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Programme of research, Development and Demonstration on District Heating and Cooling

CFC-FREE PLASTIC JACKET PIPES FOR DISTRICT HEATING

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Programme of Research, Development and Demonstration on District Heating

CFC-FREE PLASTIC JACKET PIPES FOR DISTRICT HEATING

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ENERGIETECHNIK UND FERNWÄRME MBH
Ferdinand-Porsche-Straße 4a · 6906 Leimen
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ADDENDUM

ref. to report 1992:P2

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In the appendix to the report attached you will find important biliographical references. They are cited in their original language. Please look at them not as a part of the report but as a service to the reader.

Translations of special comments to figures

page 36	Koordination	coordination
	Aufgaben	tasks
	Definition der Anforderungen	definition of requirements
	Entscheidungen	descisions
	Vorsitzender	chairman
	Versuchs-/Entwicklungsleiter	development chief
	Sekretariat	office
	Prüfinstitute	investigating institutes
	Industrie	industry
	Betreiber	operator
	Normung	standardisation
	Kommunikation	communication
	Abstimmung	harmonization
	Konzeption	concept
	Umsetzung	realisation
	Versuchsplanung/-durchführung	test planing/execution
	Dänemark	Denmark
	Deutschland	Germany
	Finnland	Finland
	Niederlande	The Netherlands
	Schweden	Sweden

Dear reader,

The Executive Committee of the Implementing Agreement on District Heating and Cooling is interested to improve the impact of the R&D activities and the effectiveness of the programme.
For that reason the Operating Agent needs your support. May I ask you to be so kind to complete the following questionnaire and to sent it back to:

Novem BV
Attn. Mr. J.C. Resing
P.O. Box 17
NL-6130 AA SITTARD

....

0 What are your name and adress

Name:

Adress:

0 What is your professional relation to the item of the report?

....
....

0 How did you receive your copy of the report?

....
....

0 Do you appreciate the activities, described in the report?

....
....

0 Do you have suggestions for further dissemination of the results presented in the report?

....
....

0 Do you have any suggestions for further tasks, or comments to the activities of the Implementing Agreement?

....
....

1. Introduction

For many years plastic jacket pipes proved worldwide to be an economic and reliable laying system for district heating pipelines. Especially during the 80's the state of knowledge was documented in numerous investigation reports [1 to 7]. For the production of the pipes up to now the blowing agent CFC-11 was used, which as cellular gas was also responsible for the good heat insulation of the PUR-foam.

Considering their ozone-depleting effect, CFC-11, as well as other fully halogenated chloric chemical compounds were adopted into the Montreal Protocol, which means that their further application is limited. As a consequence, individual countries issued laws and regulations regarding the banning of these substances during the next few years.

Searching for alternatives for the CFC-containing foam the industry followed different methods, the most importants of which are described in Section 3.

In view of new investigation results (climate measurements) and the political pressure, the Montreal Protocol as well as the national regulations are subject to constant changes. The present (February 1992) state of the plastic jacket pipes is described in Chapter 4, on the basis of a Swedish IEA-survey and a new German study.

The assessment of these alternatives is in most cases based on values obtained by the application of the proved CFC-containing foam. Chapter 5 gives a description of the technical prerequisites for new foams, paying special attention to

- shearing resistance
- compression strength
- temperature resistance
- aging resistance (service life).

During the last years numerous investigations on the new foams have been carried out. The most important investigations and the corresponding results are presented in Chapter 6.

Since the end of 1991 it is tried to internationally co-ordinate the investigation programmes (Chapter 7). In view of the cross-border co-ordination in connection with investigated foam systems, the applied stresses and the testing temperatures, there is the prospect, that single investigation results may form part of a useful global assessment (Chapter 8).

2. Summary

Within the next years, the application of CFC-11 will be forbidden in all of the investigated countries. In the district heating markets there are three alternative foams for plastic jacket pipes offered today by commercial production:

- CO2-foam from different manufacturers
- M90-foam from ABB C.I. Möller, blown with 1.1.1-trichlorethane and HCFC-22
- 'green foam' from TARCO, blown with HCTC-142b and CO_2.

Internationally there are no restrictions regarding the application of CO_2-foams.

Foams containing 1.1.1-trichlorethane (such as M90) may be used for some more years; still, there has been determined a deadline in all of the investigated countries (depending on the country there will be a ban between 1994 and 2005).

Foams based on HCFC-142b and CO_2 are still allowed in most countries except Switzerland; here, all HCFCs are banned from the year 2000 onwards. According to international statements and national legal projects there is a trend that the production or application of all ozone-relevant foams shall be reduced.

For the safe operation of plastic jacket pipes with CFC-11-free foams it is indispensable that the technical requirements resulting out of the thermo-mechanic stresses are met. These requirements regard

- shearing resistance
- compression strength
- temperature resistance and
- aging resistance (service life)

During the years 1987 to 1991 several countries carried through intensive investigations on CFC-free foams, but these investigations were substantially impaired by the following facts:

- During the above mentioned period the foams were still in a nascent stage.
- In many cases the test methods were not suitable for CFC-free foams.
- Neither the investigated foams nor the test conditions were coordinated between the testing agencies.

Not until in 1992, coordinated investigations on reference foams started. The agreement on reference foams and the coordination of the test conditions constitute important prerequisites for a global assessment. Thanks to the cooperation, investigations carried through at different testing agencies and with pipes and test cubes can be compared.

There are plans to adopt the new test concepts, which are independent from blowing agents, for the European standardization. Then, the required design approval tests for the marketed foams from the various manufacturers may be carried through. The only gap in the new test programmes which are accompanied by the European Project Group is the fact that investigations on the axial shearing resistance are missing. The axial shearing resistance is the most important characteristic of plastic jacket pipes, i.e. it allows endless-laying without expansions joints (see page 38).

It would be a pity if conclusions on the axial shearing resistance could be drawn only from tangential creep tests. If there should be any financial means available for the investigation of CFC-free foams, these should be allocated for the determination of the axial shearing resistance.

There remains the hope that the development of the CO_2-foams continues the trend shown during the last years, reaching gradually a higher temperature resistance so that this type of foam which is most favourable for the environment meets all the thermo-mechanic requirements.

3. Alternatives to CFC-blown Foames

During the last years the industry has made efforts to do without the proved but still ozone-depleting blowing and insulating agent CFC-11. To reach this aim various development strategies are followed.

3.1 Reduction of CFC-11

This was the first line of development which the industry followed in the middle and late 80's [8 and 9]. Regarding the fact that CFC-11 is forbidden, this development is not continued.

3.2 Application of HCFCs

As a consequence of their different chemical structure (single hydrogen atoms instead of perhalogens) these substances are easier decomposable and do not reach the atmosphere completely. Contrary to CFC-11, which is considered a "hard" CFC, HCFCs are called "soft" CFCs. Like CFC-11, HCFCs act as physical blowing agents, i.e. they start boiling under the influence of high reaction temperatures, without that they themselves would take part in the reaction. Therewith the application of HCFC offers the possibility to further take advantage of many characteristics as possible of the CFC-11 blown foams.

The following substances which are applicable for plastic jacket pipes form part of this group of foams:

HCFC-123
HCFC-141b
HCFC-142b
HCFC-22

It has to be mentioned, though, that none of these substances has a boiling point comparable to CFC-11 (with room temperature), so that CFC-11 cannot simply be replaced by a HCFC. Still, the production of plastic-jacket pipes is possible using different blowing agents such as HCFC-142b and CO_2 or 1.1.1-trichlorethane, HCFC-22 and pentane.

3.3 CO_2-foams

With regard to the protection of the ozone layer, CO_2-foams are absolutely undangerous, the ODP (ozone depleting potential)-value is 0. CO_2-foams will definitely not be subject to stricter regulations (which are to be expected).

With CO_2 as cellular gas, the PUR-foam has a significantly higher caloric conductability - even when it is new - than CFC-11 blown foams. Whereas CFC-11 remains mainly in the foam during its service life, CO_2 diffuses out of the cells, being replaced by atmospheric air, so that the lambda value still increases during operation time. As a consequence the heat losses are significantly higher than with CFC-11 blown pipes.

CO_2 is a chemical blowing agent which results by the reaction between water and isocyanate. The proved polyols have been developed and optimized during several years and are based on CFC-11 as blowing agent. Due to CFC's low viscosity high viscouse polyols with high OH-values could be applied which guaranteed a good thermic stability.

If CFC-11 is replaced by water (therewith CO_2-blowing method), it is not possible anymore to foam the usual pipe lengths of 12 m and more with the proved highly viscous polyols. Here, either the production method has be to changed (for instance technic applying a drawn-out filling pipe or endless manufacturing) or new free-flowing polyols have to be applied, the development of which is only in the beginning.

With the application of new polyols the first CO_2-foams which were tested at the late 80s in plastic jacket pipes, a softening of the foam was detected already with temperatures of about 100°C. CFC-11 blown foams remain hard up to over 160°C and are then thermically decomposed (burned). Since that time the softening temperature of the CO_2-foams has continuously risen thanks to intensive development work by the chemical industry. If this development continues in the future, CO_2-blown PUR-foams will be applied without any problem even in thermically highly stressed district heating networks with outgoing temperatures of 130°C or 140°C.

3.4 Future foam systems

Future foam systems for which other possible blowing (such as HFAs) and insulating agents may be applied, are possible only in view to a long-term period.

Here, it has to be pointed out that such alternative substances often have other detrimental effects to the environment. HFA 134 for instance enforces the greenhouse effect a thousand times more than CO_2.

4. Legal Outline Conditions

The development of international ozone layer protection is shown in [10]:

When the Montreal Protocol was adopted on 16 September 1987, a freeze on halons and a reduction of some CFCs by 50 per cent was all that could be agreed upon. Notwithstanding the willingness of some countries to go further, to achieve more was thought to be impossible by many in the light of the difficulties to find substitutes and regarding the costs involved.

