



Forskning och  
Utveckling

FOU 2002:68

# **ROUND ROBIN TEST II AV ISOLERFÖRMÅGAN HOS FJÄRRVÄRMERÖR**

*Ture Nordenswan, Svenska Fjärrvärmeföreningen*



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*I rapportserien publicerar projektledaren resultaten från sitt projekt. Publiceringen innebär inte att Svenska Fjärrvärmeföreningens Service AB tagit ställning till slutsatserna och resultaten.*

# Innehållsförteckning

|                           | Sida |
|---------------------------|------|
| <b>Förord</b>             | 4    |
| <b>Syfte</b>              | 5    |
| <b>Inledning/bakgrund</b> | 5    |
| <b>Metod</b>              | 6    |
| <b>Resultat</b>           | 7    |
| <b>Kommentar</b>          | 9    |

|               |                                                                                                                         |
|---------------|-------------------------------------------------------------------------------------------------------------------------|
| <b>Bilaga</b> | <b>Originalrapport: ROUND ROBIN TEST FOR THE USE OF ISO 8497 TO MEASURE THERMAL CONDUCTIVITY IN PRE-INSULATED PIPES</b> |
|---------------|-------------------------------------------------------------------------------------------------------------------------|

*Acronym Lambda II*

NORDTEST Project No 1506-00

Originalrapporten är tillgänglig på  
[www.nordtest.org/projects/finalrep/1506-00.pdf](http://www.nordtest.org/projects/finalrep/1506-00.pdf)

## Förord

Projektet genomfördes under 2000-2001 som en fortsättning på *ROUND ROBIN TEST AV ISOLERFÖRMÅGAN HOS FJÄRRVÄRMERÖR FoU 1998:22* som initierades av den arbetsgrupp inom det europeiska standardiseringsarbete som arbetar med utvecklingen av standard för fjärrvärmerörs isoleringsegenskaper CEN/TC107/WG3.

Den ursprungliga redovisningen av projektet finns som bilaga till denna sammanfattning på svenska. Precis som förra gången ingår även detta fortsättningsprojekt i Svenska Fjärrvärmeföreningens forskningsserie.

Originalrapporten har titeln *ROUND ROBIN TEST FOR THE USE OF ISO8497 TO MEASURE THERMAL CONDUCTIVITY IN PRE-INSULATED PIPE, Acronym LAMBDA II* och har givits ut av NORDTEST med projektnummer 1506-00. Ansvarig för koordineringen av projektet har varit Henning D Smidt, Dansk Teknologisk Institut i Århus, som också författat originalrapporten. Tillsammans med Rolf Besier från AGFW samt Udo Schilling från Elastogran, båda från Tyskland, har undertecknad ingått i styrgruppen för projektet.

Omkring 20 laboratorier inbjöds att medverka och 10 av dessa deltog i testet medan 7 laboratorier blev klara vid tidpunkten för slutredovisning. Testresultaten redovisas öppet.

Spridningen mellan redovisade värden blev denna gång liten. Med ISO8497 som bas och föreslagna korrigeringar i tillhörande annex elimineras de tvister som förekommit i branschen. Det lyckade resultatet bör icke minst tillskrivas projektledaren Henning D. Smidt och hans omsorgsfullt utförda arbete.

Vi önskar också tacka Nordtest för medgivande av publiceringen av rapporten i vår FoU-rapportserie.

Stockholm 2002-04-20

Ture Nordenswan

## Syfte

Föregående ringtest, Round Robin I, hade till syfte att identifiera, studera och värdera de mätmetoder som vid den tidpunkten användes för bestämning av värmekonduktiviteten hos fjärrvärmerör. Härvid användes olika metoder, standarder och rörlängder för att fastställa värmekonduktiviteten.

Syftet denna gång har varit att utforma en provmetod baserad på *ISO 8497 Thermal insulation - Determination of steady state thermal transmission properties of thermal insulation for circular pipes* med samtidig verifiering av resultaten.

## Inledning/bakgrund

Prefabricerade fjärrvärmerör, som omfattas av detta projekt, består av ett inre medieförande rör av stål, direktapplicerade PUR-isolering och med en mantel av polyeten. PUR-isoleringen består av ett stort antal små slutna celler som innehåller en blandning av luft och koldioxid.

Fjärrvärme som uppvärmningsform finns i ett stort antal länder med en speciell koncentration till Norden, Tyskland och Östeuropa. I Europa produceras årligen cirka 10 000 km isolerade rör av denna konstruktion för att användas vid fjärrvärmedistribution.

Inom det europeiska standardiseringsarbetet finns provmetoder och kravnivåer för fjärrvärmerör beskrivna i standarden EN 253. För bestämning av värmekonduktiviteten, eller  $\lambda$ -värdet, av polyuretanisoleringen hänvisas till standarden *ISO 8497 Thermal Insulation - Determination of steady-state thermal transmission properties of thermal insulation for circular pipes*. Denna standard gäller för isolering av rör, ej specifikt för prefabricerade fjärrvärmerör, vilket innebär att metodbeskrivningen i ISO 8497 inte direkt går att applicera på fjärrvärmerör, eftersom stålrör, polyuretanisolering och polyetenhölje bildar en sammanhängande konstruktion och följaktligen måste provas som en konstruktion och inte som om vore det ett homogent isoleringsmaterial.

Värmekonduktiviteten hos fjärrvärmerör är en viktig marknadsföringsparameter. Om olika provningslaboratorier redovisar varierande värden för samma produkt, innebär det att bedömningsgrunderna för val av fabrikat och beräkning av verkliga energiförluster inte blir korrekta.

## Metod

De fjärrvärmerör som skulle provas tillverkades denna gång enligt standardmetod med koldioxidblåst isolering. Rören DN 50/140 åldrades i 250 dygn vid 90 °C temperatur. Denna tid motsvarar 12,3 år för CO<sub>2</sub>, 8,6 år för O<sub>2</sub> och 6,0 år för N<sub>2</sub> vid 25 °C vilket betyder att rören endast försumbart förändrats under själva provtiden på de olika provplatserna.

De deltagande laboratorierna erhöll 3 stycken fjärrvärmerör vardera slumpvis uttagna för provning.

Samtidigt distribuerades ett frågeformulär för att undersöka mätmetoder, utrustning och förhållandena under mätningarna. Frågor och svar finns också med som bilagor i rapporten.

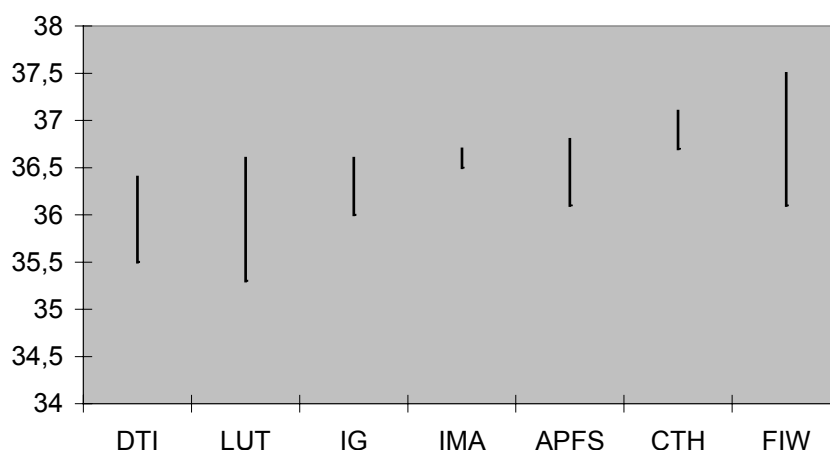
Förra gången var rören DN50/125 tillverkade enligt en kontinuerlig process med förslutna ändar och åldrade i 11 dygn i 70 °C. Rören innehöll cyklopentan.

FEM-beräkningar visar att distansernas inverkan är försumbar då inverkan i ett helt rör endast är 0,0002 W/(mK).

## Resultat från mätningarna av värmekonduktiviteten

| Laboratorium  | Provbit nr. | Värmekonduktivitet W/(m K) | Medelvärde W/(m K) | Standard avvikelse W/(m K) | 95% Konfidensintervall W/(m K) |        |
|---------------|-------------|----------------------------|--------------------|----------------------------|--------------------------------|--------|
| <b>LUT</b>    | 15          | 0,0366                     | 0,0358             | 0,0007                     | 0,0351                         | 0,0366 |
|               | 17          | 0,0353                     |                    |                            |                                |        |
|               | 22          | 0,0356                     |                    |                            |                                |        |
| <b>IG</b>     | 1           | 0,0362                     | 0,0364             | 0,0003                     | 0,0361                         | 0,0367 |
|               | 31          | 0,0366                     |                    |                            |                                |        |
|               | 22          | 0,0360                     |                    |                            |                                |        |
| <b>APFS</b>   | 9           | 0,0368                     | 0,0365             | 0,0004                     | 0,0361                         | 0,0369 |
|               | 18          | 0,0365                     |                    |                            |                                |        |
|               | 27          | 0,0361                     |                    |                            |                                |        |
| <b>FIW</b>    | 5           | 0,0363                     | 0,0369             | 0,0006                     | 0,0362                         | 0,0376 |
|               | 14          | 0,0375                     |                    |                            |                                |        |
|               | 26          | 0,0369                     |                    |                            |                                |        |
| <b>CTH</b>    | 7           | 0,0367                     | 0,0369             | 0,0002                     | 0,0366                         | 0,0371 |
|               | 16          | 0,0371                     |                    |                            |                                |        |
|               | 24          | 0,0368                     |                    |                            |                                |        |
| <b>DTI</b>    | 11          | 0,0364                     | 0,0360             | 0,0005                     | 0,0355                         | 0,0365 |
|               | 25          | 0,0360                     |                    |                            |                                |        |
|               | 28          | 0,0355                     |                    |                            |                                |        |
| <b>IMA</b>    | 8           | 0,0365                     | 0,0366             | 0,0001                     | 0,0365                         | 0,0367 |
|               | 13          | 0,0367                     |                    |                            |                                |        |
|               | 23          | 0,0366                     |                    |                            |                                |        |
| <b>Totalt</b> |             |                            | 0,0364             | 0,0004                     | 0,0359                         | 0,0369 |

|             |                                                         |
|-------------|---------------------------------------------------------|
| <b>LUT</b>  | Lappeenranta University of Technology, Finland          |
| <b>IG</b>   | Instituto Giordano SpA, Italien                         |
| <b>APFS</b> | Alstom Power Flow Systems, Danmark                      |
| <b>FIW</b>  | Forschungsinstitut für Wärmeschutz eV München, Tyskland |
| <b>CTH</b>  | Chalmers Tekniska Högskola, Sverige                     |
| <b>DTI</b>  | Dansk Teknologisk Institut, Danmark                     |
| <b>IMA</b>  | Materialforschung und Anwendungstechnik GmbH, Tyskland  |



Nedan visas resultaten grafiskt, enheten är mW/(mK)

Provmethoderna har således varit möjliga att justera så att medelvärdena hos de olika laboratorierna ligger mellan 35,5 och 37,5 mW/(mK) vid medeltemperaturen 50 °C.

Standardavvikelsen är 1,2% vilket är acceptabelt. Detta bygger på resultat från de 7 laboratorier som lämnade uppgifter före det avslutande mötet.

Resultaten som redovisades förra gången låg för 10 av de 11 deltagande laboratorierna mellan 25,8 och 32,1 mW/(mK). För ett av laboratorierna låg värdet på 37,1. Rören var den gången tillverkade med cyklopentan, vilket förklarar de generellt sett lägre värdena.

