	282.5	283.3		255.2	253.8	268,8				

Table 4b Specimen: **Rubber, NT4**

Specimen width and length, mm	641	641		640	640	640				
Specimen thickness, mm	42.2	42.2		42.5	42.5	42.6				
Specimen density, kg/m³	1279	1279		1264	1264	1260				
Ambient temperature, °C	20-23	20-23		10.2	10.3	10.0				
Specimen temperature drop, °C	9.58	5.30		7.00	13.23	11.0				
Mean specimen temperature, °C	11.4	9.63		10.45	10.10	10.0				
Density of heat flow rate, W/m²	62.33	34.39		42.47	80.22	71.0				
Transfer factor, mW/mK	274.6	273.8		257.9	257.7	275				

Table 4c Specimen: **Rubber, NT3 and NT4, average values**

Specimen width and length, mm	640.5	640.5	640	640	640	640.0	640	640	640	400
Specimen thickness, mm	42.30	42.30	42.5	42.5	42.5	42.6	42.5	42.5	42.5	43.5
Specimen density, kg/m³	1266	1266	1246	1246	1246	1245	1243	1243	1243	1220
Ambient temperature, °C	20-23	20-23	10.0	10.3	10.3	9.95	11	11	11	
Specimen temperature drop, °C	9.24	5.35	15.9	7.07	13.43	7.60	14.5	15.36	13.89	14.6
Mean specimen temperature, °C	10.99	9.71	10.26	10.45	10.08	10.05	9.57	11.97	15.7	10.1
Density of heat flow rate, W/m²	60.81	35.20	95.35	42.67	80.77	48.75	87.06	92.32	83.44	99.68
Transfer factor, mW/mK	278.4	278.6	254.9	256.5	255.7	271.9	255.2	255.4	255.3	297.0

6. ANALYSIS OF THE RESULTS

In the tables below, the results of the measurements made when the temperature difference between the hot and cold side of the specimen was 20 °C, are compared by calculating the deviation in % in relation to the arithmetical mean for all apparatus used, 6 or 5.

The thermal conductivity values have been corrected to apply to exactly 10.0 °C. The temperature coefficients used when making the correction were determined on the basis of measurements carried out at DTI.

Table 5 Specimen: **Expanded polystyrene, NT1 and NT2,**
Transfer factors corrected to 10°C mean specimen temperature

Institute	NPL	NBI	NBI	SP	DTI	VTT	Average
Type of apparatus	GHP	GHP	HFM	HFM	GHP	HFM	
Specimen temperature drop, °C	20.17	19.67	19.26	19.5	25.48	15.8	20.00
Transfer factor, mW/mK	33.37	33.07	32.31	33.50	32.73	32.86	32.97
Deviation from average value, %	1.2	0.3	-2.0	1.6	-0.7	-0.4	0.0

Table 6 Specimen: **Glass fibre, LA7 and LA9,**
Transfer factors corrected to 10°C mean specimen temperature

Institute	NPL	NBI	NBI	SP	DTI		Average
Type of apparatus	GHP	GHP	HFM	HFM	GHP		
Specimen temperature drop, °C	20.59	20.11	19.53	19.6	25.97		21.16
Transfer factor, mW/mK	30.81	30.06	30.21	30.11	29.91		30.22
Deviation from average value, %	2,0	-0.5	0.0	-0.3	-1.0		0.0

Table 7 Specimen: **Rubber, NT3 and NT4,**
Transfer factors corrected to 10°C mean specimen temperature

Institute	NPL	NBI	NBI	SP	DTI	VTT	Average
Type of apparatus	GHP	GHP	HFM	HFM	GHP	HFM	
Specimen temperature drop, °C	5.35	15.90	13.43	7.6	15.36	14.6	12.04
Transfer factor, mW/mK	278.6	254.8	255.7	271.9	255.4	297.0	268.9
Deviation from average value, %	3.6	-5.2	-4.9	1.1	-5.0	10.4	0.0

7. COMMENTS AND CONCLUSIONS

The EPS measurements show slightly greater deviation than when comparative measurements last took place at the Nordic laboratories in 1987. The difference between the highest and lowest values is now 3.6 % compared with 2.1 then. All the values are within +/- 2 % of the arithmetical mean. All the Nordic values are lower than those from NPL except from the ones from SP which are just above.

There is still good conformity between the three Nordic laboratories as regards measurements on glass fibre insulation. The difference between the highest and the lowest values is now 1.0 % compared with 1.1 % last time. All the Nordic values are lower than those from NPL.

There is good agreement between the Nordic laboratories and the three foreign laboratories regarding measurement on glass fibre insulation. The difference between the arithmetical mean for the glass wool specimens LA4/LA6 in Table A1 in Annex 1 and the arithmetical mean for the specimens LA7/LA9 from the Nordtest project, see Table 6, is 0.4 %.

There are slightly better agreement now between the Nordic laboratories as regards the measurements on rubber. The difference between the highest and the lowest values is now 15.6 % compared with 29 % last time. All the Nordic values are lower than those from NPL except those from VTT which are somewhat higher.

8. REFERENCES

Svenningsen, N. *Samkalibrering af nordiske apparater for måling af varmeledningstal. Intercalibration of Nordic Apparatus for Measuring Thermal Transmissivity.* Report from Nordtest Project NR 661-87, Tåstrup Denmark 1987

ISO 8301, *Thermal Insulation - Determination of Steady-State Thermal Resistance and Related Properties - Heat Flow Meter Method,* 1991.

ISO 8302, *Thermal Insulation - Determination of Steady-State Thermal Resistance and Related Properties - Guarded Hot Plate Apparatus,* 1991.

ISO 9288, *Thermal Insulation - Heat Transfer by Radiation - Physical Quantities and Definitions.*

ANNEX A

Some results from an intercalibration at NPL in England, Isover in France and NRC in Canada are shown in Table A1. The results are from measurements on glass fibre specimens, LA4 and LA6, from the same batch as the specimens used in the Nordtest project. The average density of these specimen was 52.9 kg/m³.
All the results will be published in an internal report to the NRC, National Research Council, Canada.

There is good agreement between the Nordic laboratories and the three foreign laboratories regarding measurement on glass fibre insulation. The difference between the arithmetical mean for the glass wool specimens LA4/LA6 in Table A1 and the arithmetical mean for the specimens LA7/LA9 from the Nordtest project, see Table 6, is 0.4 %.

Institute	NPL	NRC	Isover	Average
Type of apparatus	GHP single-sided	GHP double-sided	GHP single-sided	
Specimen thickness, mm	75.0	75.0	75.0	75.0
Specimen density, kg/m³	52.9	52.9	52.9	52.9
Mean specimen temperature, °C	8.85	9.98	9.5	9.44
Transfer factor, mW/mK	30.25	30.36	30.25	30.29
Transfer factor at 10.0 °C, mW/mK	30.39	30.36	30.31	30.35

Table A1, Specimen: **Glass fibre LA4 and LA6**
The results are average values for the two specimens.

uke 21