Barely three years later the amendments adopted in London on 29 June 1990 revised and strengthenend the original protocol in two important respects: first the scope of the Montreal Protocol was widened to include more groups of substances and second it was agreed on a tighter timetable for phasing-out CFCs and halons. The London amendment imposed a ban on all CFCs and halons from the year 2000; the same timetable was imposed on carbon tetrachloride. A ban on 1.1.1-trichloroethane was set for 2005. A non-binding phase-out was agreed upon concerning partially halogenated HCFCs. Technical progress achieved between the adoption of the original protocol and the amendments thereon meant that an accelerated reduction schedule could be agreed upon with the confidence that the wish of phasing-out the use of ozone-depleting substances could be fulfilled by the use of new technologies. The experience might be interpreted as proof that innovation actually can take place very quickly, if the need for it is evident and the political framework reflects that need.

So far, the dynamic technical in the substitution of ozone depleting substances has allowed for the reduction of the production and the application of ozone depleting substances to be accelerated. The international declarations and legislative measures adopted at national level indicate that an agreement concerning a tightening of the phase-out schedules is not only possible but rather likely.

In October 1990, Mr. Sture Anderson of Malmö Energi AB interviewed international colleagues about the legal regulations for the application of CFC-11 and various HCFCs as well as in view to the estimated market shares for single tpyes of foams for the laying of plastic jacket pipes in their countries [11]. The result of these interviews is shown in Tables 4-1 to 4-3.

Country	Expiring date	
Denmark	1995-01-01	
Finland	1999-01-01 *)	Investigation
Germany	1995-01-01	from
The Netherlands	2000-01-01	1990
Sweden	1995-01-01 **)	
Switzerland	1995-01-01 ***)	
USA	2000-01-01	

*) Proposal of speeding up to 1995-01-01 is made. Decision will be taken before end of year.

**) Proposal of speeding up to 1991-07-01 is made. GATT has been notified about planned import restrictions.

***) For most applications already during 1991.

Table 4-1: Time schedule for banning of CFC-11 [11]

Country	Expiring date		
Denmark	No decision taken	*)	
Finland	No decision taken		Investigation
Germany	2000-01-01	**)	from
The Netherlands	No decision taken		1990
Sweden	2000-01-01	***)	
Switzerland	2000-01-01	****)	
USA	2000-01-01		

*) Trichloroethane banned from 2005

**) For HCFC-22

***) Special import taxes notified from 1991-07-01

****) Trichloroethane banned from 1995

Table 4-2: Time schedule for banning of HCFCs [11]

Country	CFC-11	HCFC-22	CO_2
	Blowing agent		
Denmark	*)	*)	*)
Finland	90	5	5 ***)
Germany	100	0	0
Holland	70	20	10
Sweden	≤ 80	? **)	≈ 20 ***)
Switzerland	≈ 100	0	≈ 0,1
USA	98	≈ 0	≈ 0 ****)

*) No answer given in questionnaire

**) The HCFC-share in Sweden ist not investigated, but ought to be low, if any

***) In Sweden and Finland local authorities (communities) may take decisions not to allow the use of CFCs

****) In USA, CFCs are believed to become phased out of the market in 1993-94.

Table 4-3: Estimated Market Shares 1990 (%) [11]

The result of these interviews may be comprised as follows:

In most of the interrogated countries CFC-11 will have to be banned between 1995 and 2000. In some countries the application of HCFCs has not been regulated so far, in other countries there are phase-out schedules for HCFC-22 or 1.1.1-trichlorethane. In the year 1990, CFC-11 blown pipes still had the largest market share in the interrogated countries.

From 1990 on further international agreements were concluded as to the protection of the ozone layer. This is reported in [10].

Comparable to the adoption of the Montreal Protocol was the adoption by the European Economic Community (EEC) of its Regulation (EEC) No. 594/91 of 4 March 1991 on "Substances that Deplete the Ozone Layer." This legislative act, too, involved an agreement by a number of countries with differing interests and positions. The phase-out schedules adopted by the EEC in this regulation are tighter than those agreed to in London just eight months before. The reduction timetables for CFCs, halons and carbon tetrachloride were tightened whilst that for 1.1.1-trichloroethane was maintained.

The Swedish government went even further than the EEC in its Government Bill 1990/91:90, "A Living Environment", which not only accelerated phase-out schedules for all groups of substances but brought HCFCs into the scope of the regulation. These substances, which are regarded as sorely needed substitutes for fully halogenated CFCs by some people but as an extension of the problematical use of ozone-depleting chemicals by others are to be banned - subject to exceptions - from the year 1994. Sweden has probably gone farthest in the adoption of legally binding timetables for phasing out the use of ozone depleting substances and is therefore included in this comparison. The following table gives a comparative overview of the development of these phase-out-schedules.

The first column identifies the substances as they appear in the annexes of the Montreal Protocol and the baselines to which reduction percentages refer. In the middle of the table, two columns the phase-out-schedules adopted in Montreal in 1987 and in London in 1990. For better understanding, entries are made only for those years in which changes in the reduction occur. Between such lines, previous reduction percentages apply. The comparison of these two columns gives an impression of the progress made in the meantime. Note that the London Amendment changed the basis for the halon reduction schedule to 1989 quantities.

The third column contains the phase-out-schedule adopted by the European Economic Community in 1991 involving even tighter reduction timetables. Note that 1986 quantities remain the basis for the halon reduction percentages. Progress is most visible in the reduction of CFCs.

The last column, following the same logic, presents the reduction regime adopted in the Swedish Environmental Bill.

Substances and baselines		Montreal Protocol		EEC Regulation	Sweden
		Original Protocol	London Amendment		
Date format: YYYY MM DD	YEAR	16 September 1987	29 June 1990	4 March 1991	Governmt. Bill 1990
		operating July to June	following calendar years		
Annex A	1991			33.3 per cent reduction[1]	50.0 per cent reduction
	1992	freeze			
Group I	1993	20.0 per cent reduction		50.0 per cent reduction	
	1994				
baseline 1986	1995		50.0 per cent reduction	67.5 per cent reduction	*)
	1996			85.0 per cent reduction	ban from 1996 01 01
CFC	1997		85.0 per cent reduction	ban from 1997 06 30[2]	
11, 12, 113, 114, 115	1998	50.0 per cent reduction			
	1999				
	2000		ban from 2000 01 01		
	2005	etc.			
Annex A	1992	freeze	baseline altered to 1989	baseline remained 1986	
	1993			freeze	
Group II	1994				
	1995		50.0 per cent reduction	50.0 per cent reduction	estim. 95.0 % reduction
baseline 1986	1996				
	1997				
Halon	1998				ban from 1988 01 01
1211, 1301, 2402	1999				
	2000		ban from 2000 01 01	ban from 2000 01 01	
	2005	etc.			
Annex B	1992	not included		50.0 per cent reduction	50.0 per cent reduction
	1993		20.0 per cent reduction		
Group I	1994				
	1995			67.5 per cent reduction	
baseline 1989	1996			85.0 per cent reduction	ban from 1996 01 01
	1997		85.0 per cent reduction	ban from 1997 07 01[3]	
CFC 13, 111, 112,	1998				
211, 212, 213, 214,	1999				
215, 216, 217	2000		ban from 2000 01 01		
Annex B	1992	not included		50.0 per cent reduction	
	1993				50.0 per cent reduction
Group II	1994				
	1995		85.0 per cent reduction	85.0 per cent reduction	85.0 per cent reduction
baseline 1989	1996				
	1997				
Carbon tetrachloride	1998			ban from 1998 01 01	ban from 1998 01 01
	1999				
	2000		ban from 2000 01 01		
Annex B	1992	not included		freeze	
	1993		freeze		
Group III	1994				
	1995		30.0 per cent reduction	30.0 per cent reduction	ban from 1995 01 01
baseline 1989	1996				
	1997				
1,1,1-trichloroethane	1998				
	1999				
	2000		70.0 per cent reduction	70.0 per cent reduction	
	2005		ban from 2005 01 01	ban from 2005 01 01	
Annex C	1994	not included			ban from 1994 01 01[5]
	1995			Reporting and information requirements only	
baseline 1989	2000				
	2005				
34 HCFC[4]	2020		phase-out if possible		
	2040		non-binding phase-out		

[1] Except for Member States having produced less than 15000 tonnes in 1986 where a freeze is applied from 1 July 1991 to 31 December 1992.

[2] 92.5 per cent reduction from 1997 01 01 to 1997 06 30. Exceptions for essential uses possible until 31 December 1999 at the latest if no alternatives exist.

[3] 92.5 per cent reduction from 1997 01 01 to 1997 06 30.

[4] HCFC 21, 22, 31, 121, 122, 123, 124, 131, 132, 133, 141, 142, 151, 221, 222, 223, 224, 225, 226, 231, 232, 233, 234, 235, 241, 242, 243, 244, 251, 252, 253, 261, 262, 271

[5] Subject to exceptions and consultations with EFTA and EEC.

*) Later changed to 1991-07-01 [17]

Table 4-4: Comparison of phase-out-schedules [10]

The table demonstrates the progress made in the regulation of ozone-depleting substances in the short period of three and a half years. The table also shows the trend towards including more and more substances in the phase-out-regime and the trend towards accelerating phase-out-schedules of those substances already within the scope of the Montreal Protocol. These trends are likely to persist, if the declared position of a number of countries favouring an even earlier ban of ozone-depleting chemicals prevails.

Perhaps the most important recent development in this respect was the Nairobi Declaration which can be expected to exert a significant influence during the discussion leading up the revision of the Montreal Protocol in Copenhagen in November 1992.