## Rörens homogenitet

Resultatet av provrörens homogenitet följer av nedanstående tabell

| Rörnummer                               |                   | 11          | 28          | -    | EN 253      |
|-----------------------------------------|-------------------|-------------|-------------|------|-------------|
| Densitet                                | g/cm <sup>3</sup> | 58,7 (3,1)  | 68,8 (1,5)  | -    | >60         |
| Andel slutna celler                     | %                 | 92,3 (0,6)  | 92,7 (0,6)  | -    | >88         |
| Färg                                    |                   | Gräddgul    | Gräddgul    | -    | -           |
| Cellstorlek                             | mm                | 0,21 (0,03) | 0,23 (0,05) |      | <0,05       |
| Hålrum och blåsor                       | mm                | -           | -           | -    | <5          |
| Diameter                                | mm                | 141         | 143,5       | -    | 140 – 141,3 |
| Centrumlinjens avvikelse                | mm                | 1,4         | 1,7         | -    | 3,0         |
| Mantelrörets vägg tjocklek              | mm                | 2,9         | 3,0         | -    | 3,0 – 3,5   |
|                                         |                   |             |             |      |             |
| Rörnummer                               |                   | 07          | 16          | 24   | -           |
| Luft (N <sub>2</sub> + O <sub>2</sub> ) | kPa               | 37,4        | 49,5        | 44,8 | -           |
| CO <sub>2</sub>                         | kPa               | 5,5         | 4,5         | 4,7  | -           |
| Vatten                                  | kPa               | 1,3         | 1,6         | 1,3  | -           |
| Övriga                                  | kPa               | 1,3         | 1,3         | 2,1  | -           |

*Tabellen visar resultatet av homogenitetstest utförd av DTI på ändstyckena av provrören. Chalmers Tekniska Högskola utförde cellgastestet*

Som framgår ur tabellen uppfyller rören standardkraven utom för densitet och diameter. Tabell 7 i originalrapporten visar att densiteten uppmätt på mitten av rören uppfyller kraven hos de övriga laboratorierna.

Vid beräkning av värmekonduktiviteten inkluderas diametern. Detta innebär att provstyckena uppfyller kraven för provrör.

Det finns fortfarande en del koldioxid kvar i rören. Detta innebär att värmeledningsförmågan fortsätter att öka.

## **Kommentar**

Resultaten som redovisades förra gången från 10 av 11 laboratorier låg mellan 0,0268 till 0,0321 W/(mK). Rören var blåsta med cyklopentan, vilket förklarar varför värdena låg på en lägre nivå än denna gång.

Endast 7 av de 10 deltagande laboratorierna levererade resultat inför det avslutande mötet.

Några smärre justeringar gjordes i annexet till ISO8497. Annexet inklusive justeringar redovisas i rapporten.

I samband med typtest av fjärrvärmerör föreslås att tre rör testas och att resultatet redovisas med tre siffror. Om 4 siffror används i exempelvis utvecklingssyfte måste osäkerheten fastställas.

Resultatet kan överlämnas till standardiseringskommittén CEN TC107 för behandling och inarbetning i standarden EN 253 för fjärrvärmerör.

## **Bilaga**

### **Originalrapport:**

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MEASURE THERMAL CONDUCTIVITY IN PRE-  
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**NORDTEST Project No. 1506-00**

**ROUND ROBIN TEST FOR THE USE OF  
ISO8497 TO MEASURE THERMAL  
CONDUCTIVITY IN PRE-INSULATED PIPES**

*Acronym LAMBDA II*

**Organised by:**

**Energy Division  
Centre for District Heating  
Kongsvang Allé 29  
DK-8000 Aarhus C**

ROUND ROBIN TEST FOR THE USE OF ISO8497 TO MEASURE THERMAL  
CONDUCTIVITY IN PRE-INSULATED PIPES

NORDTEST Project No. 1506-00

2. edition, July 2001

Danish Technological Institute, Energy Division

Danish Technological Institute is an independent non-profit enterprise with 1000 employees and an annual turnover of DKK 750 million, corresponding to EUR 100 million. Services provided by the Institute include consultancy, testing, documentation, information and training.

## **Foreword**

This project was initiated by CEN/TC107/WG3, which is the European working group that puts forward proposals for standards for polyurethane cellular plastic in district heating pipes.

The project was carried out by an international steering committee with the participation of the following user organisations: Arbeitsgemeinschaft Fernwärme, Germany, the Swedish District Heating Association and a producer of raw materials for district heating pipes - BASF, Germany.

Approximately 20 laboratories were invited, and 10 took part in the Round Robin Test.

The Nordic laboratories were supported partly by NORDTEST (project No. 1506-00), whereas the other participants paid for their own participation. In addition, the following companies have kindly supported the project: ALSTOM Power FlowSystems A/S, Denmark, Elastogran GmbH, Germany, Huntsman Polyurethanes, Belgium, and Løgstør Rør A/S, Denmark. Without their contribution it would not have been possible to complete this project.

I would like to thank all participants for their support in finishing the project.

Aarhus, July 2001  
Henning D. Smidt  
Project Manager

## Summary

Is it possible to use the standard *ISO8497 Thermal insulation - Determination of steady-state thermal transmission properties of thermal insulation for circular pipes* together with an annex when measuring thermal conductivity in pre-insulated pipes? This was investigated in a Round Robin Test where 7 laboratories participated.

The test samples were prepared as water-blown pre-insulated pipes with a steel medium pipe and a HDPE casing pipe. The test samples were artificially aged for 250 days at 90°C. By means of ageing the cell gas content changed to a composition that did not change the thermal conductivity during the measuring period.

The 7 laboratories received 3 aged random pipes, and measured single results between 0.0353 and 0.0375 W/(m K). The standard variation was in the range of 0.0001 to 0.0007 W/(m K), measured on 3 pipes in relation to a thermal conductivity of 0.036 W/(m K) that corresponds to 0.3% - 2.0% of the measured value.

The average results from the laboratories were from 0.0358 to 0.0369 W/(m K) with a standard deviation in the area of 0.0001 to 0.0007 W/(m K).

The average of all measurements was 0.0364 W/(m K) with a standard deviation of 0.00043 W/(m K) or 1.2%.

By using FEM analyses it was calculated that the spacers in the entire pipe increase thermal conductivity by 0.0002 W/(m K).

The applied equipment gives uniform results though 4 laboratories use calculated end caps, 2 laboratories use guarded ends and 1 laboratory uses calibrated end caps.

There was an overlap between all the laboratories in the 95% confidence interval and the 95% confidence interval from the average value of the test samples. There was also an overlap between the 95% confidence interval between most of the laboratories.

Uniform results were obtained from the few laboratories that also measured foam properties.

In the annex to ISO8497 some minor changes were carried out. The annex included the corrections stated in the report.

In connection with type testing of pre-insulated pipes it was recommended to test 3 pipes and to state the result with 3 digits. If 4 digits are used, e.g. for development purposes, the uncertainty has to be stated.

## Table of contents

|     |                                                                                        |                                     |
|-----|----------------------------------------------------------------------------------------|-------------------------------------|
| 1   | Objective .....                                                                        | 6                                   |
| 2   | Introduction .....                                                                     | 6                                   |
| 3   | The samples .....                                                                      | 7                                   |
| 3.1 | Homogeneity .....                                                                      | <b>Error! Bookmark not defined.</b> |
| 3.2 | Changes by ageing .....                                                                | 7                                   |
| 3.3 | Determination of the number of test pipes .....                                        | 9                                   |
| 4   | Production of test pipes .....                                                         | 9                                   |
| 5   | Questionnaires .....                                                                   | 9                                   |
| 6   | Results .....                                                                          | 10                                  |
| 6.1 | Homogeneity.....                                                                       | 10                                  |
| 6.2 | Thermal conductivity .....                                                             | 11                                  |
| 6.3 | Foam properties .....                                                                  | 12                                  |
| 6.4 | Questionnaires .....                                                                   | 14                                  |
| 6.5 | Spacers.....                                                                           | 14                                  |
| 7   | Conclusions .....                                                                      | 14                                  |
| 8   | References .....                                                                       | 15                                  |
| 9   | Enclosures .....                                                                       | 15                                  |
| 9.1 | Working document TC107 WG3 Sub-group: Thermal conductivity of pre-insulated pipes..... | 15                                  |
| 9.2 | Organisations and addresses .....                                                      | 20                                  |
| 9.3 | Questionnaires .....                                                                   | 23                                  |

## 1 Objective

The objective of the project is to verify the results of the annex and the standard ISO8497:1994, when measuring thermal conductivity in pre-insulated district heating pipes.

## 2 Introduction

The objective of this Round Robin Test was to form a basis for measuring thermal conductivity in pre-insulated district heating pipes and thereby to obtain more reliable results. That is why the Round Robin Test Lambda I - Nordtest report No. 387 (1997) - was carried out. The result of 40 measurements from 10 laboratories was that thermal conductivity 50 °C -  $\lambda_{50}$  - shows results from 0.0268 W/mK to 0.0321 W/mK. The standard deviation was from 0.00010 W/mK to 0.00082 W/mK.

A further scrutiny of the results shows that 6 laboratories quote the thermal conductivity of the foam while the other 5 state the results of the entire pre-insulated pipe. Of the participating laboratories 6 of them measure according to DIN52613:77. One laboratory carries out measurements according to ISO8497:94, one according to ISO/DIS8497:88, one according to ASTM C335-69 and 2 laboratories according to their own method. The standard EN253:94 prescribes ISO 8497.

On the basis of the results and simultaneously collected information regarding the circumstances of the measurements, a number of recommendations were stated. These recommendations are proposed as an annex to ISO8497, when the standard is used for measuring thermal conductivity in pre-insulated pipes.

The objective of this Round Robin Test is to verify the results when the annex is used together with ISO8497:1994.

### 3 The samples

#### 3.1 Homogeneity

It is necessary to investigate the following properties of the foam: density, colour homogeneity, cell size, including voids and bubbles, and the composition of cell gas to ensure that the specimens are homogeneous in composition. The closed cell content will form part of this investigation. In addition to this, it is necessary to determine geometric conditions such as diameter, coaxiality and jacket pipe thickness to ensure that homogeneous test pipes are obtained.

#### 3.2 Changes by ageing

Pre-insulated pipes change thermal conductivity during ageing because of diffusion of cellular gases. With the object to obtain test pipes with constant thermal conductivity it was decided to use water-blown PUR foam and to artificially age the test pipes in an oven. The calculated change in cellular gas is shown below.