During the third meeting of the Parties to the Montreal Protocol on 19-21 June 1991 in Nairobi the heads of the delegations of several countries agreed on a statement reflecting their concern about the slow speed of the CFC and halon phase out in the light of recent scientific findings about the stratospheric ozone layer. The seven signatory states are Sweden, Finland, Norway, Switzerland, Austria, Germany und Denmark. These states thereby declared their intention to accelerate the phase-out of the reduction and consumption of CFCs, halons, carbon tetrachloride and 1.1.1-trichloroethane laid down in the London amendment to the Montreal Protocol. At the same time, the use of HCFCs is to be limited to specific key applications, and to be allowed only temporarily. The Nairobi Declaration commits the ignatories to work towards a tightening of the timetables agreed upon in the Montreal Protocol. The wording of the Nairobi Declaration is contained in the following box:

STATEMENT MADE BY:

SWEDEN, FINLAND, NORWAY, SWITZERLAND, AUSTRIA, GERMANY AND DENMARK

We believe that the recent analysis of the state of the stratospheric ozone layer calls for the adoption of more stringent control measures at the Fourth Meeting of the Parties in 1992.

We are also of the opinion that the substitution of the controlled substances with transitional substances must be as moderate and temporary as possible.

We note that the London resolution urges the adoption, in accordance with the spirit of the paragraph 11 of Article 2 of the Protocol, of more stringent measures in order to protect the Ozone Layer.

Because of this we express our firm determination to phase-out the production and the consumption of CFCs, halons and carbon tetrachloride controlled in the Montreal Protocol, as soon as possible but not later than the year 2000. We also think it is necessary to tighten the timetable agreed upon in the Montreal Protocol taking due account of the special situation of developing countries.

We are also determined to limit by no later than 1995 the use of transitional substances (HCFCs) to specific key application where other more environmentally suitable alternative substances or technologies are not available, and to phase-out their use in those areas as soon as technically feasible.

Some of the countries that signed the Nairobi Declaration have already adopted national legislation effecting an accelerated phase out of ozone-depleting substances and restrictions on the use of HCFCs, or they intend to do so during 1992, notably Germany, Sweden and Switzerland.

As will be seen in the next table a comparision of the phase-out-schedules in force or declared at the end of the year 1991 reveals that there is already a large number of countries among those investigated in this study which have adopted schedules for phasing out ozone depleting substances faster than was laid down to in the Montreal Protocol.

All the Member States of the European Community are bound to apply tighter reduction schedules than the Montreal Protocol, and they constitute the majority of countries studied. Together they form a block at the top of the following table.

The lines in the table identify the countries surveyed and the columns to the substances as they appear in the annexes of the Montreal Protocol. The phase-out-schedule adopted in Montreal is presented in the head of the table. Each cell contains a very brief summary of the phase-out-dates known at this time. Were no specific reduction schedules could be found, the entries "following Montreal Protocol" or "EEC Regulation applies" appear. The latter refers to Council Regulation (EEC) No 594/91 of 4 March 1991 on "Substances that Deplete the Ozone Layer". The use of the word "ban" implies that legally binding prohibitions apply from that date. The use of the phase "to be phased out" refers to reduction schedules that are contained in policy programmes or are otherwise not strictly binding. Obviously, there is a degree of uncertainty in the assessment of the binding force of such statements, especially if secondary sources had to be consulted.

Table 4-5: International and National Phase-out-Schedules [10]

Montreal Protocol (London amendment)	Annex A, Group I CFCs 11, 12, 113, 114, 115 to be phased out in 1999	Annex A, Group II Halons 1211, 1301, 2402 to be phased out in 1999	Annex B, Group I 10 CFCs 13, 111, 112, 211-217 to be phased out in 1999	Annex B, Group II Carbon tetrachloride, CCl_4 to be phased out in 1999	Annex B, Group III 1,1,1-trichloroethane, CCl_3CH_3 to be phased out in 2004	Annex C 34 HCFCs non binding ban in 2040
EEC	to be phased out in 1997	to be phased out in 1999	to be phased out in 1997	to be phased out in 1998	70 % red. by 2000 ban from 2005	
Belgium	EEC Regulation applies non-binding ban in 1995	EEC Regulation applies	EEC Regulation applies non-binding ban in 1995	EEC Regulation applies	EEC Regulation applies	
Denmark	EEC Regulation applies early phase-out in 1996	EEC Regulation applies early phase-out in 1998	EEC Regulation applies early phase-out in 1996	EEC Regulation applies banned as of 1. 1. 1992	EEC Regulation applies early phase-out in 1995	Nairobi Declaration
France	EEC Regulation applies	EEC Regulation applies	EEC Regulation applies	EEC Regulation applies	EEC Regulation applies	
Germany	EEC Regulation applies early phase-out in 1995	EEC Regulation applies early phase-out in 1992	EEC Regulation applies early phase-out in 1995	EEC Regulation applies phase-out of use in 1992	EEC Regulation applies phase-out of use in 1992	Nairobi Declaration ban of HCFC 22 in 2000[1]
Greece	EEC Regulation applies	EEC Regulation applies	EEC Regulation applies	EEC Regulation applies	EEC Regulation applies	
Ireland	EEC Regulation applies	EEC Regulation applies	EEC Regulation applies	EEC Regulation applies	EEC Regulation applies	
Italy	EEC Regulation applies	EEC Regulation applies	EEC Regulation applies	EEC Regulation applies	EEC Regulation applies	
Luxembourg	EEC Regulation applies	EEC Regulation applies	EEC Regulation applies	EEC Regulation applies	EEC Regulation applies	
Netherlands	EEC Regulation applies to be phased out in 1995	EEC Regulation applies to be phased out in 1995	EEC Regulation applies to be phased out in 1995	EEC Regulation applies	EEC Regulation applies	
Portugal	EEC Regulation applies	EEC Regulation applies	EEC Regulation applies	EEC Regulation applies	EEC Regulation applies	
Spain	EEC Regulation applies	EEC Regulation applies	EEC Regulation applies	EEC Regulation applies	EEC Regulation applies	
United Kingdom	EEC Regulation applies ban proposed for 1996	EEC Regulation applies ban proposed for 1995	EEC Regulation applies ban proposed for 1996	EEC Regulation applies ban proposed for 1996	EEC Regulation applies ban proposed for 1996	
Australia	phase-out before 1998	following Montreal Prot.	phase-out before 1998	following Montreal Prot.	following Montreal Prot.	
Austria	to be phased out in 1995	to be phased out in 2000	to be phased out in 1995	following Montreal Prot.	following Montreal Prot.	Nairobi Declaration[2] draft ban in aerosol
Canada	to be phased out in 1997 draft for phase-out 1995	prod. banned, import quantities restricted	to be phased out in 1997 draft for phase-out 1995	following Montreal Prot.	to be phased out in 2000	
Finland	to be phased out in 1994	following Montreal Prot.	to be phased out in 1994	following Montreal Prot.	following Montreal Prot.	Nairobi Declaration
Japan	following Montreal Prot.	following Montreal Prot.	following Montreal Prot.	following Montreal Prot.	following Montreal Prot.	
New Zealand	phase-out before 1998	following Montreal Prot.	phase-out before 1998	phase-out until 1999	phase-out until 2000	
Norway	90 - 100 % red. by 1995	phase-out as soon as possible (mid 1990s)	90 - 100 % red. by 1995	following Montreal Prot.	following Montreal Prot.	Nairobi Declaration
Sweden	ban on use of all CFC as of 1. 1. 1993	to be phased out in 1997	ban on use of all CFC as of 1. 1. 1993	50 % red. on in 1993, 85 % in 1995, ban in 1997	phase-out in 1994	Nairobi Declaration ban of all HCFC in 1994[3]
Switzerland	planned phase out in '95	planned phase-out in '95	planned phase-out in '95	planned phase-out in '99	planned phase-out in '95	Nairobi Declaration ban on all HCFC for 2000
United States	following Montreal Prot.	following Montreal Prot.	following Montreal Prot.	following Montreal Prot.	to be phased out in 2002	use phase-out in 2015 prod. ban from 2030

1 Germany: Ban of HCFC 22 except for use as a cooling medium and in the manufacture of hard foam rubber for insulation purposes until 2000.
2 Austria: Ban on HCFC 22 as aerosol propellant proposed as of 31 December 1993, except for applications where no alternative exists.
3 Sweden: Including HCFC 22 except for use as a cooling medium and in the manufacture of hard foam rubber for insulation purposes, and for use in aerosol containers for medical use.

As a rule, phase-out schedules contain exceptions and temporary regulations in the different countries. Denmark for instance, allows CFC-11 in PUR-rigid foam for district heating networks to be applied only until January 1, 1993; and 1.1.1-trichlorethane may be applied in case of polyurethane insulating foams only until January 1, 1996.

In table 4-6 (see below) we tried to show how long the presently used ozone-relevant PUR-foams may be applied in countries with markets for district heating. Blowing agents and cellular gases which are subject to the regulation for the protection of the ozone layer are CFC-11 (conventional PUR-foam), 1.1.1-trichlorethane and HCFC-22 (M90 foam from ABB I.C.Möller) as well as HCFC-142b and CO_2 (green foam from TARCO).

The interpretation of this table should be subject to the fact that inspite of all care taken it cannot be guaranteed that all of the regulations issued in the investigated states have actually been considered.

Regarding ozone-relevant foams the following conclusions may be drawn:

- The application of CFC-11 will be forbidden in all of the investigated countries.

- Foams containing 1.1.1-trichlorethane (such as M90) may be used for some more years; still, there has been determined a deadline in all of the investigated countries (depending on the country there will be a ban between 1994 and 2005).

Phase-out Schedules for			
Country	CFC-11 foam	M90 foam (ABB)	Green foam (TARCO)
Austria	1995	Nairobi [3] 2004	Nairobi [3]
Canada	1997 draft for 1995	2000	
Denmark	1992	Nairobi [3] 1995	Nairobi [3]
Finland	1994	Nairobi [3] 2004	Nairobi [3]
Germany	1994	Nairobi [3] 1994	Nairobi [3]
Italy	1997 [1]	2005 [2]	
The Netherlands	1993	2005 [2]	
Norway	1995	Nairobi [3] 2004	Nairobi [3]
Sweden	ban on use of all CFC as of 1.7.1991 [*]	Nairobi [3] 1994	Nairobi [3]
Switzerland	draft for 1995	Nairobi [3] 2000 (draft for 1995)	Nairobi [3] 2000
The United Kingdom	1997 [1] ban proposed for 1996	2005 [2]	
The United States	2000	2002	

*) [18]

1) EEC: ban from 1997 06 30

2) EEC: ban from 2005 01 01

3) Nairobi Declaration: the use of HCFCs is to be limited to specific key applications, and to be allowed only temporarily

Table 4-6: Phase-out-Schedules for 3 PUR-foams in Different Countries (as of the Beginning of 1992)

- Foams based on HCFC-142b and CO_2 are still allowed in most countries. Although, this might change with the next revision of the Montreal Protocol which is going to take place in November 1992 in Copenhague. The discussion initiated by the Nairobi Declaration at least shows this trend.

- According to international statements and national legal projects there is a trend that the production or application of all ozone-relevant foams shall be reduced.

Considering the fact that in some places the municipalities make demands which are even tighter than the actual legal regulations, this suggests that from what we know today - on a long term-basis - CO_2-foam is the best possible alternative for the application in plastic jacket pipes, with respect to the protection of the ozone layer.

5. Technical Prerequisites To CFC-11-free Foams

There are quite different prerequisites to the new foams. Foams for the plastic jacket pipe system should - if possible

* not enforce the greenhouse effect
* not contribute to a depletion of the ozone layer
* be non-toxic, causing only little working place concentrations during the production process
* have low costs
* admit that heat losses of the district heating network are low
* be easy to be processed for the production of plastic jacket pipes
* definitely resist the thermo-mechanic stresses which occur in practice during the period of utilization

Disregarding the ozone depleting effect and the greenhouse effect, the old CFC-11-foam meets all the conditions very well. It has excellent insulating capacities, can be stressed thermo-mechanically, it is easy to be processed and economic. Although CFC-11-free foams do not at all or only little deplete the ozone layer, these foams do not reach the characteristics of the CFC-11 foam in any respect.

In the following the ecologic and economic conditions shall be discussed. In Sections 5.1 to 5.4 the technical conditions shall be treated in detail.

In connection with PUR-foams the <u>greenhouse effect</u> is not in discussion right now. Still, it is possible that some day restrictions which are not known yet might be issued.

The regulations for the protection of the ozone-layer were already described in chapter 4. Today, CO_2-foam is the only material which allow big scale production and which has a QDP-factor of 0.

The production of plastic jacket pipes still involves that factory workers are exposed to blowing agent concentrations, which are in some cases higher, in other cases lower. In view to the internal working place concentration CO2-foam is the most uncritical substance; CFC-11, HCFC-22 and HCFC-142b are about the same level. Only the application of 1.1.1 triethane chlorid makes necessary that smaller additional measures are adopted for the protection of the workers.

The plastic jacket pipe's success is - among others - due to the economic production costs using CFC-11 blown foams. An essential price increase would mean the end of the plastic jacket pipe technique and also the end of the economic supply of district heat, because in this case the former, cost intensive laying systems like concrete channel and steel-jacket pipe would have to be applied again. By application of the presently discussed CFC-11-free foams the production prices for plastic jacket pipes are only slightely increased.

The possible bad insulating capacities of CFC-free foams have a negative effect on the efficiency of the district heating, because either the operational costs are increased due to the higher loss of heat, or the investment costs for the next higher insulation thickness will raise. Heat losses of HCFC-foams are only slightly higher than those of the CFC-11-foam and even the incresed heat losses of the CO_2-foam do not justify a change to other laying techniques. According to [16] the thermal conductivity of the unaged compound pipe must not be higher than 0.033 W/(m K). In the event of a widely planned optimization of insulation thicknesses [12] carried out by GEF Ingenieurgesellschaft für Energietechnik mbH, Leimen by order of the AGFW, it turned out that for CO_2-blown plastic jacket pipes a higher insulation thickness is economic only in case of heat prices of more than 40 DM/MWh compared to CFC-11 blown pipes.

With the conventional production of plastic jacket pipes a foam shows favorable production characteristics, if it is used to foam pipes bars as long as possible in one single course of manufacture.

If for instance in case of large diameters, only pipes of 12 m instead of 16 m length can be produced, or in case of smaller pipe diameters, pipe lengths of 6 m only instead on 12 m ca be produced, this causes increased costs for additional pipe joints, although this effect is to some extent compensated by somewhat lower prices for transport and storage. For the future the application of new foams will lead to innovations for the production of plastic jacket pipes. An example may be the introduction of endless manufacturing with the company Lögstör in Denmark.

For the safe operation of plastic jacket pipes with CFC-11-free foams it is indispensable that the technical requirements resulting out of the thermo-mechanic stresses are met. Figure 5-1 shows the connection between the necessary investigations, the limits for the application and the design of plastic jacket pipes with new foams.

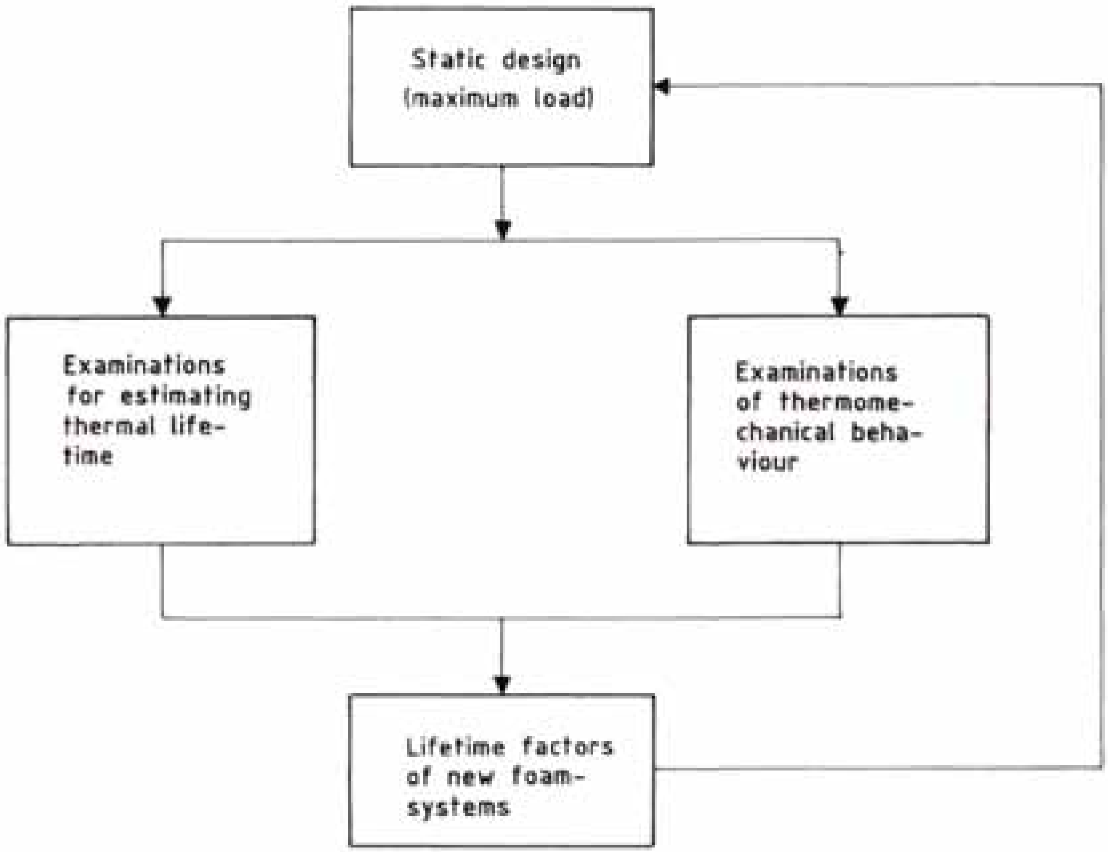

Figure 5-1: Connection between Technical Prerequisites and the Design of Plastic Jacket Pipes

These requirements regard
- shearing resistance
- compression strength
- temperature resistance and
- aging resistance (service life)

5.1 Shearing resistance

In the gliding areas of plastic jacket pipelines there are frictional forces acting on the jacket pipe, which are transferred to the medium pipe by shear stresses in the foam. The PUR shear stress is independent from the operating temperature and the laying procedure (cold laying or pre-heating). It depends mainly on the depth of coverage and on the dimensions from jacket pipe and medium pipe. High shear stresses always occur when small nominal diameters and large depths of coverage are combined. Larger insulation thicknesses cause larger jacket pipe diameters even with the same service pipe diameters an consequently, they increase the PUR shear stress.

Due to its smaller surface the shear stress is highest at the medium pipe, i.e. where the highest temperature is registred. The admissible value for the shear stress is a creep failure strength value, which means that also the influences by load, temperature and time are considered. For the CFC-11-foam the admissible shear stress in most countries comes up to TAUPUR = 0.03 MPa, in some cases also to TAUPUR = 0.04 MPa. In case of TAUPUR = 0.03 MPa the depth of coverage for DN 25 must not be higher than 1.5 m. On the contrary, a pipe DN 200 may be laid as deep as 2.8 m without the admissible shear stress in the PUR-foam beeing exceeded. Normally, in practice the admissible shear stress is not utilized. The shear stress for DN 200 and 1 m peak coverage is only 0.011 MPa. Only in few exceptional cases (such as the crossing of a roadway) TAUPUR = 0.03 MPa is exceeded and the plastic jacket pipe has to be laid within a protective pipe for a certain distance.

Plastic jacket pipes have to show certain minimum shearing resistance, because only then the compound effect between jacket and medium pipe is guaranteed. Without the compound effect the medium pipe would expand much more. In this case endless laying without expansion joint, which is the main advantage of the plastic jacket pipe system, would not be possible.