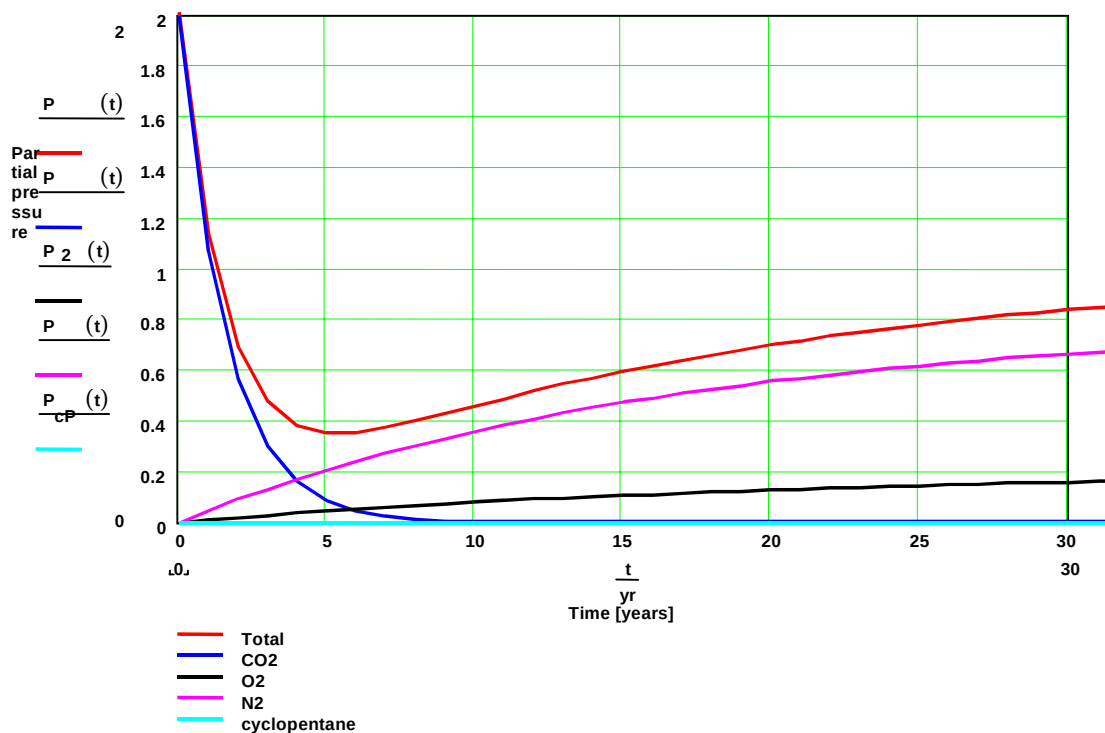


Figure 1: The calculated change in cellular gas in a PUR water-blown pre-insulated pipe, dimension 60.3 steel pipe in 140 mm HDPE casing pipe.

On the basis of this, thermal conductivity can be calculated - see below.

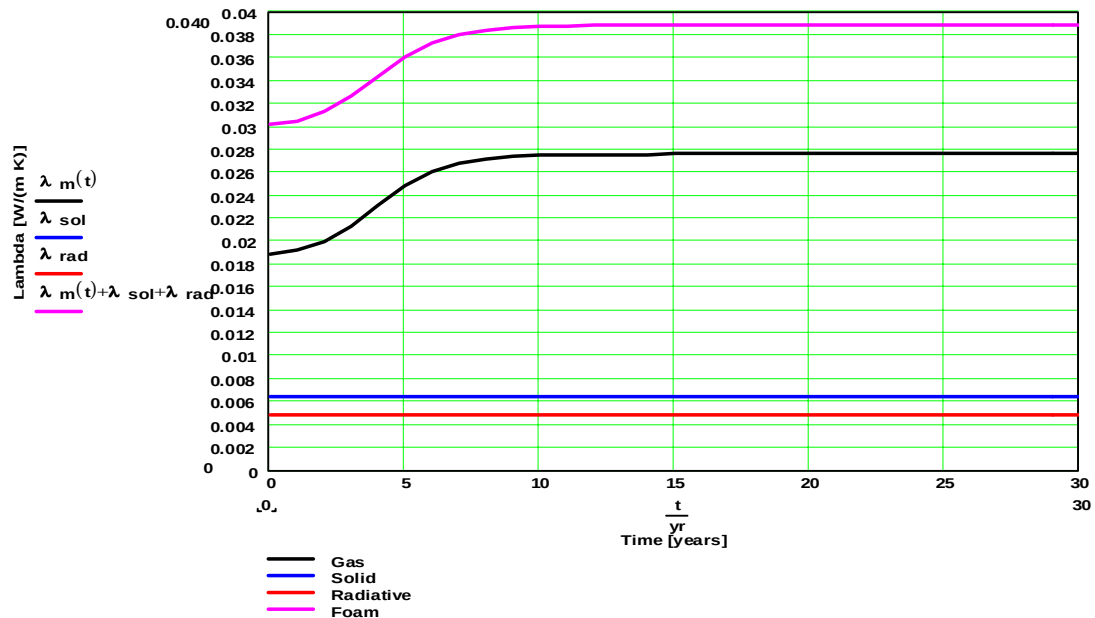


Figure 2: The calculated change in thermal conductivity in a PUR water-blown pre-insulated pipe, dimension 60.3 steel pipe in 140 mm HDPE casing pipe.

The activation energy for permeability of the simple cellular gases CO<sub>2</sub>, O<sub>2</sub> and N<sub>2</sub> is determined from 5 °C till 40 °C by Olson. As no physical changes occur in the structure of HDPE in the temperature range from 40 °C to 90 °C, the determined activation energies can be used to calculate the relationship between time and temperature in the temperature range by using the Arrhenius equation.

| Air             | Activation Energy [J/mol] | Time at 90 °C [Days] | Time at 25 °C [Days] | Time at 25 °C [Years] |
|-----------------|---------------------------|----------------------|----------------------|-----------------------|
| CO <sub>2</sub> | 40 x 10 <sup>3</sup>      | 250                  | 4494                 | 12.3                  |
| O <sub>2</sub>  | 35 x 10 <sup>3</sup>      | 250                  | 3132                 | 8.6                   |
| N <sub>2</sub>  | 30 x 10 <sup>3</sup>      | 250                  | 2182                 | 6.0                   |

Table 1: The relationship between time and temperature for permeation of gas through HDPE.

If the figure in the column called “Years” in table 1 is compared with figure 3.2 it appears that thermal conductivity will remain almost constant.

### 3.3 Determination of the number of test pipes

It is required that an error of 1 mW/mK can be detected, i.e. the result can be stated, e.g.  $0.030 \pm 0.001$  W/mK. The Standard Deviation was determined at 0.00039W/m K in the *Lambda 1* project.

When the number of samples are to be determined, the STD is to be multiplied by a factor of  $0.001/0.00039 = 2.56$ . From a student t-test table it can be found that the first figure is smaller than 2.59 for the 95% level is 2.48. That means that 3 samples are to be measured.

## 4 Production of test pipes

The specimens were of the dimension DN50 i.e. d/D 60.3/140 mm with a casing pipe thickness of 2.5 mm. The cellular plastic was water-blown polyurethane while the casing pipe material was a standard product.

Normally, the dimension d/D 60.3/125 is chosen to measure thermal conductivity. In this test it was desired that the test samples should have constant thermal conductivity. That was the reason why water-blown foam was used. Water-blown foam has a higher thermal conductivity than normal cyclopentane blown foam. On the other hand, the heat flow during the test should be the same. Therefore, an oversize pipe was chosen.

The pipes were blown in the traditional way. The pipes were 5.5 m long and cut to 4.5 m before ageing at 90 °C. After ageing for 250 days at 90 °C the pipes were randomised before labelling and distribution to the laboratories.

## 5 Questionnaires

With the purpose of obtaining knowledge of the measuring method, the equipment and the circumstances during measuring, a questionnaire was prepared. The questions and the answers can be seen under *enclosures*, chapter 9.3.

## 6 Results

Only 7 of the 10 laboratories supplied the results before the final meeting. The results from these laboratories are included in the data below.

### 6.1 Homogeneity

The results of the homogeneity test of the samples are shown below:

| Pipe #                                 |                   | 11          | 28          | -    | EN253       |
|----------------------------------------|-------------------|-------------|-------------|------|-------------|
| Density                                | g/cm <sup>3</sup> | 58.7 (3.1)  | 68.8 (1.5)  | -    | > 60        |
| Closed cell content                    | %                 | 92.3 (0.6)  | 92.7 (0.6)  | -    | > 88        |
| Colour                                 |                   | Cream       | Cream       | -    | -           |
| Cell size                              | mm                | 0.21 (0.03) | 0.23 (0.05) |      | < 0.05      |
| Voids and bubbles                      | mm                | -           | -           | -    | < 5         |
| Diameter                               | mm                | 141         | 143.5       | -    | 140 – 141.3 |
| Centre line deviation                  | mm                | 1.4         | 1.7         | -    | 3.0         |
| Casing pipe thickness                  | mm                | 2.9         | 3.0         | -    | 3.0 – 3.5   |
| Pipe                                   | no.               | 07          | 16          | 24   | -           |
| Air (N <sub>2</sub> + O <sub>2</sub> ) | kPa               | 37.4        | 49.5        | 44.8 | -           |
| CO <sub>2</sub>                        | kPa               | 5.5         | 4.5         | 4.7  | -           |
| Water                                  | kPa               | 1.3         | 1.6         | 1.3  | -           |
| Others                                 | kPa               | 1.3         | 1.3         | 2.1  | -           |

Table 2: The table shows the results of the homogeneity tests carried out by DTI on end pieces from test pipes. Chalmers Tekniska Högskola carried out the cell gas analyses. ( ) are STD.

As can be seen from table 4, the test pipes meet the requirements of the standard except for the density and diameter. The density measured in the middle of the samples by other laboratories meets the requirements – see table 6. The calculation of thermal conductivity includes the diameter. That means that the samples meet the requirements for test pipes.

There is still a carbon dioxide content although it is low. This means that thermal conductivity will continue to increase.

## 6.2 Thermal conductivity

The measured values and a graphical presentation of the results is seen below.

| Lab no. | Lab. abb     | Pipe no. | Thermal conductivity W/(m K) | Average W/(m K) | Standard deviation W/(m K) | 95% Confidence Interval W/(m K) |        |
|---------|--------------|----------|------------------------------|-----------------|----------------------------|---------------------------------|--------|
| 1       | LUT          | 15       | 0,0366                       | 0,0358          | 0,0007                     | 0,0351                          | 0,0366 |
|         |              | 17       | 0,0353                       |                 |                            |                                 |        |
|         |              | 22       | 0,0356                       |                 |                            |                                 |        |
| 2       | IG           | 1        | 0,0362                       | 0,0364          | 0,0003                     | 0,0361                          | 0,0367 |
|         |              | 31       | 0,0366                       |                 |                            |                                 |        |
|         |              | 22       | 0,0360                       |                 |                            |                                 |        |
| 3       | APFS         | 9        | 0,0368                       | 0,0365          | 0,0004                     | 0,0361                          | 0,0369 |
|         |              | 18       | 0,0365                       |                 |                            |                                 |        |
|         |              | 27       | 0,0361                       |                 |                            |                                 |        |
| 4       | FIW          | 5        | 0,0363                       | 0,0369          | 0,0006                     | 0,0362                          | 0,0376 |
|         |              | 14       | 0,0375                       |                 |                            |                                 |        |
|         |              | 26       | 0,0369                       |                 |                            |                                 |        |
| 5       | CTH          | 7        | 0,0367                       | 0,0369          | 0,0002                     | 0,0366                          | 0,0371 |
|         |              | 16       | 0,0371                       |                 |                            |                                 |        |
|         |              | 24       | 0,0368                       |                 |                            |                                 |        |
| 6       | DTI          | 11       | 0,0364                       | 0,0360          | 0,0005                     | 0,0355                          | 0,0365 |
|         |              | 25       | 0,0360                       |                 |                            |                                 |        |
|         |              | 28       | 0,0355                       |                 |                            |                                 |        |
| 7       | IMA          | 8        | 0,0365                       | 0,0366          | 0,0001                     | 0,0365                          | 0,0367 |
|         |              | 13       | 0,0367                       |                 |                            |                                 |        |
|         |              | 23       | 0,0366                       |                 |                            |                                 |        |
|         | <b>Total</b> |          |                              | 0,0364          | 0,0004                     | 0,0359                          | 0,0369 |

Table 3: The table shows the results of the Round Robin Test.

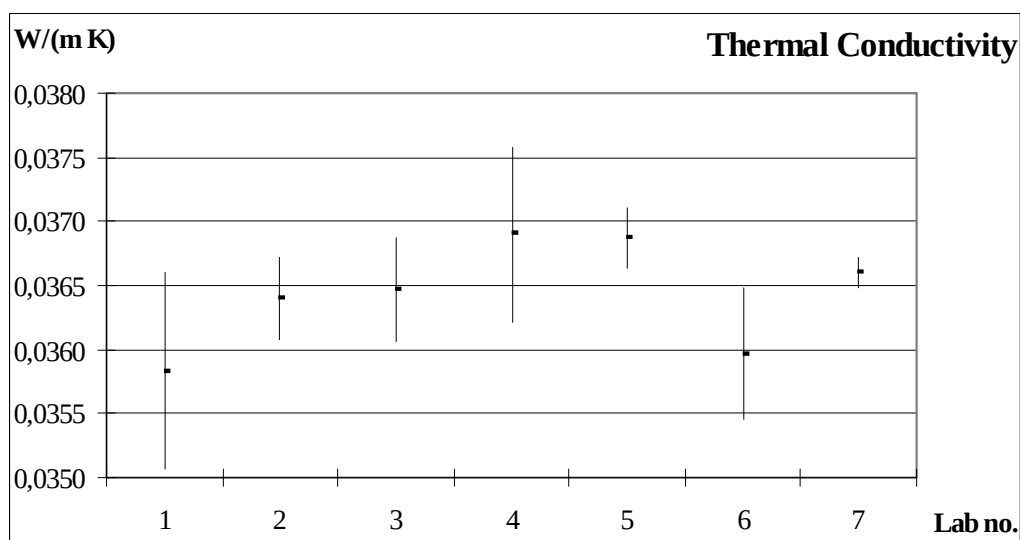


Figure 3: The picture shows the average and the 95% confidence interval.

The results vary from 0.0355 to 0.0375 W/mK. The average is 0.0364 W/(m K) with a standard deviation of 0.00043 W/(m K) or 1.2% of the average.

The standard variation is in the range of 0.0001 to 0.0007 W/(m K), measured on 3 pipes. In relation to a thermal conductivity of 0.036 W/(m K) that corresponds to 0.3% - 2.0% of the measured value. The standard deviation in *Nordtest report No. 387* is stated to be in the range of 0.0001 to 0.00082 W/(m K) with an average of 0.00039 W/(m K) or 1.4% of 0.028 W/(m K).

By using the student t-test, the 95% confidence interval can be calculated at  $0.0364 \pm 0.0005$  or between 0.0359 and 0.0369.

4 laboratories calculated the uncertainty according to prEN 1946-5, annex C. All 4 laboratories used end caps and the results were as below. The uncertainty of the results on the foam type used in practice is  $\pm 0.001$  W/(m K) or the double as the 95% confidence interval.

| Laboratory  | LUT   | IG   | FIW  | DTI  |
|-------------|-------|------|------|------|
| Uncertainty | -     | 3.6% | 2.9% | 3.6% |
| End losses  | 8.05% | -    | -    | 2%   |

Table 4: The table shows the uncertainty and the end losses.

### 6.3 Foam properties

| Laboratory        |              | LUT        | APFS      | FIW  |      |      | CTH |        |    | DTI  |      | IMA |      |      |
|-------------------|--------------|------------|-----------|------|------|------|-----|--------|----|------|------|-----|------|------|
| Pipe No.          |              | 15, 17, 22 | 9, 18, 27 | 5    | 14   | 26   | 7   | 16     | 24 | 11   | 28   | 8   | 13   | 23   |
| Property          | Unit         | -          | -         | -    | -    | -    | -   | -      | -  | -    | -    |     |      |      |
| Cell size         | mm           | (0.33)     | -         | 0.11 | 0.15 | 0.12 | -   | -      | -  | 0.21 | 0.23 |     |      |      |
| Closed cell ratio | %            | (96.7)     | -         | 97   | 97   | 96   | -   | -      | -  | 92.3 | 92.4 |     |      |      |
| Voids and bubbles | number       | -          | -         | 11   | 4    | 10   | -   | -      | -  | -    | -    |     |      |      |
| Foam density      | kg (m)-<br>3 | (76.1)     | 74 - 76   | 76.8 | 77.8 | 76.6 | -   | (77.3) | -  | 58.7 | 68.8 | 78  | 76.1 | 77.9 |
| Compres. strength | MPa          | -          | -         | -    | -    | -    | -   | -      | -  | 0.32 | 0.56 |     |      |      |
| Water absorption  | %            | (3.9)      | -         | -    | -    | -    | -   | -      |    | 4.8  | 3.9  |     |      |      |
| Cell gas pressure | kPa          | -          | -         | 55.3 | 53.2 | 53.9 | 45  | 57     | 53 | -    | -    |     |      |      |
| Carbon dioxide    | %            |            | -         | 8    | 8    | 8    | 12  | 8      | 9  | -    | -    |     |      |      |
| Air               | %            | -          | -         | 92   | 90   | 92   | 83  | 87     | 85 | -    | -    |     |      |      |
| I-pentane         | %            | -          | -         | -    | 1    | 1    | -   | -      | -  | -    | -    |     |      |      |
| Water             | %            | -          | -         | -    | -    | -    | 3   | 3      | 2  | -    | -    |     |      |      |
| Others            | %            | -          | -         | -    | -    | -    | 3   | 2      | 4  | -    | -    |     |      |      |

( ) are supposed to be average values. Some of the values have been recalculated from the questionnaires in order to make them comparable. The cell properties measured by DTI are from end pieces.

Table 5: The table shows the results from the participating laboratories.

Only a few laboratories decided to measure cell properties on the samples.

## 6.4 Questionnaires

See enclosure annex 9.3.

## 6.5 Spacers

The placement of the spacers can be determined by using infrared photography on a heated pipe. This was done by FIW. The pictures show that the casing pipe temperature was 4 °C higher when a spacer was placed inside the pipe for example 34 °C instead of 30 °C.

The effect of the spacers on the thermal conductivity was calculated by FIW by using FEM analyses. The results were that the spacers increased the thermal conductivity of the entire pipe by app. 0.0002 W/(m K).

## 7 Conclusions

The test pipes are uniform. It has been calculated that thermal conductivity infinitely can increase to 1.3 W/(m K). From figure 3 it is realistic to fix thermal conductivity between 0.036 and 0.037 W/m K within a couple of years and to use the pipes as internal reference when storing at normal room conditions.

The results vary from 0.0355 to 0.0375 W/mK. The standard variation is in the range of 0.0001 to 0.0007 W/(m K), measured on 3 pipes in relation to a thermal conductivity of 0.036 W/(m K) that corresponds to 0.3% - 2.0% of the measured value.

The average is 0.0364 W/(m K) and the standard deviation is 0.00043 W/(m K) or 1.2% of the average.

There is overlap between all of the 95% confidence intervals from all of the laboratories and the 95% confidence interval from the average value figure 3. There is also overlap between the 95% confidence interval between most of the laboratories.

The applied equipment gives uniform results, even though 4 laboratories use calculated end caps, 2 laboratories use guarded ends and 1 laboratory uses calibrated end caps.

In the annex to ISO8497 some minor changes have been carried out. The annex is included in enclosure No. 9.1.

For type testing it was recommended to test 3 pipes and to state the result with 3 digits. If 4 digits are used, e.g. for development purposes, the uncertainty has to be stated.

By using FEM analyses it was determined that the spacers in the entire pipe make thermal conductivity increase by 0.0002 W/(m K).

The results from the few laboratories that measured foam properties were uniform.

## 8 References

Olson, M E.: Thesis for Ph.D., Long-term Thermal Performance of Polyurethane-Insulated District Heating Pipes. Chalmers University of Technology, Gothenburg, 2001.

Nordtest report No. 387: Round Robin Test for measuring Thermal Conductivity in Pre-insulated Pipes. Danish Technological Institute, Aarhus, 1997.

## 9 Enclosures

### 9.1 Working document TC107 WG3 Sub-group: Thermal conductivity of pre-insulated pipes

#### 1. Scope

Together with ISO 8497 this specification describes a method for determining the steady-state thermal conductivity of polyurethane foam in pre-insulated district heating pipes.

#### 2. Requirements (ISO 8497:1994 Clause 5)

##### 2.1 Test specimen (ISO 8497:1994 Clause 5.1)

The pipe shall have a circular cross section. The test specimen shall be taken from the middle of the pipe with a length of no less than 3 m. In connection with type testing the test specimen shall be taken from a pipe assembly with the dimension 60.3/125 mm.

##### 2.2 Operating temperature (ISO 8497:1994 Clause 5.2)

The apparatus shall operate in static air maintained at an ambient temperature  $23 \pm 2^\circ\text{C}$ .

##### 2.3 Types of apparatuses (ISO 8497:1994 Clause 5.5)

A guarded end apparatus as well as a calibrated end and a calculated end apparatus can be used.

#### 3. Apparatus (ISO 8497:1994 Clause 7)

##### 3.1 Dimensions (ISO 8497:1994 Clause 7.2)

No restrictions are placed on the heater pipe diameter, but the length of the test section shall be no less than 1.0 m for the guarded end apparatus and no less than 2.0 m for calibrated end and calculated end apparatuses.

**NOTE:** *The guarded end apparatus uses separately heated pipe sections, called "guards", located at each end of the metered test section which are maintained at the test section temperature to eliminate axial heat flow in the apparatus, and to aid in achieving uniform temperatures so that all heat flow in the specimen test section will be in the radial direction. Both test and guard section heaters shall be designed to achieve uniform temperatures over their lengths unless it has been shown that the expected deviation from temperature uniformity does not cause unacceptable errors in test results.*

*A gap, normally not more than 4 mm in width, shall be provided in the heater pipe between the guards and the test section. A similar gap shall also be provided in the steel pipe of the test specimen between the metered section and the guard sections.*

*Internal barriers shall be installed at each gap to minimise convection and radiation heat transfer between the sections. Thermocouples, connected as differential thermopiles, shall be installed in the heater pipe on both sides of each gap, and not more than 25 mm from the gap, for the purpose of monitoring the temperature differential across each gap.*

*When using the calibrated end apparatus, corrections are required for the heat loss through the end caps. These corrections are obtained by carrying out measurements on specimens with different lengths taken from the same pipe sample. Three test specimens with different lengths, i.e. 3.0 m, 1.5 m and 0.75 m shall be used. For each test length (L) the total heat input ( $Q_{tot}$ ) shall be recorded. When plotting the measured total heat input vs. the pipe length, a straight-line-relationship shall be obtained where the correlation coefficient shall be stated. The heat loss through the end caps is determined as the intercept for  $L=0$  and shall be stated in the test report.*

### **3.2 Heater pipe surface temperature**

The surface temperature of the heater pipe test section shall be measured by a minimum number of 4 temperature sensors equally placed along the test pipe section.

## **4. Test specimens (ISO 8497:1994 Clause 8)**

### **4.1 Conditioning (ISO 8497:1994 Clause 8.4)**

The test specimen shall be conditioned at room temperature for 1 week.

For type testing thermal conductivity shall be performed on a pipe sample, stored at room temperature for 4 weeks  $\pm$  1 week after production.

### **4.2 Dimension measurement (ISO 8497:1994 Clause 8.5)**

The inside and outside diameters of the service pipe ( $D_1$ ) and ( $D_2$ ) shall be measured with a slide calliper. The casing pipe shall be measured with a flexible steel tape to obtain the circumference, which is divided by  $\pi$  to obtain the outside diameter ( $D_4$ ), in at least 4 equally placed positions along the test specimen.

The thickness of the casing pipe ( $t$ ) shall be measured at 4 points equally placed around the circumference at both ends of the specimen and the inside diameter ( $D_3$ ) is then calculated.

### 4.3 Surface temperature measurement

Sensors for measuring the temperature of the specimen shall be attached to the service pipe inner surface and casing pipe outer surface.