If the admissible shearing resistance of CFC-11-free foams also should range around 0.03 MPa, (which actually seems possible) plastic jacket pipes which are fabricated on this basis may be laid in the same manner as the former CFC-11-blown pipes, except the special cases which were already mentioned.

Taking it for granted that the longterm trend bases on CO_2-foam with its lowest insulation characteristics (as a consequence of its physical condition) and regarding the fact that in view to rising heat prices the next larger insulation thickness is applied, generally higher shear stresses will appear. In order to be able to follow the same laying practice as today, a higher admissible shear stress would be necessary. The minimum requirements for the testing are according to [16] for the unaged as well as for the aged pipe with 20°C 0,12 MPa and with 140° C 0.08 MPa.

required admissible shearing stress = 0.03 MPa (better 0.05 MPa)

5.2 Compression Strength

There are compressive strains acting on the PUR-foam at all changes of direction. The compressive strain SIGPUR is highest at the medium pipe. Like the shearing resistance, the compression strength, too, is a creep failure strength value. A minimum creep failure compressive strength is desired, though it is not as important as the minimum shearing resistance.

The admissible PUR-compressive strain is temperature-dependant and is indicated in Denmark and Sweden with 0.3 MPa, in Finland values from 0.1 to 0.3 MPa are used [13 and 18]. In Germany the values range between 0.10 and 0.15 MPa [14]. There are many places such as 90°-bends with long legs, where significantly higher PUR-compressive strains would occur, if the plastic jacket pipes were not protected by expansion pads against the soil restraint. The necessary lengths and thicknesses of the expansion pads are also determined by the compression strength of the PUR-foam. In case of small and medium pipe diameters the admissible angle of the segmental cuts as well as the admissible radius of line bends depend on the compression strength of the PUR-foam.

If the admissible compression strength of CFC-11 free foams was significantly lower than those of the CFC-blown foams, plastic jacket pipes still could be laid, although the costs would be higher. In this case cavities, for instance in form of expansion channels would have to be applied instead of expansion pads. This form is still a common construction technique in Sweden. With this technique the admissible angles are smaller, the necessary minimum line radius larger.

While the minimum shearing resistance is required for large lengths (in the total variation zone), high radial compressive strains act only on a limited distance, for instance only near to a 90°-bend. Therefore, the compression strength of a "soft"-foam can be enforced locally and with simple methods. In [15] it is described how extremely low the compression strength of a special CO_2-foam (with a development stage of 1989) may be increased many times by reinforcing it with glass beads.

The future use of the plastic jacket pipe system does not basically depend on reaching a certain compression strength, but the higher the compression strength, the more costs can be saved with this design. With low compression strength the design turns more expensive.

According to [16] a minimum compression strength of 0.3 MPa is required. This value refers to unaged foam with room temperature.

required admissible compression strength: 0.1 MPa with higher compression strength: design turn more economic

5.3 Temperature Resistance

The resistance characteristics of the PUR-foam depend on the temperature. From a certain temperature on the foam turns soft and its resistance is reduced significantly. In case of the foam containing CFC-11 the softening range starts only with more than 170° C (see figure 5-2)

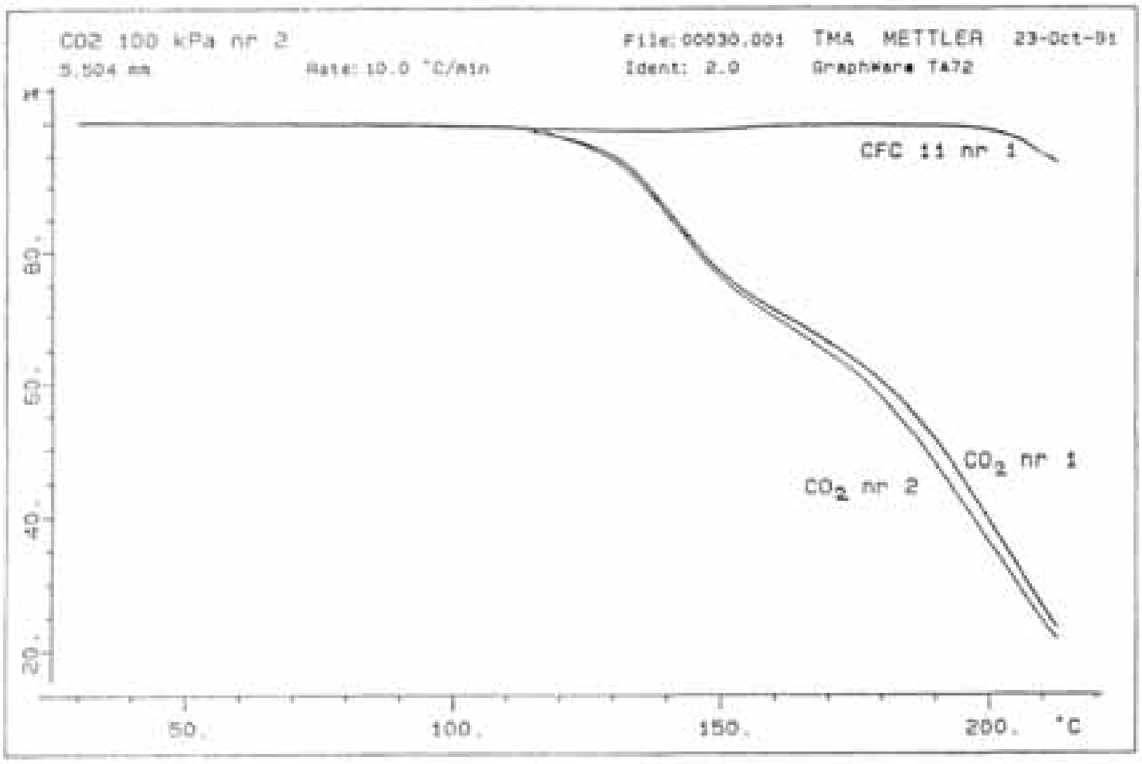

Figure 5-2: Softening Behaviour of a CFC-11-Foam, Measured by TMA (Thermo Mechanical Analysis).

Softening temperature of the first CO_2-foams which were tested at the end of the 80's, was approx. 100°C. Since that time specialists succeded to raise the softening temperature year by year to some extent. In the year 1991 the new foams reached softening temperatures of about 130°C, and the development seems to continue.

Commercial HCFC-foams from ABB I.C. Möller and TARCO have softening temperatures of more than 150°C.

With maximum outgoing temperatures as low as 110°C or less, as they are usual for instance in Denmark, today good CFC-11-free foams are totally uncritical in view to temperature resistance. Only with high outgoing temperatures the temperature resistance is an important factor. In Germany so far CFC-11-blown plastic jacket pipes are applied with maximum temperatures of 140°C. In these cases it is definitely not sufficient if the softening starts already with 140°C.

The test for the axial shearing resistance with 140°C provided for in [16] guarantees that there is no fast creeping. Methods for testing the long-term behaviour in view to slow creeping are only in a nascent stage (see Section 7).

The beginning of the softening has to take place after the maximum peak temperature, paying special attention to a safety margin (test methods have not been developed so far).

5.4 Aging Resistance (service life)

Under the influence of temperature and time all plastics are aging. In order to meet the requirements regarding thermal stress the above-mentioned prerequisite for the temperature resistance is not enough. Rather it has to be secured that the aspired thermal service life is reached. For the former CFC-11-blown plastic jacket pipes Arrhenius published straight lines indicating the service life; these lines indicate the service life corresponding to a certain temperature. The investigations are described in [1], [2] and [3].

In case of sliding network temperatures, damaging percentages are calculated, whereas the service life can be determined with the help of a damage-accumulation-hypothesis (Minor-Rule). The method is described in [5]; besides it was adopted in [16].

As a rough value for CFC-11-blown plastic jacket pipes an isothermal temperature resistance of 130°C over a period of 30 years is supposed. The district heating network of the city of Mannheim which is run under gliding temperatures reaching maximum temperatures of 140°C requires a PUR-hard foam with an isothermal temperature resistance of 110°C over a period of 30 years in order to reach a sufficient lifetime (= 30 years) [5].

Changing from physical to chemical blowing agents has influences on the viscosity of the reaction mixture during the production process, which requires changes in the chemical structure of the polyols and the relative strength of isocyanate.

Thermical testing of the aging in the revised EN 253 [16] is based on the activation energy valid for PUR-foams which were foamed with physical blowing agents.

It is well known that the structure of polyol and the relative strength of isocyanate influence the activation enery for thermal aging.

The introduction of a chemical blowing agent can increase the activation energy which leads to longer service lifes. This has not been investigated entirely, though.

Until the present investigations are finished the determinations under Appendix A of the revised EN 253 [16] should be applied.

required thermal service life with a constant temperature of 120°C: 30 years

6. Investigation Programmes Carried Through So Far

During the years 1987 to 1991 many investigations on CFC-free foams were carried through. Quite a number of tests, which shall not be described in detail, were utilized by the industry for a product development. Here, the investigations carried through by independent testing agencies by order of the state, associations or supply undertakings shall be described. We shall concentrate on the most important investigations without any claim to completeness.

During the period from 1987 to 1991 the tests were restricted essentially by the following facts:

- In spite of opposite statements from the industry it turned out that the development of the foams is not finished yet. Some investigations showed that the investigated foams were not suitable for district heating purposes, which means that these tests were worthless. Besides, test results obtained in respect to CO_2-foams in the year 1991 may not be compared with the results obtained in 1989, because meanwhile the foams have been developed.

- Test methods which had already been standardized for CFC-11 foams did not serve automatically for CFC-free foams. On one hand, foams containing chemical blowing agents have a different chemisme and therewith a completely different behaviour in view to thermal aging and long-term creeping. On the other hand, conventional test methods failed to detect certain weak points which CFC-foams did not have, such as problems in connection with the softening. First, investigations proved for instance that the new foams were suitable for district heating although later it was found out that these foams could not be used with higher temperatures.