#### 4.3.1 Location of temperature sensors (ISO 8497:1994 Clause 8.6)

The test section length shall be divided into at least 4 equal parts and at least one temperature sensor on the steel pipe and on the casing pipe shall be longitudinally located at the centre of each part. The sensors shall be circumferentially equally placed.

### 5 Procedure (ISO 8497:1994 Clause 9)

#### 5.1 Test length (ISO 8497:1994 Clause 9.1.1)

The actual test length (L) shall be no less than 1.0 m for guarded end apparatuses and no less than 2.0 m for calibrated end and calculated end apparatuses. Accuracy:  $\pm 1.0$  mm.

#### 5.2 Diameter (ISO 8497:1994 Clause 8.5)

The mean outside diameter of the casing pipe shall be obtained by measuring the circumference with a flexible steel tape. The outside diameter of the steel pipe shall be measured with a slide calliper.

Accuracy:       Casing pipe diameter  $\pm 0.5$  mm  
                    Service pipe diameter  $\pm 0.2$  mm

#### 5.3 Thickness of casing pipe

The thickness of the casing pipe shall be measured with a slide calliper.  
Accuracy:  $\pm 0.2$  mm

#### 5.4 Ambient requirements (ISO 8497:1994 Clause 9.2)

Operate the apparatus in a room or enclosure controlled to the desired ambient temperature,  $23 \pm 2^\circ\text{C}$ , so that it does not vary during testing more than  $\pm 1^\circ\text{C}$ . The test shall take place in essentially static air.

#### 5.5 Test pipe temperature (ISO 8497:1994 Clause 9.3)

Tests are to be run at a minimum of three service pipe temperatures. Accuracy of temperature measurements shall be within  $\pm 0.3^\circ\text{C}$ . For type tests the temperatures shall be approximately equally placed in the temperature interval  $70\text{--}90^\circ\text{C}$  measured at the inside surface of the service pipe.

#### 5.6 Power supply (ISO 8497:1994 Clause 7.9)

The accuracy of the power measuring system to the test section heater shall be within 1.0%.

#### 5.7 Axial heat loss (ISO 8497:1994 Clause 5.7)

When a guarded end apparatus is used then all tests where the axial heat flow at either end is estimated to be more than 0.5% of the mean heat input to the test section should be rejected. When calibrated end or calculated end apparatuses are used the heat loss through the end caps shall be determined and reported.

### 5.8 Test period and stability (ISO 8497:1994 Clause 9.5.3)

Continue the observations until at least three successive sets of observations, made with a minimum time interval of half an hour between each set, differ by no more than 1% from the mean value of the three sets, and do not exhibit unidirectional trends. Where the power measurement is made with an integrating instrument, each observation shall be of duration of 30 min.

## 6. Calculations (ISO 8497:1994 Clause 11)

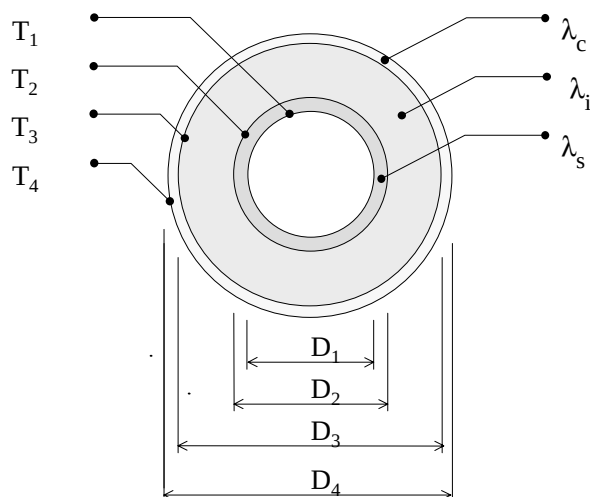
### 6.1 Thermal conductivity (ISO 8497:1994 Clause 3.5)

The thermal conductivity at the mean temperature in the insulation material shall be calculated by linear regression using the results obtained at the different pipe temperatures. The result is reported as  $\lambda$  at the mean temperature ( $T_m$ ). For type testing the mean temperature shall be 50°C and the thermal conductivity shall be reported as  $\lambda_{50}$  (EN253 clause 5.4.5).

Appropriate corrections shall be made to the temperature drop in the casing pipe (thermal conductivity of the HD-polyethylene is stated to be 0.40<sup>a</sup> (W·m<sup>-1</sup>·K<sup>-1</sup>). Any correction for the temperature drop in the steel service pipe can be neglected ( $\lambda_{\text{steel}} = 50^a$  (W·m<sup>-1</sup>·K<sup>-1</sup>)). If other materials are used as service pipe material, corrective calculations have to be made.

<sup>a</sup> prEN 12524: 1996 E, Building materials and products - Energy related properties - Tabulated design values, CEN/TC 89.

## 7. Symbols and units (ISO 8497:1994 Clause 4)



|                                             |             |                                       |
|---------------------------------------------|-------------|---------------------------------------|
| Heat flow rate                              | $\Phi$      | (W)                                   |
| Test section length                         | L           | (m)                                   |
| Temperature of service pipe inner surface   | $T_1$       | (°C)                                  |
| Temperature of insulation inner surface     | $T_2$       | (°C)                                  |
| Temperature of insulation outer surface     | $T_3$       | (°C)                                  |
| Temperature of casing pipe outer surface    | $T_4$       | (°C)                                  |
| Mean temperature of the insulation          | $T_m$       | (°C)                                  |
| Service pipe inner diameter                 | $D_1$       | (m)                                   |
| Inner diameter of insulation material       | $D_2$       | (m)                                   |
| Outer diameter of insulation material       | $D_3$       | (m)                                   |
| Outer diameter of casing pipe               | $D_4$       | (m)                                   |
| Thickness of casing pipe                    | t           | (m)                                   |
| Thermal conductivity of insulation material | $\lambda_i$ | (W·m <sup>-1</sup> ·K <sup>-1</sup> ) |
| Thermal conductivity of casing              | $\lambda_c$ | (W·m <sup>-1</sup> ·K <sup>-1</sup> ) |
| Thermal conductivity of service pipe        | $\lambda_s$ | (W·m <sup>-1</sup> ·K <sup>-1</sup> ) |

$$\lambda_i = \frac{\ln\left(\frac{D_3}{D_2}\right)}{\frac{2 \cdot \pi \cdot (T_1 - T_4) \cdot L}{\Phi} - \frac{1}{\lambda_c} \ln\left(\frac{D_4}{D_3}\right) - \frac{1}{\lambda_s} \ln\left(\frac{D_2}{D_1}\right)}$$

$$T_m = \frac{(T_3 + T_2)}{2}$$

$$T_3 = T_4 + \frac{\Phi}{2 \cdot \pi \cdot L \cdot \lambda_c} \ln\left(\frac{D_4}{D_3}\right)$$

$$T_2 = T_1 - \frac{\Phi}{2 \cdot \pi \cdot L \cdot \lambda_s} \ln\left(\frac{D_2}{D_1}\right)$$

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### 9.3 Questionnaires

#### Round Robin Test II for Thermal Conductivity $\lambda_{50}$ in Pre-insulated Pipes

*Lappeenranta University of Technology, Finland*

**Documents:**

EN ISO 8497

Thermal insulation – Determination of steady-state thermal transmission properties of thermal insulation for circular pipes.

Working document TC107 WG3 Sub-group:

Thermal conductivity of pre-insulated pipes.

EN 1946-1

Thermal performance of building products and components – Specific criteria for the assessment of laboratories measuring heat transfer properties – Part 1: Common criteria.

EN 1946-5

Thermal performance of building products and components – Specific criteria for the assessment of laboratories measuring heat transfer properties – Part 5: Measurements by pipe test methods.

**Questionnaire**

- 1 Deviations from EN ISO 8497 as described in EN 1946-5  
annex A.1: Accuracy and repeatability, stability, uniformity  
annex A.2: Equipment design requirements  
annex A.3: Acceptable specimen characteristics  
annex A.4: Acceptable testing conditions

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## 2 Information

Wires:

| Use            | Numbers | Area<br>[mm <sup>2</sup> ] | Length<br>[m] | Material |
|----------------|---------|----------------------------|---------------|----------|
| Thermostat     |         |                            |               |          |
| Heater         | 1       |                            | 0.95          |          |
| Thermocouplers | 20      | 0.05                       | 2.5           | J-type   |

Accuracy of the meter: W or %

Electrical voltage: 17-20.5 V AC V, AC or DC

Date of traceable calibration: 26.5.2000

Date of internal calibration:

Duration of measuring periods: 0.5 hours

Number of measuring periods: 3

Heat transporting media in pipe: air, oil, sand, others: Water

Room temperature: 25 +/- 1 °C

Wind speed around the test pipe: 0 m/s

Corrections for the end loss: End caps 8.05% End guards

Test rig placement: Horizontal X Vertical

3 Test pipe: Lengths 3 m

Casing pipe diameter and thickness: 0.143 m 3 mm

Thickness of casing pipe: 3 mm

Steel pipe diameter and thickness: 0.0603m 2.9 mm

4 Has the procedure been tested with a view to verifying the uncertainty

- prEN 1946-5 annex C: No; Result : \_\_\_\_\_%

## 5 Results:

| Pipe No. | Result $W \text{ (m K)}^{-1}$ |
|----------|-------------------------------|
| 15       | 0.0366                        |
| 17       | 0.0353                        |
| 32       | 0.0356                        |

## 6 For those who want to compare foam test results please fill in your data below:

| Property                  | Method               | Unit                 | Result |
|---------------------------|----------------------|----------------------|--------|
| Cell size                 | EN253 clause 5.2.2.1 | mm                   | 0.33   |
| Open to closed cell ratio | EN253 clause 5.3.2.2 | %                    | 3.3    |
| Voids and bubbles         | EN253 clause 5.2.2.3 | number               |        |
| Foam density              | EN253 clause 5.3.3   | $\text{kg (m)}^{-3}$ | 76.1   |
| Compressive strength      | EN253 clause 5.3.4   | MPa                  |        |
| Water absorption          | EN253 clause 5.3.5   | %                    | 3.9    |
| Cell gas pressure         |                      | kPa                  |        |
| Cell gas composition      |                      | CO <sub>2</sub>      |        |
|                           |                      | Air                  |        |

## Round Robin Test II for Thermal Conductivity $\lambda_{50}$ in Pre-insulated Pipes

*Instituto, Giordano, S.p.A., Italy*

### Documents:

EN ISO 8497

Thermal insulation – Determination of steady-state thermal transmission properties of thermal insulation for circular pipes.

Working document TC107 WG3 Sub-group:

Thermal conductivity of pre-insulated pipes.

EN 1946-1

Thermal performance of building products and components – Specific criteria for the assessment of laboratories measuring heat transfer properties – Part 1: Common criteria.

EN 1946-5

Thermal performance of building products and components – Specific criteria for the assessment of laboratories measuring heat transfer properties – Part 5: Measurements by pipe test methods.