- None of the numerous investigations were coordinated, so it happened quite often that one testing agency did not know what another testing agency was doing. This led to the fact that different foams from different manufacturers or charges were tested. In case of the tested pipes neither their length nor their pipe diameter nor their insulation thickness were standardized. Each of the testing agency determined its own test load, its own temperatures and duration periods for the tests. The steps taken to avoid inadmissible diffusion of oxygen were not standardized either. Several tests were carried through without diffusion protection, on other occasions specialists worked with diffusion linings (diffusion barriers) and there were also tests which included rinsing with different ambient media.

The investigations carried through so far do not admit general statements regarding thermo-mechanic behaviour of CFC-free foams. There are single statements contradicting each other, so that a general interpretation is not possible.

Generally, several single results could be obtained which showed phenomena unknown until then (such of softening) which taken as a whole cannot comprised systematically.

Main advantage of the investigations carried through so far is that there is international understanding that future investigations have to be coordinated (see <u>Section 7</u>).

In <u>Table 6-1</u> important investigations carried through so far are presented as a uniform scheme. Even if this table should not be perfect in detail, this does not have any effect on the assessment of standardized investigations which have to be appreciated, as already mentioned.

So far, investigations are carried through in Sweden and Germany. The order of the following list is not accidental and is not supposed to constitute an assessment of the separate investigations.

Table 6-1: Investigation Programmms carried through so far

Testing agency ——— Party Ordering	Aim of the Investigation	Investigated foam	Testing Load [MPa]	Testing Temperature [°C]	Duration of the test [d]	Note
RWTÜV in D-Essen ——— FW Dinslaken GEF Leimen GEW Köln	Radial creep rupture compressive strength	CO_2-Schaum [1]	0.1,0.3	140 160	230 [2] 142 [3]	see Appendix 1
		CFC-11-Schaum	0.05,0.1,0.4	140 150 160	230 120 [4] 142 [5]	
		M 90 [6] HCFC-142b [6]	0.05,0.1,0.4 0.05,0.1,0.4	150 150	120 120	
	Thermomechanical-analysis (TMA)		0.1	until failure	short time	
Chalmers University of Technology S-Gothenburg [9] ——— Swedish Energy Agency Malmö Energi SDHA	The quality of the foam in accordance with EN 253 Densitiy Water absorption Compressive strength Cell structure Ageing Axial shear strength	CO_2-foam [7] for joints CFC-11 foam [7] for joints	until failure	room temperature	short time test	see Appendix 3
	Axial shear strength	CO_2-foam [7] CFC-11 foam [7] M 90 [7] HCFC-142b [7]	until failure	23 140	short time test	see Appendix 4
	Radial creep properties	CO_2-foam	0.1,0.3	23 [7] 140 [8]	83	see Appendix 5

1) State of Investigations: End of 1989

2) 3 out of 4 specimens failed according to about 40 d

3) all of the 4 specimens had reached the failing criteria after 12 days

4) 4 out of 15 specimens had reched the failing criteria after 100 days

5) Specimens loaded with 0.4 MPa had reached the failing criteria after 50 days

6) No statistical proof (only one testing pipe)

7) Aged and unaged foam

8) Unaged foam

9) see Appendix 2

Testing Agency / Party Ordering	Aim of the Investigation	Investigated foam	Testing Load [MPa]	Testing Temperature [°C]	Duration of the test [d]	Note
Chalmers University of Technology S-Gothenburg / National Energy Administration of Sweden	Composition of the gas phase in PUR foam					see Appendix 6
	Test result of compressive strength and axial shear strength on district heating pipes after exposure to operating conditions	CO_2-foam 10) 25 % CFC + 75 % CO_2 CFC-11-foam	until failure	room temperature	short time test	see Appendix 7
SDHA	Test results in accordance with EN 253 of CFC-free products available on the Swedish market from different pipe manufacturers	CO_2-foam 7) M 90 7) HCFC-142b 7)	until failure	23 140	short time test	see Appendix 8
Chalmers University and SP-Swedish National Testing and Research Institute S-Gothenburg / Swedish Energy Agency	Load and temperature dependent compression of foam cubes in different ambient media	CO_2-foam CFC-11-foam	0,0.1	23 120 130 140	4 - 83	see Appendix 9

10) Aged by in influence of 180 temperature cycles between 23 and 90 °C (field test)

Testing Agency / Party Ordering	Aim of the Investigation	Investigated foam	Testing Load [MPa]	Testing Temperature [°C]	Duration of the test [d]	Note
University o.T. SF-Lappeenranta	Pipe-test with pipes from 5 manufactures in accordance with EN 253 - λ value 11) - Axial shear-strength 12) - Compressive strength - Overall density	CO_2-foam CO_2/CFC HCFC	until failure	room temperature	short time test	see Appendix 10
Studsvik Research Institut S-Nyköping	Aerogel-Insulations as Substitutes for PUR-foams	VSI-pipe Aerogel				does not apply for the plastic jacket pipe technique
IKP D-Stuttgart / AGFW	Softening temperatures with TMA and measurement of modulus of transverse elasticity on test cubes	CO_2-foam CFC-11-foam	0.2	until failure	short time	see Appendix 11 rinsing gas = N_2 Testing load too high
TWS D-Stuttgart / TWS	Tangential shear creep of pipes	CO_2-foam 13) CO_2-foam 13) CO_2-foam 14)	0.1 15) 0.2 16)* 0.05 17) 0.1 18)* 0.05 19) 0.1 20)*	100 + 160 100 + 150 100 + 144	15 26 109	see Appendix 12 rinsing with inert gas no comparison with CFC-foam

11) finnish method (120 °C in water tank)

12) unaged and aged 1000 h in 130 °C, tested in 20 °C

13) continuously foamed pipes

14) discontinuously foamed pipe

15) significant deformation from 135 °C on failure during preheating shortly before or after reaching 160 °

16) failure after 2-7 days with 100 °C

17) failure of 2 specimens after 4 and 8 days with 150 °C

18) failure of all of the 5 specimens after 34 minutes with 150 °C

19) no failure, twisting of torsion after 109 d between 7,5 and 9,5° (continued creeping)

20) failure of 3 specimens after turning off the heating unit when cooling down

Testing Agency / Party Ordering	Aim of the Investigation	Investigated foam	Testing load [MPa]	Testing Temperature [°C]	Duration of the test [d]	Note
AMPA D-Hannover	Axial und tangential shear strength in accordance with EN 253 21)	CO_2-foam 22) M 90 22) HCFC-142b 22) CFC-11-foam	until failure	20 130 140	short time test	see Appendix 13

21) Testing of pipes:

- unaged
- aged with 170 °C 1400 h
- aged with 160 °C 3600 h

22) only qualitative results are known (larger or smaller than minimum requirements according to EN 253)

7. Present or Planned Investigations

Regarding the bad experience with uncoordinated investigations (see Section 6), district heating associations of several countries agreed on a coordination for further proceedings at the end of 1991. District heating undertakings, the industry, standardization and testing agencies got together in order to coordinate their investigations. As shown in Figure 7-1, representatives from

- Belgium
- Denmark
- Germany
- Finland
- The Netherlands
- Sweden

are cooperating in order to solve the problems together. The organisation invites further countries to cooperate.

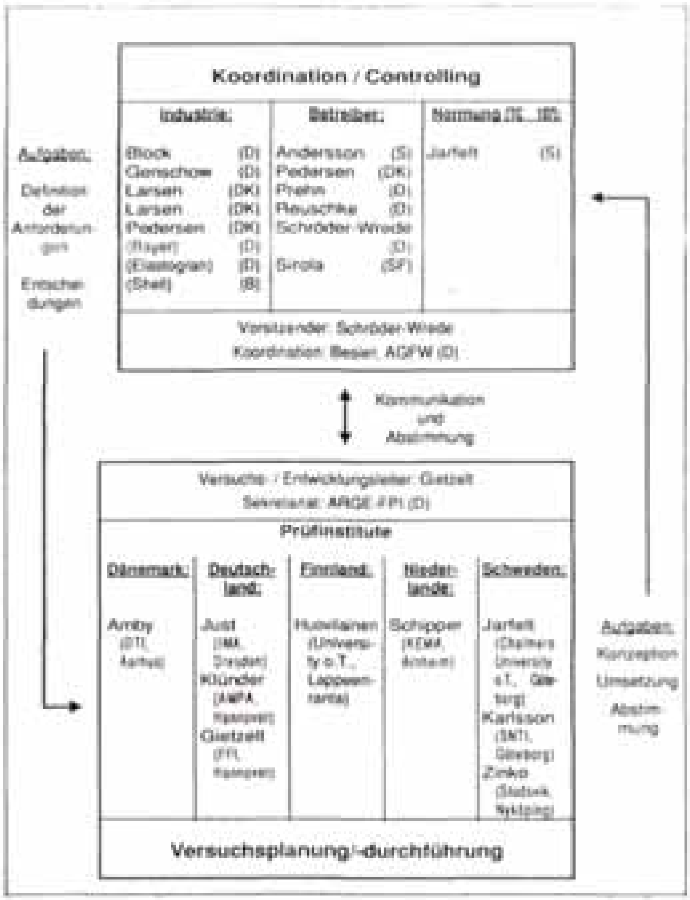

Figure 7-1 Coordination of International Projects

The organisation takes care for arranging the tasks according to their priority. Afterwards these tasks are given to suitable test agencies. The most important decision which the project group "coordination/ controlling" adopted was to make for carrying through all further tests on standardized reference foams

- FEBIS I, CFC-11-blown reference foam, as of 1991
- FEBIS II, CO_2-blown reference foam, as of 1991

A sufficient number of pipes of the same charge were manufactured by ABB I.C. Möller.

Besides, the project group takes care that test loads, testing temperatures, duration periods for the tests and the protection against the diffusion of oxygen are coordinated as far as possible.