### Questionnaire

- 1 Deviations from EN ISO 8497 as described in EN 1946-5  
annex A.1: Accuracy and repeatability, stability, uniformity  
annex A.2: Equipment design requirements  
annex A.3: Acceptable specimen characteristics  
annex A.4: Acceptable testing conditions

Type apparatus: guarded end apparatus

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Pipe test section length: 1200 mm

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Pipe guard length: 600 mm

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Gap between the guarded end test section: 5 mm

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Surface temperature in the pipe metering section: n. 8 thermocouples for external surface +

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n. 8 for internal surface (ANSI special grade type T thermocouples 30AWG)

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## 2 Information

Wires for **each gap**:

| Use            | Numbers | Total Area [mm <sup>2</sup> ] | Length [m] | Material |
|----------------|---------|-------------------------------|------------|----------|
| Thermostat     | 1       | 4.5E-4                        |            | Cu       |
|                | 1       | 4.5E-4                        |            | Co       |
| Heater         | 2       | 0.4                           |            | Cu       |
| Thermocouplers | 12*     | 54E-4                         |            | Cu       |
|                | 12*     | 54E-4                         |            | Co       |

(\*) 4 thermocouples for the measurement of internal temperature  
 8 differential thermocouples across the gap

|                                  |                                                                                |
|----------------------------------|--------------------------------------------------------------------------------|
| Accuracy of the meter:           | 0.2 %                                                                          |
| Electrical voltage               | DC                                                                             |
| Date of traceable calibration:   | 03/05/2001                                                                     |
| Date of internal calibration:    |                                                                                |
| Duration of measuring periods:   | 1 hour                                                                         |
| Number of measuring periods:     | 3                                                                              |
| Heat transporting media in pipe: | Expanded polyethylene<br>(thickness: 6 mm, thermal conductivity: 0.05 W/(m K)) |
| Room temperature:                | 23 +/- 1°C                                                                     |
| Wind speed around the test pipe: | 0 m/s                                                                          |
| Corrections for the end loss:    | end guards 0                                                                   |
| Test rig placement:              | Horizontal                                                                     |

|   |                                     |                                                                   |
|---|-------------------------------------|-------------------------------------------------------------------|
| 3 | Test pipe: Lengths                  | 1.2 m                                                             |
|   | Casing pipe diameter and thickness: | 0.1430 m    3.03 mm<br>0.1421 m    2.94 mm<br>0.1423 m    2.99 mm |
|   | Thickness of casing pipe:           | mm                                                                |
|   | Steel pipe diameter and thickness:  | 0.0544 m    2.90 mm<br>0.0544 m    3.02 mm<br>0.0544 m    2.94 mm |

## 4 Has the procedure been tested with a view to verifying the uncertainty

- prEN 1946-5 annex C:\_\_\_\_\_; Result : 3.6 %

5 Results:

| Pipe No. | Result $W \text{ (m K)}^{-1}$ |
|----------|-------------------------------|
| 01       | 0.0362                        |
| 31       | 0.0366                        |
| 22       | 0.0360                        |

6 For those who want to compare foam test results please fill in your data below:

| Property                  | Method               | Unit                 | Result |
|---------------------------|----------------------|----------------------|--------|
| Cell size                 | EN253 clause 5.2.2.1 | mm                   |        |
| Open to closed cell ratio | EN253 clause 5.3.2.2 | %                    |        |
| Voids and bubbles         | EN253 clause 5.2.2.3 | number               |        |
| Foam density              | EN253 clause 5.3.3   | $\text{kg (m)}^{-3}$ |        |
| Compressive strength      | EN253 clause 5.3.4   | MPa                  |        |
| Water absorption          | EN253 clause 5.3.5   | %                    |        |
| Cell gas pressure         |                      | kPa                  |        |
| Cell gas composition      |                      | CO <sub>2</sub>      |        |
|                           |                      | Air                  |        |

## Round Robin Test II for Thermal Conductivity $\lambda_{50}$ in Pre-insulated Pipes

### *ALSTOM Power FlowSystems, Denmark*

#### **Documents:**

EN ISO 8497

Thermal insulation – Determination of steady-state thermal transmission properties of thermal insulation for circular pipes.

Working document TC107 WG3 Sub-group:

Thermal conductivity of pre-insulated pipes.

EN 1946-1

Thermal performance of building products and components – Specific criteria for the assessment of laboratories measuring heat transfer properties – Part 1: Common criteria.

EN 1946-5

Thermal performance of building products and components – Specific criteria for the assessment of laboratories measuring heat transfer properties – Part 5: Measurements by pipe test methods.

#### Questionnaire

- 1      Deviations from EN ISO 8497 as described in EN 1946-5  
annex A.1: Accuracy and repeatability, stability, uniformity  
annex A.2: Equipment design requirements  
annex A.3: Acceptable specimen characteristics  
annex A.4: Acceptable testing conditions

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## 2 Information

Wires:

| Use            | Numbers | Area<br>[mm <sup>2</sup> ] | Length<br>[m] | Material |
|----------------|---------|----------------------------|---------------|----------|
| Thermostat     |         |                            |               |          |
| Heater         | 2       | 1.0                        | 1.0           | Cu       |
| Thermocouplers | 9       | $6.28 \cdot 10^{-2}$       | 1.0           | Type T   |

Accuracy of the meter: 0.05W or %

Electrical voltage: 30 V, DC V, AC or DC

Date of traceable calibration:

Date of internal calibration:

Duration of measuring periods: 1/3600 hours

Number of measuring periods: min. 3600

Heat transporting media in pipe: air, oil, sand, others: air

Room temperature: 28.9 +/- 0.6 °C

Wind speed around the test pipe: 0.2 m/s

Corrections for the end loss: End caps End guards X

Test rig placement: Horizontal Vertical X

3 Test pipe: Lengths: 1.00 m

Casing pipe diameter and thickness: 142.9 m 3.0 mm

Thickness of casing pipe: 3.0 mm

Steel pipe diameter and thickness: 60.3 m 2.9 mm

4 Has the procedure been tested with a view to verifying the uncertainty

- prEN 1946-5 annex C: \_\_\_\_; Result : \_\_\_\_\_ %

## 5 Results:

| Pipe No. | Result $W \text{ (m K)}^{-1}$ |
|----------|-------------------------------|
| 09       | 0.0368                        |
| 18       | 0.0365                        |
| 27       | 0.0361                        |

## 6 For those who want to compare foam test results please fill in your data below:

| Property                  | Method               | Unit                 | Result  |
|---------------------------|----------------------|----------------------|---------|
| Cell size                 | EN253 clause 5.2.2.1 | mm                   |         |
| Open to closed cell ratio | EN253 clause 5.3.2.2 | %                    |         |
| Voids and bubbles         | EN253 clause 5.2.2.3 | number               |         |
| Foam density              | EN253 clause 5.3.3   | $\text{kg (m)}^{-3}$ | 74 - 76 |
| Compressive strength      | EN253 clause 5.3.4   | MPa                  |         |
| Water absorption          | EN253 clause 5.3.5   | %                    |         |
| Cell gas pressure         |                      | kPa                  |         |
| Cell gas composition      |                      | CO <sub>2</sub>      |         |
|                           |                      | Air                  |         |

## Round Robin Test II for Thermal Conductivity $\lambda_{50}$ in Pre-insulated Pipes

*Forschungsinstitut für Wärmeschutz e.V., München, Germany*

### Documents:

EN ISO 8497

Thermal insulation – Determination of steady-state thermal transmission properties of thermal insulation for circular pipes.

Working document TC107 WG3 Sub-group:

Thermal conductivity of pre-insulated pipes.

EN 1946-1

Thermal performance of building products and components – Specific criteria for the assessment of laboratories measuring heat transfer properties – Part 1: Common criteria.

EN 1946-5

Thermal performance of building products and components – Specific criteria for the assessment of laboratories measuring heat transfer properties – Part 5: Measurements by pipe test methods.

### Questionnaire

- 1 Deviations from EN ISO 8497 as described in EN 1946-5  
annex A.1: Accuracy and repeatability, stability, uniformity  
annex A.2: Equipment design requirements  
annex A.3: Acceptable specimen characteristics  
annex A.4: Acceptable testing conditions

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## 2 Information

Wires:

| Use            | Numbers | Area<br>[mm <sup>2</sup> ] | Length<br>[m] | Material       |
|----------------|---------|----------------------------|---------------|----------------|
| Thermostat     | -       | -                          | -             | -              |
| Heater         | 2       | 0,75                       | -             | Copper         |
| Thermocouplers | 2 x 8   | 0,07                       | 3             | Cu-Cu/Ni 2x0,3 |

Accuracy of the meter: 0.3 % W or %

Electrical voltage: 10 to 40 V, AC or DC

Date of traceable calibration: 19 April 2001

Date of internal calibration: 19 April 2001

Duration of measuring periods: 0.5 hours

Number of measuring periods: 10

Heat transporting media in pipe: air, oil, sand, others: SAND

Room temperature: (21 to 23) +/- 0.2 °C

Wind speed around the test pipe: 0 m/s

Corrections for the end loss: End caps X End guards

Test rig placement: Horizontal X Vertical

## 3 Test pipe: Lengths: 2 m

Casing pipe diameter and thickness: 0.1415/0.1420/0.1421 m 3.0/3.1/3.0 mm  
(test pipe or specimen?)

Thickness of casing pipe: mm (same as above?)

Steel pipe diameter and thickness: 0.042 m 3 mm (FIW test pipe of brass)

## 4 Has the procedure been tested with a view to verifying the uncertainty

- prEN 1946-5 annex C: 9 ; Result : 2.9 %

## 5 Results:

| Pipe No. | Thermal conductivity<br>at 50 °C mean temperature<br>of the PUR rigid foam<br>including spacers<br><br>$W (m K)^{-1}$ | Thermal conductivity<br>at 50 °C mean temperature<br>of the PUR rigid foam<br>without spacers<br><br>$W (m K)^{-1}$ |
|----------|-----------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------|
| 5        | 0.0363                                                                                                                | 0.0361                                                                                                              |
| 14       | 0.0375                                                                                                                | 0.0373                                                                                                              |
| 26       | 0.0369                                                                                                                | 0.0367                                                                                                              |

## 6 For those who want to compare foam test results please fill in your data below:

| Property                  | Method               | Unit            | Result |      |      |
|---------------------------|----------------------|-----------------|--------|------|------|
|                           |                      |                 | 5      | 14   | 26   |
| Cell size                 | EN253 clause 5.3.2.1 | mm              | 0.11   | 0.15 | 0.12 |
| Open to closed cell ratio | EN253 clause 5.3.2.2 | %               | 97     | 98   | 96   |
| Voids and bubbles         | EN253 clause 5.3.2.3 | number          | 11     | 4    | 10   |
| Foam density              | EN253 clause 5.3.3   | $kg (m)^{-3}$   | 76.8   | 77.8 | 76.6 |
| Compressive strength      | EN253 clause 5.3.4   | MPa             | -      | -    | -    |
| Water absorption          | EN253 clause 5.3.5   | %               | -      | -    | -    |
| Cell gas pressure         |                      | kPa             | 55.3   | 53.2 | 53.9 |
| Cell gas composition      |                      | CO <sub>2</sub> | 8      | 8    | 7    |
|                           |                      | Air             | 92     | 90   | 92   |
|                           |                      | i-Pentan        | -      | 1    | 1    |

## Round Robin Test II for Thermal Conductivity $\lambda_{50}$ in Pre-insulated Pipes

### *Chalmers Tekniska Högskola, Sweden*

#### **Documents:**

EN ISO 8497

Thermal insulation – Determination of steady-state thermal transmission properties of thermal insulation for circular pipes.

Working document TC107 WG3 Sub-group:

Thermal conductivity of pre-insulated pipes.

EN 1946-1

Thermal performance of building products and components – Specific criteria for the assessment of laboratories measuring heat transfer properties – Part 1: Common criteria.

EN 1946-5

Thermal performance of building products and components – Specific criteria for the assessment of laboratories measuring heat transfer properties – Part 5: Measurements by pipe test methods.