First, test-concepts for the reference foams should be developed, which are independent from the blowing agent. These concepts are going to form part in the European standardization because of their close relation to TC 107. Then, the design approval tests for the commerial foam systems shall take place. The project group established priorities for the investigations:

Priority 1:

* radial creep tests	DTI (DK)
* tangential creep tests	invitation for tenders to all testing agencies
* axial shearing resistance	results within the scope of the FFI/IMA-tests
* thermal service life	investigations by FFI and IMA

Priority 2:

* thermal conductivity, diffusion	Chalmers U.o.T (S), other investigation
* tests according to EN 253	after working out test concepts
* socket foam	presently open

In Table 7-1 the projects, the financing of which was guaranteed by April 1992, are listed. For this Table the same classification as in Table 6-1 was used. It becomes clear that present investigations are based on standardized test conditions. Here, too, the order of the Table does not have any meaning.

Table 7-1: Present or planned Investigations

Testing Agency / Party Ordering	Aim of the Investigation	Investigated foam	Testing load [MPa]	Testing Temperature [°C]	Duration of the test [d]	Note
DTI DK-Aarhus / Danish EA DFF, danish manufacturers	Radial creep behaviour of PUC cellular plastis in preinsultated pipes	FEBIS I 1) FEBIS II 2)	0.05,0.15 0.25,0.35	90, 110 130, 150	40 365	see Appendix 14
IMA D-Dresden und FFI D-Hannover / AIF	Influence of halogene-free PUR-isolations on the long-term behaviour of plastic jacket pipes	FEBIS I 1) FEBIS II 2)	unloaded	140 + 170		see Appendix 15
CTH and SP S-Gothenburg / NUTEK CTH	Creep properties, radial creep on the cubes of pipes	FEBIS I 1) FEBIS II 2) CO_2-foam HCFC-foam	0.05,0.1 4)	23, 100, 120 140, 160		see Appendix 16
	Creep properties, axial creep-test samples of PUR-material taken from district heating pipes	FEBIS I 1) FEBIS II 2) CO_2-foam HCFC-foam	0.04,0.08 4)	23, 100, 120 140, 160		see Appendix 17
	Model for creep behaviour. FEM analysis					see Appendix 18

1) CFC-11 blown

2) CO_2 blown

3) At the FFI also thermo-mechanic tests

4) Testing parameter will be coordinated with other thermo-mechanic investigation

Testing Agency / Party Ordering	Aim of the Investigation	Investigated foam	Testing load [MPa]	Testing Temperature [°C]	Duration of the test [d]	Note
Chalmers University of Technology S-Gothenburg / NUTEK	Thermal conductivity and ageing of PU-foams. Diffusion of gases through cell walls and through surface materials of pipes	CFC-11 CO2 HCFC and mixtures				see Appendix 19
5) / by order of the European project group	tangential creep tests	FEBIS I 1) FEBIS II 2)	0.02,0.04 0.08,0.16	90, 110, 130 150	41	see Appendix 20

5) For this investigation invitation were made to 11 European testing institutes at the beginning of April 1992

8. Outlook

The international coordination as it is described in Section 7 offers a basis for the required test concepts for the new foams. In several countries govern mental fundings are available for the implementation of the test programmes, so that the planned investigations can be realized.

The agreement on reference foams and the coordination of the test conditions are important prerequisites for an interrelated assessment. This allows that investigations on pipes and test cubes carried through at different testing agencies may be compared.

There is only one gap in the testing programme accompanied by the European project group, i.e. the fact that investigations on the axial shearing resistants are missing. The axial shearing resistance is the most important characteristic of plastic jacket pipes, which allows for endless laying without expansion joints. Such an investigation has been formulated and proposed by Dr. Jarfelt, Gothenburg, as part of the coordinated program in the beginning of 1992 [17]

It would be a pity if conclusions regarding the axial shearing resistance could be drawn only on the basis of tangential creep bahaviour. If there should be any financial means available for the investigation on CFC-free foam systems, they are spent best on investigations in view to the axial shearing resistance.

It has to be hoped that the development of the CO_2-foams continues the trend of the last few years, reaching an increased temperature resistance so that this kind of foam which is most favourable for the environment also offers optimum characteristics in respect to thermo-mechanics.

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APPENDIX 1

KUNSTSTOFF MANTELROHRE FÜR DIE FERNWÄRME

RADIALE ZEITSTAND-DRUCKVERSUCHE

Die Forschungsvorhaben des AGFW-Verbundprojektes
Neuartige Wärmeverteilung
"Betriebliche Selbstvorspannung/Unterverteilung" und
"Neue Prüftechniken und Systemkomponenten
beim Kunststoff-Mantelrohr"

AGFW-VERBUNDPROJEKT
NEUARTIGE WÄRMEVERTEILUNG

Neuartige Wärmeverteilung: Kunststoff Mantelrohre für die Fernwärme

Betriebliche Selbstvorspannung bei Kunststoff-Mantelrohren

Wenn eine kaltverlegte Leitung zum ersten Mal die maximale Betriebstemperatur erreicht, treten an den Leitungsenden große Dehnwege auf, die je nach den Randbedingungen ungefähr 3 bis 4 mal so groß wie die entsprechenden Dehnwege vorgewärmter Leitungen sind.

Radiale Druckbelastung

Von vornherein war klar, daß die Ringbiegebeanspruchung des Stahlrohres durch eine Erhöhung der Wanddicke verringert werden kann. Dagegen stellt die radiale Druckbeanspruchung des PUR-Schaumes das Hauptproblem dar. Die Dehnpolsterdicke kann kaum weiter erhöht werden, weil damit die Mantelrohrtemperatur weiter ansteigt und dickere Dehnpolster auch durch den Erddruck stärker komprimiert werden.

Die Grundlage für weitere Überlegungen bildet die Untersuchung der Druckfestigkeit des PUR-Schaumes unter praxisnahen Bedingungen.

Die zulässige radiale Druckbelastung von Kunststoff-Mantelrohren bei den üblichen maximalen Mediumtemperaturen zwischen 130 °C und 140 °C ist bisher nicht untersucht worden.

Zeitstand-Druckversuche

Erstmals wurden in den Forschungsvorhaben "Betriebliche Selbstvorspannung/Unterverteilung" der Fernwärmeversorgung Niederrhein GmbH und "Neue Prüftechniken und Systemkomponenten beim Kunststoffmantelrohr" der Gas-, Elektrizitäts- und Wasserwerke Köln AG Kunststoff-Mantelrohre radialen Zeitstand-Druckversuchen unterzogen, bei denen die tatsächlich auftretenden Belastungen bei erhöhten Temperaturen aufgebracht werden, um einen Zeitraffereffekt zu erzielen.

Dabei wurden 80 cm lange gerade Rohrabschnitte DN 80 am Mediumrohr aufgelagert und in fünf Prüfabschnitte unterteilt. Auf die Prüfabschnitte wurden radiale Druckspannungen aufgebracht, die Rückstellkräfte von weichen Dehnpolstermaterialien bis zur zweifachen maximalen Erdreichreaktion abdecken.

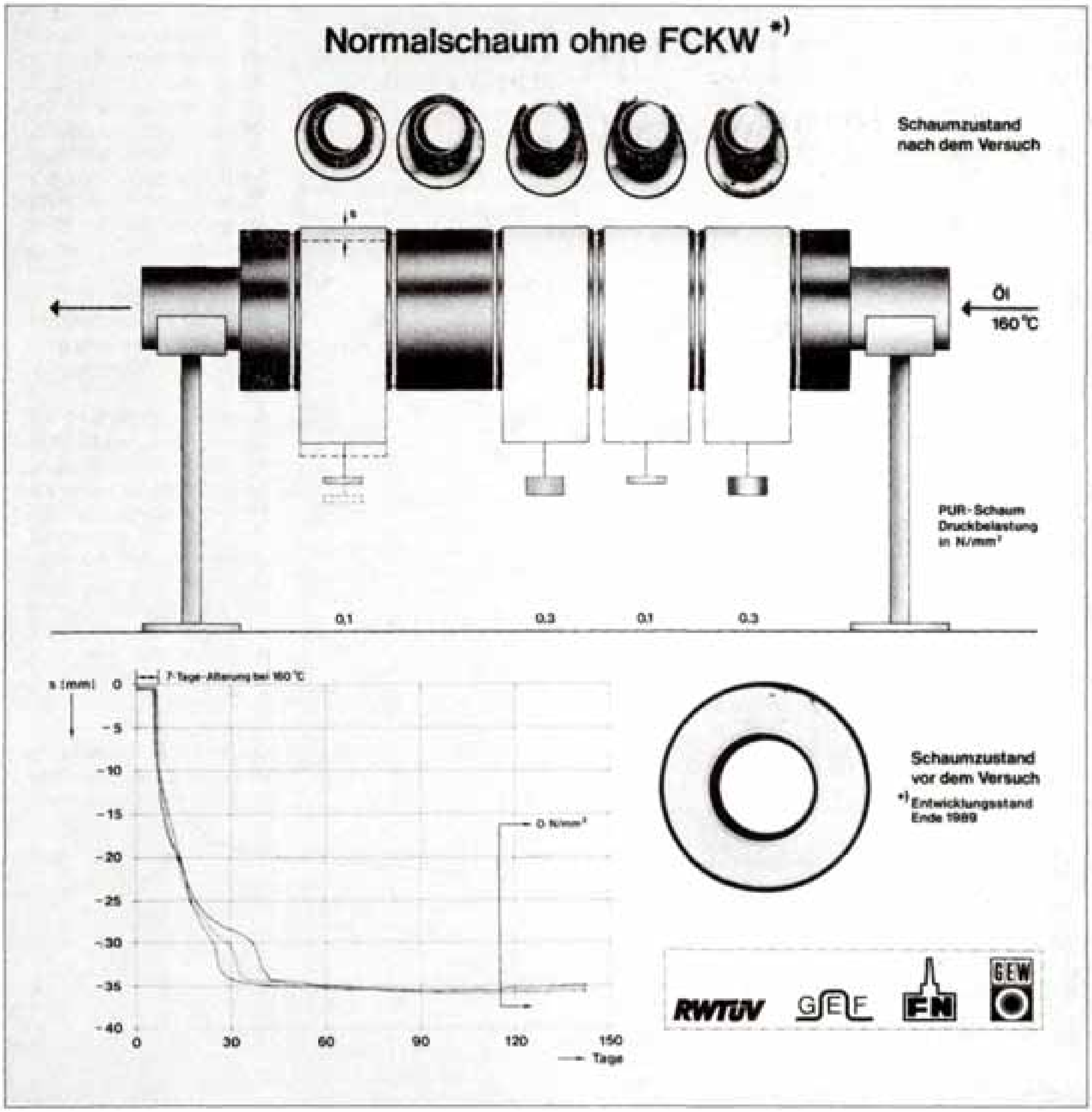
Die von der GEF, Leimen, geplanten Versuche wurden beim RWTÜV in Essen durchgeführt. Es wurde PUR-Normalschaum, FCKW-freier Normalschaum (Stand 1989), höherfester Schaum und höherfester FCKW-freier Schaum (Stand 1989) untersucht.