#### Questionnaire

- 1      Deviations from EN ISO 8497 as described in EN 1946-5  
annex A.1: Accuracy and repeatability, stability, uniformity  
annex A.2: Equipment design requirements  
annex A.3: Acceptable specimen characteristics  
annex A.4: Acceptable testing conditions

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## 2 Information

Wires:

| Use            | Numbers | Area<br>[mm <sup>2</sup> ] | Length<br>[m] | Material |
|----------------|---------|----------------------------|---------------|----------|
| Thermostat     |         |                            |               |          |
| Heater         |         |                            |               |          |
| Thermocouplers |         |                            |               |          |

Accuracy of the meter: &lt; 0.5% W or %

Electrical voltage: V, AC or DC

Date of traceable calibration:

Date of internal calibration:

Duration of measuring periods: ~ 12 hours

Number of measuring periods:

Heat transporting media in pipe: air, oil, sand, others: air

Room temperature: 20 +/- 21 °C

Wind speed around the test pipe: 0 m/s

Corrections for the end loss: End caps End guards YES

Test rig placement: Horizontal YES Vertical

3 Test pipe: Lengths: 1000 m

Casing pipe diameter and thickness: ~ 0.142 m \_\_\_\_\_ mm

Thickness of casing pipe: ~ 3.0 mm

Steel pipe diameter and thickness: ~ 0.0603 m \_\_\_\_\_ mm

4 Has the procedure been tested with a view to verifying the uncertainty

- prEN 1946-5 annex C: No; Result : \_\_\_\_\_ %

## 5 Results:

| Pipe No. | Result $W (m K)^{-1}$ |
|----------|-----------------------|
| 07       | 0.0367                |
| 16       | 0.0371                |
| 24       | 0.0368                |

## 6 For those who want to compare foam test results please fill in your data below:

| Property                  | Method               | Unit                 | Result |      |      |
|---------------------------|----------------------|----------------------|--------|------|------|
| Cell size                 | EN253 clause 5.2.2.1 | mm                   |        |      |      |
| Open to closed cell ratio | EN253 clause 5.3.2.2 | %                    |        |      |      |
| Voids and bubbles         | EN253 clause 5.2.2.3 | number               |        |      |      |
| Foam density              | EN253 clause 5.3.3   | kg (m) <sup>-3</sup> | 77.3   |      |      |
| Compressive strength      | EN253 clause 5.3.4   | MPa                  |        |      |      |
| Water absorption          | EN253 clause 5.3.5   | %                    |        |      |      |
| Cell gas pressure         |                      | kPa                  | 45     | 57   | 53   |
| Cell gas composition      |                      | CO <sub>2</sub>      | 5.5    | 4.5  | 4.7  |
|                           |                      | Air                  | 37.4   | 49.7 | 44.8 |
|                           |                      | Pipe No.             | 07     | 16   | 24   |

## Round Robin Test II for Thermal Conductivity $\lambda_{50}$ in Pre-insulated Pipes

***Danish Technological Institute, Aarhus, Denmark***

### **Documents:**

EN ISO 8497

Thermal insulation – Determination of steady-state thermal transmission properties of thermal insulation for circular pipes.

Working document TC107 WG3 Sub-group:

Thermal conductivity of pre-insulated pipes.

EN 1946-1

Thermal performance of building products and components – Specific criteria for the assessment of laboratories measuring heat transfer properties – Part 1: Common criteria.

EN 1946-5

Thermal performance of building products and components – Specific criteria for the assessment of laboratories measuring heat transfer properties – Part 5: Measurements by pipe test methods.

### Questionnaire

- 1      Deviations from EN ISO 8497 as described in EN 1946-5  
annex A.1: Accuracy and repeatability, stability, uniformity  
annex A.2: Equipment design requirements  
annex A.3: Acceptable specimen characteristics  
annex A.4: Acceptable testing conditions

End loss is calculated by using a documented ball shell model, where the ball shell thickness is at least 3 times the thickness of the insulation on the pipe.

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## 2 Information

Wires:

| Use            | Numbers | Area<br>[mm <sup>2</sup> ] | Length<br>[m] | Material |
|----------------|---------|----------------------------|---------------|----------|
| Thermostat     | 2       | 0,30                       | 1,2           | Cu/Kon   |
| Heater         | 3       | 0,75                       | 0,4           | Cu       |
| Thermocouplers | 8       | 0,30                       | 1,0           | Cu/Kon   |

Accuracy of the meter: 0.36W

Electrical voltage: 220 V AC

Date of traceable calibration: 24.11.2000

Date of internal calibration: 14.05.2001

Duration of measuring periods: 1 – 2 hours

Number of measuring periods: 3

Heat transporting media in pipe: air, oil, sand, others: Air

Room temperature: 23 + 1 °C

Wind speed around the test pipe: &lt; 0.1 m/s

Corrections for the end loss: 2%    End caps    X    End guards

Test rig placement:    Horizontal    X    Vertical

3    Test pipe: Lengths: 2.98 m

Casing pipe diameter: 143.5 mm 3.0 mm

Thickness of casing pipe: 3.0 mm

Steel pipe diameter and thickness: 60.3 mm \_\_\_\_ mm

4    Has the procedure been tested with a view to verifying the uncertainty

- prEN 1946-5 annex C: Result : 3.6 %

## 5 Results:

| Pipe No. | Result $W (m K)^{-1}$ |
|----------|-----------------------|
| 11       | 0.0364                |
| 25       | 0.0360                |
| 28       | 0.0355                |

## 6 For those who want to compare foam test results please fill in your data below:

| Property                  | Method               | Unit            | Results     | Results     |
|---------------------------|----------------------|-----------------|-------------|-------------|
| Pipe no                   | -                    | -               | 11          | 28          |
| Cell size                 | EN253 clause 5.2.2.1 | mm              | 0.21 (0.03) | 0.23 (0.05) |
| Open to closed cell ratio | EN253 clause 5.3.2.2 | %               | 7.7 (0.6)   | 7.3 (0.6)   |
| Voids and bubbles         | EN253 clause 5.2.2.3 | number          | -           | -           |
| Foam density              | EN253 clause 5.3.3   | $kg (m)^{-3}$   | 58.7 (3.1)  | 68.8 (1.5)  |
| Compressive strength      | EN253 clause 5.3.4   | MPa             | 0.32 (0.02) | 0.56 (0.03) |
| Water absorption          | EN253 clause 5.3.5   | %               | 4.8 (0.2)   | 3.9 (0.2)   |
| Cell gas pressure         | -                    | kPa             | -           | -           |
| Cell gas composition      | -                    | CO <sub>2</sub> | -           | -           |
|                           |                      | Air             | -           | -           |

(STD)

## Round Robin Test II for Thermal Conductivity $\lambda_{50}$ in Pre-insulated Pipes

### *IMA, Germany*

#### **Documents:**

EN ISO 8497

Thermal insulation – Determination of steady-state thermal transmission properties of thermal insulation for circular pipes.

Working document TC107 WG3 Sub-group:

Thermal conductivity of pre-insulated pipes.

EN 1946-1

Thermal performance of building products and components – Specific criteria for the assessment of laboratories measuring heat transfer properties – Part 1: Common criteria.

EN 1946-5

Thermal performance of building products and components – Specific criteria for the assessment of laboratories measuring heat transfer properties – Part 5: Measurements by pipe test methods.

#### Questionnaire

- 1      Deviations from EN ISO 8497 as described in EN 1946-5  
annex A.1: Accuracy and repeatability, stability, uniformity  
annex A.2: Equipment design requirements  
annex A.3: Acceptable specimen characteristics  
annex A.4: Acceptable testing conditions

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## 2 Information

Wires:

| Use            | Numbers | Area<br>[mm <sup>2</sup> ] | Length<br>[m] | Material |
|----------------|---------|----------------------------|---------------|----------|
| Thermostat     |         |                            |               |          |
| Heater         | 1       | 3.1                        | 12            | NiCr     |
| Thermocouplers | 12      | 49                         | 7             | NiCr-Ni  |

Accuracy of the meter: &lt; 0.5% W or %

Electrical voltage: 32-35 V, DC V, AC or DC

Date of traceable calibration: 06.2000

Date of internal calibration: 10.05.2001

Duration of measuring periods: 3.5 hours

Number of measuring periods: 8

Heat transporting media in pipe: air, oil, sand, others: air, Cu, PTFE

Room temperature: 22 +/- 1 °C

Wind speed around the test pipe: &lt; 0.1 m/s

Corrections for the end loss: End caps X End guards

Test rig placement: Horizontal X Vertical

3 Test pipe: Lengths: 2.0 m

Casing pipe diameter and thickness: 142 mm 2.9 mm

Thickness of casing pipe: 2.9 mm

Steel pipe diameter and thickness: 60.3 m 2.9 mm

4 Has the procedure been tested with a view to verifying the uncertainty: No

- prEN 1946-5 annex C: \_\_\_\_\_; Result : \_\_\_\_\_%

5 Results:

| Pipe No. | Result $W \text{ (m K)}^{-1}$ | $\rho[\text{kg/m}^3]$ |
|----------|-------------------------------|-----------------------|
| 08       | 0.0365                        | 78.0                  |
| 13       | 0.0367                        | 76.1                  |
| 23       | 0.0366                        | 77.9                  |

6 For those who want to compare foam test results please fill in your data below:

| Property                  | Method               | Unit                 | Result |
|---------------------------|----------------------|----------------------|--------|
| Cell size                 | EN253 clause 5.2.2.1 | mm                   |        |
| Open to closed cell ratio | EN253 clause 5.3.2.2 | %                    |        |
| Voids and bubbles         | EN253 clause 5.2.2.3 | number               |        |
| Foam density              | EN253 clause 5.3.3   | $\text{kg (m)}^{-3}$ |        |
| Compressive strength      | EN253 clause 5.3.4   | MPa                  |        |
| Water absorption          | EN253 clause 5.3.5   | %                    |        |
| Cell gas pressure         |                      | kPa                  |        |
| Cell gas composition      |                      | CO <sub>2</sub>      |        |
|                           |                      | Air                  |        |

# Rapportförteckning

Samtliga rapporter kan beställas hos Fjärrvärmeföreningens Förlagsservice.  
Telefon: 026 – 24 90 24, Telefax: 026 - 24 90 10

| <i>Nr</i>                                   | <i>Titel</i>                                                                                                             | <i>Författare</i>                               | <i>Publicerad</i> |
|---------------------------------------------|--------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------|-------------------|
| <b>FORSKNING OCH UTVECKLING - RAPPORTER</b> |                                                                                                                          |                                                 |                   |
| 1                                           | Inventering av skador på befintliga skarvar med CFC-blåsta respektive CFC-fria fogskum                                   | Hans Torstensson                                | maj-96            |
| 2                                           | Tryckväxlare - Status hösten 1995                                                                                        | Bror-Arne Gustafson<br>Lena Olsson              | maj-96            |
| 3                                           | Bevakning av internationell fjärrvärmeforskning                                                                          | Sture Andersson<br>Gunnar Nilsson               | maj-96            |
| 4                                           | Epoxirelining av fjärrvärmerör                                                                                           | Jarl Nilsson                                    | sep-96            |
| 5                                           | Effektivisering av konventionella fjärrvärmecentraler (abonnentcentraler)                                                | Lena Råberger<br>Håkan Walletun                 | okt-96            |
| 6                                           | Auktorisation av montörer för montage av skarvhylsor och isolering<br>Former och utvärdering                             | Lars-Åke Cronholm                               | okt-96            |
| 7                                           | Direkt markförlagda böjar i fjärrvärmeledningar                                                                          | Jan Molin<br>Gunnar Bergström                   | dec-96            |
| 8                                           | Medierör av plast i fjärrvärmesystem                                                                                     | Håkan Walletun<br>Heimo Zinko                   | dec-96            |
| 9                                           | Metodutveckling för mätning av värmekonduktiviteten i kulvertisoler-<br>ing av polyuretanskum                            | Lars-Åke Cronholm<br>Hans Torstensson           | dec-96            |
| 10                                          | Dynamiska värmelaster från fiktiva värmebehov                                                                            | Sven Werner                                     | mars-97           |
| 11                                          | Torkning av tvätt i fastighetstvättstugor med fjärrvärme                                                                 | H. Andersson<br>J. Ahlgren                      | maj-99            |
| 12                                          | Omgivningsförhållandenas betydelse vid val av strategi för ombyggnad<br>och underhåll av fjärrvärmenät. Insamlingsfasen  | Sture Andersson<br>Jan Molin<br>Carmen Pletikos | dec-97            |
| 13                                          | Svensk statlig fjärrvärmeforskning 1981-1996                                                                             | Mikael Henriksson<br>Sven Werner                | dec-97            |
| 14                                          | Korrosionsrisker vid användning av stål- och plaströr i fjärrvärmesys-<br>tem - en litteraturstudie                      | Peeter Tarkpea                                  | dec-97            |
| 15                                          | Värme- och masstransport i mantelrör till ledningar för fjärrkyla och<br>fjärrvärme                                      | Daniel Eriksson<br>Bengt Sundén                 | dec-97            |
| 16                                          | Utvärdering av fuktinträngning och gasdiffusion hos gamla kulvertrör<br>”Hisings-Backa”                                  | Ulf Jarfelt                                     | dec-97            |
| 17                                          | Kulvertförläggning med befintliga massor                                                                                 | Jan Molin<br>Gunnar Bergström<br>Stefan Nilsson | dec-97            |
| 18                                          | Värmeåtervinning och produktion av frikyla - två sätt att öka markna-<br>den för fjärrvärmedrivna absorptionskylmaskiner | Peter Margen                                    | dec-97            |
| 19                                          | Projekt och Resultat 1994-1997                                                                                           | Anders Tvärne                                   | mars-98           |

| <i>Nr</i> | <i>Titel</i>                                                                                          | <i>Författare</i>                                                      | <i>Publicerad</i> |
|-----------|-------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------|-------------------|
| 20        | Analys av befintliga fjärrkylakunders kylbehov                                                        | Stefan Aronsson<br>Per-Erik Nilsson                                    | mars-98           |
| 21        | Statusrapport<br>Trycklösa Hetvattenackumulatorer                                                     | Mats Lindberg<br>Leif Breitholtz                                       | maj-98            |
| 22        | Round Robin<br>test av isolerförmågan hos fjärrvärmerör                                               | Ulf Jarfelt                                                            | maj-98            |
| 23        | Mätvärdesinsamling från inspektionsbrunnar i fjärrvärmesystem                                         | Håkan Walletun                                                         | juni-98           |
| 24        | Fjärrvärmerörens isolertekniska långtidsegenskaper                                                    | Ulf Jarfelt<br>Olle Ramnäs                                             | juni-98           |
| 25        | Termisk undersökning av koppling av köldbärarkretsar till fjärrkylanät                                | Erik Jonson                                                            | juni-98           |
| 26        | Reparation utan uppgrävning av skarvar på fjärrvärmerör                                               | Jarl Nilsson<br>Tommy Gudmundson                                       | juni-98           |
| 27        | Effektivisering av fjärrvärmecentraler – metodik, nyckeltal och användning av driftövervakningssystem | Håkan Walletun                                                         | apr-99            |
| 28        | Fjärrkyla. Teknik och kunskapsläge 1998                                                               | Paul Westin                                                            | juli-98           |
| 29        | Fjärrkyla – systemstudie                                                                              | Martin Forsén<br>Per-Åke Franck<br>Mari Gustafsson<br>Per-Erik Nilsson | juli-98           |
| 30        | Nya material för fjärrvärmerör. Förstudie/litteraturstudie                                            | Jan Ahlgren<br>Linda Berlin<br>Morgan Fröling<br>Magdalena Svanström   | dec-98            |
| 31        | Optimalt val av värmemätarens flödesgivare                                                            | Janusz Wollerstrand                                                    | maj-99            |
| 32        | Miljöanpassning/återanvändning av polyuretanisolerade fjärrvärmerör                                   | Morgan Fröling                                                         | dec-98            |
| 33        | Övervakning av fjärrvärmenät med fiberoptik                                                           | Marja Englund                                                          | maj-99            |
| 34        | Undersökning av golvvärmesystem med PEX-rör                                                           | Lars Ehrlén                                                            | apr-99            |
| 35        | Undersökning av funktionen hos tillsatser för fjärrvärmevatten                                        | Tuija Kaunisto<br>Leena Carpén                                         | maj-99            |
| 36        | Kartläggning av utvecklingsläget för ultraljudsflödesmätare                                           | Jerker Delsing                                                         | nov-99            |
| 37        | Förbättring av fjärrvärmecentraler med sekundärnät                                                    | Lennart Eriksson<br>Håkan Walletun                                     | maj-99            |
| 38        | Ändgavlar på fjärrvärmerör                                                                            | Gunnar Bergström<br>Stefan Nilsson                                     | sept-99           |
| 39        | Användning av lågtemperaturfjärrvärme                                                                 | Lennart Eriksson<br>Jochen Dahm<br>Heimo Zinko                         | sept-99           |
| 40        | Tätning av skarvar i fjärrvärmerör med hjälp av material som sväller i kontakt med vatten             | Rolf Sjöblom<br>Henrik Bjurström<br>Lars-Åke Cronholm                  | nov-99            |

| <i>Nr</i> | <i>Titel</i>                                                                                                                        | <i>Författare</i>                                        | <i>Publicerad</i> |
|-----------|-------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------|-------------------|
| 41        | Underlag för riskbedömning och val av strategi för underhåll och förnyelse av fjärrvärmeledningar                                   | Sture Andersson<br>Jan Molin<br>Carmen Pletikos          | dec-99            |
| 42        | Metoder att nå lägre returtemperatur med värmeväxlardimensionering och injusteringsmetoder. Tillämpning på två fastigheter i Borås. | Stefan Petersson                                         | mars-00           |
| 43        | Vidhäftning mellan PUR-isolering och medierör. Har blåstring av medieröret någon effekt?                                            | Ulf Jarfelt                                              | juni-00           |
| 44        | Mindre lokala produktionscentraler för kyla med optimal värmeåtervin-<br>ningsgrad i fjärrvärmesystemen                             | Peter Margen                                             | juni-00           |
| 45        | Fullskaleförsök med friktionsminskande additiv i Herning, Danmark                                                                   | Flemming Hammer<br>Martin Hellsten                       | feb-01            |
| 46        | Nedbrytningen av syrereducerande medel i fjärrvärmenät                                                                              | Henrik Bjurström                                         | okt-00            |
| 47        | Energimarknad i förändring<br>Utveckling, aktörer och strategier                                                                    | Fredrik Lagergren                                        | nov-00            |
| 48        | Strömförsörjning till värmemätare                                                                                                   | Henrik Bjurström                                         | nov-00            |
| 49        | Tensider i fjärrkylanät - Förstudie                                                                                                 | Marcus Lager                                             | nov-00            |
| 50        | Svensk sammanfattning av AGFWs slutrapport<br>”Neuartige Wärmeverteilung”                                                           | Heimo Zinko                                              | jan-01            |
| 51        | Vattenläckage genom otät mantelrörsskarv                                                                                            | Gunnar Bergström<br>Stefan Nilsson<br>Sven-Erik Sällberg | jan-01            |
| 52        | Direktförlagda böjar i fjärrvärmeledningar<br>Påkänningar och skadegränser                                                          | Gunnar Bergström<br>Stefan Nilsson                       | jan-01            |
| 53        | Korrosionsmätningar i PEX-system i Landskrona och Enköping                                                                          | Anders Thorén                                            | feb-01            |
| 54        | Sammanlagring och värmeförluster i närvärmenät                                                                                      | Jochen Dahm<br>Jan-Olof Dalenbäck                        | feb-01            |
| 55        | Tryckväxlare för fjärrkyla                                                                                                          | Lars Eliasson                                            | mars-01           |
| 56        | Beslutsunderlag i svenska energiföretag                                                                                             | Peter Svahn                                              | sept-01           |
| 57        | Skarvtätning baserad på svällande material                                                                                          | Henrik Bjurström<br>Pal Kalbantner<br>Lars-Åke Cronholm  | okt-01            |
| 58        | Täthet hos skarvar vid återfyllning med befintliga massor                                                                           | Gunnar Bergström<br>Stefan Nilsson<br>Sven-Erik Sällberg | okt-01            |
| 59        | Analys av trerörssystem för kombinerad distribution av fjärrvärme och fjärrkyla                                                     | Guaxiao Yao                                              | dec-01            |
| 60        | Miljöbelastning från läggning av fjärrvärmerör                                                                                      | Morgan Fröling<br>Magdalena<br>Svanström                 | jan-02            |
| 61        | Korrosionsskydd av en trycklös varmvattenackumulator med kvävgas-<br>teknik – fjärrvärmeverket i Falkenberg                         | Leif Nilsson                                             | jan-02            |
| 62        | Tappvarmvattenreglering i P-märkta fjärrvärmecentraler för villor<br>– Utvärdering och förslag till förbättring                     | Tommy Persson                                            | jan-02            |

| <i>Nr</i> | <i>Titel</i>                                                              | <i>Författare</i>                                        | <i>Publicerad</i> |
|-----------|---------------------------------------------------------------------------|----------------------------------------------------------|-------------------|
| 63        | Experimentell undersökning av böjar vid kallförläggning av fjärrvärme-rör | Sture Andersson<br>Nils Olsson                           | jan-02            |
| 64        | Förändring av fjärrvärmenäts flödesbehov                                  | Håkan Walletun<br>Daniel Lundh                           | jan-02            |
| 65        | Framtemperatur vid värmegles fjärrvärme                                   | Tord Sivertsson<br>Sven Werner                           | mars-02           |
| 66        | Fjärravläsning med signaler genom rörnät – förstudie                      | Lars Ljung<br>Rolf Sjöblom                               | mars-02           |
| 67        | Fukttransport i skarvskum                                                 | Gunnar Bergström<br>Stefan Nilsson<br>Sven-Erik Sällberg | april-02          |
| 68        | Round Robin test II av isolerförmågan hos fjärrvärmerör                   | Ture Nordenswan                                          | april-02          |

## **FORSKNING OCH UTVECKLING – ORIENTERING**

|   |                                                                                                                                   |                                       |         |
|---|-----------------------------------------------------------------------------------------------------------------------------------|---------------------------------------|---------|
| 1 | Fjärrkyla: Behov av forskning och utveckling                                                                                      | Sven Werner                           | jan-98  |
| 2 | Utvärdering av fjärrkyla i Västerås. Uppföljning av Värmeforsk rapport nr 534. Mätvärdesinsamling för perioden 23/5 – 30/9 1996.  | Lars Lindgren<br>Conny Nikolaisen     | jan-98  |
| 3 | Symposium om Fjärrvärmeforskning på Ullinge Wärdshus i Eksjö kommun, 10-11 december 1996                                          | Lennart Thörnqvist                    | jan-98  |
| 4 | Utvärdering av fjärrkyla i Västerås. Uppföljning av Värmeforsk rapport nr 534. Mätvärdesinsamling för period 2. 1/1 – 31/12 1997. | Conny Nikolaisen                      | juli-98 |
| 5 | Metodutveckling för mätning av värmekonduktiviteten i kulvertisole-ring av polyuretanskum                                         | Lars-Åke Cronholm<br>Hans Torstensson | sept-99 |

Svenska Fjärrvärmeföreningens Service AB och Statens Energi-  
myndighet bedriver forskningsprogram inom området fjärrvärme  
hetvattenteknik och fjärrkyla.

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