Die Ergebnisse der 160°C-Versuche und die Zwischenergebnisse der 140°C-Versuche sind in den folgenden Abbildungen dargestellt.

Eine Zwischenbewertung zeigt, daß die radiale Druckfestigkeit des FCKW-freien Schaumes (Stand 1989) bei den untersuchten Temperaturen wesentlich unter den Werten des Normalschaumes liegt. Die unterschiedlichen FCKW-freien Schäume sind deshalb für den Fernwärmeeinsatz nicht geeignet. Die Druckfestigkeit des höherfesten Schaumes liegt etwa um den Faktor 5–10 über der des PUR-Normalschaumes.

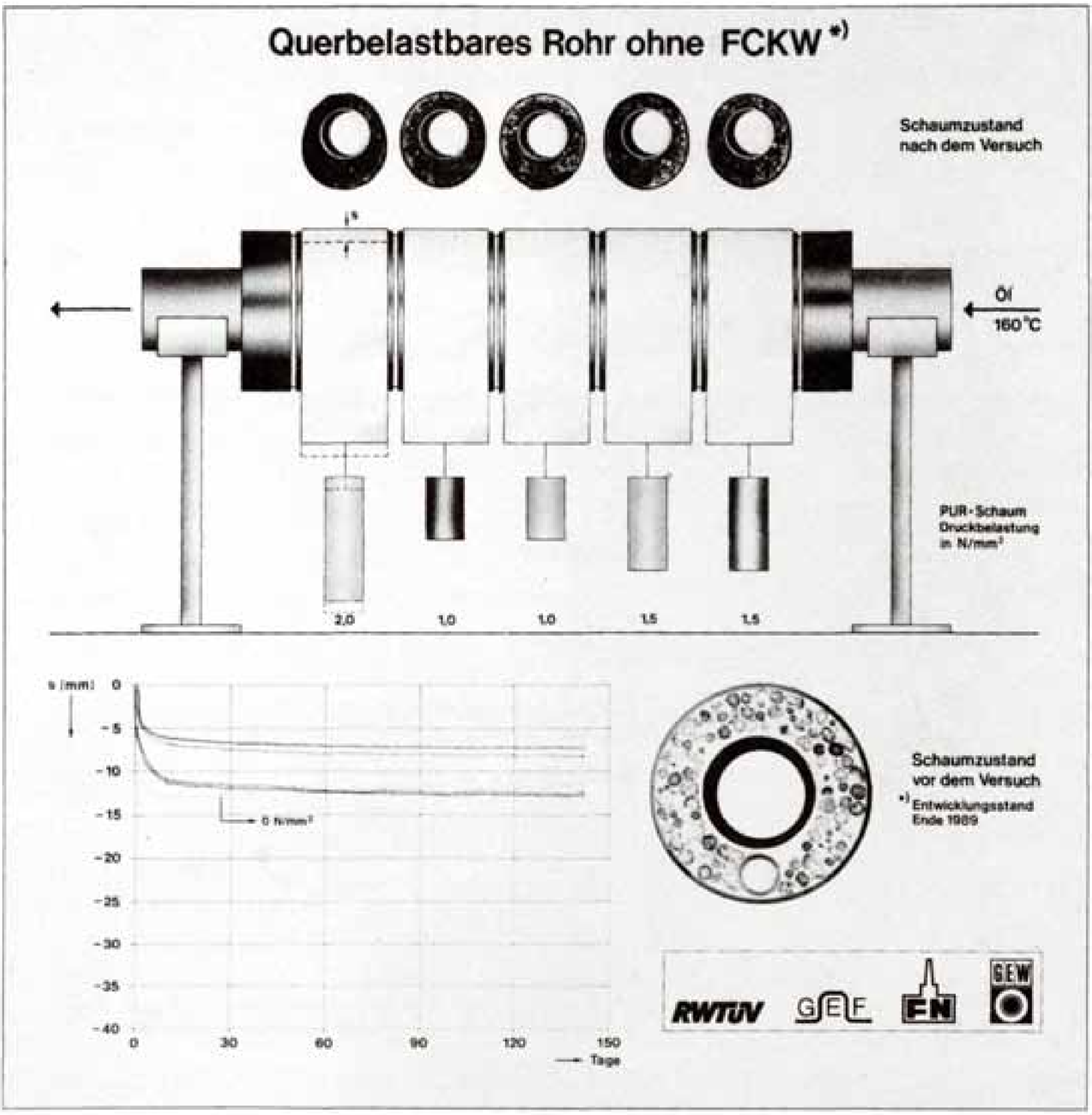
Eine abschließende Bewertung kann erst vorgenommen werden, wenn weitere Versuchsergebnisse vorliegen.

Radiale Zeitstand-Druckversuche von Kunststoff-Mantelrohren



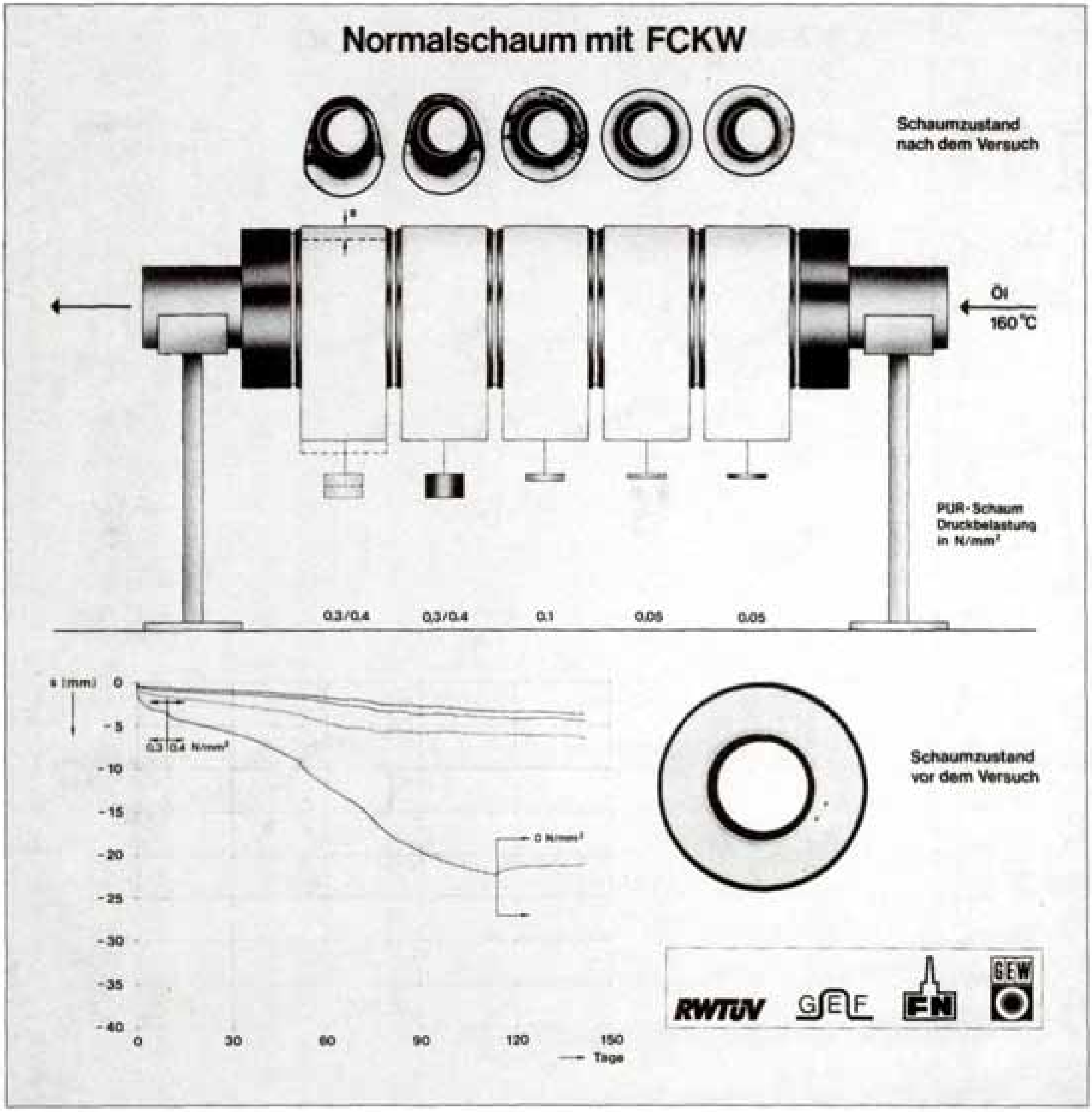
ERSTE ZWISCHENERGEBNISSE
BEI 160° CELSIUS

RADIALE ZEITSTAND-DRUCKVERSUCHE VON KUNSTSTOFF-MANTELROHREN



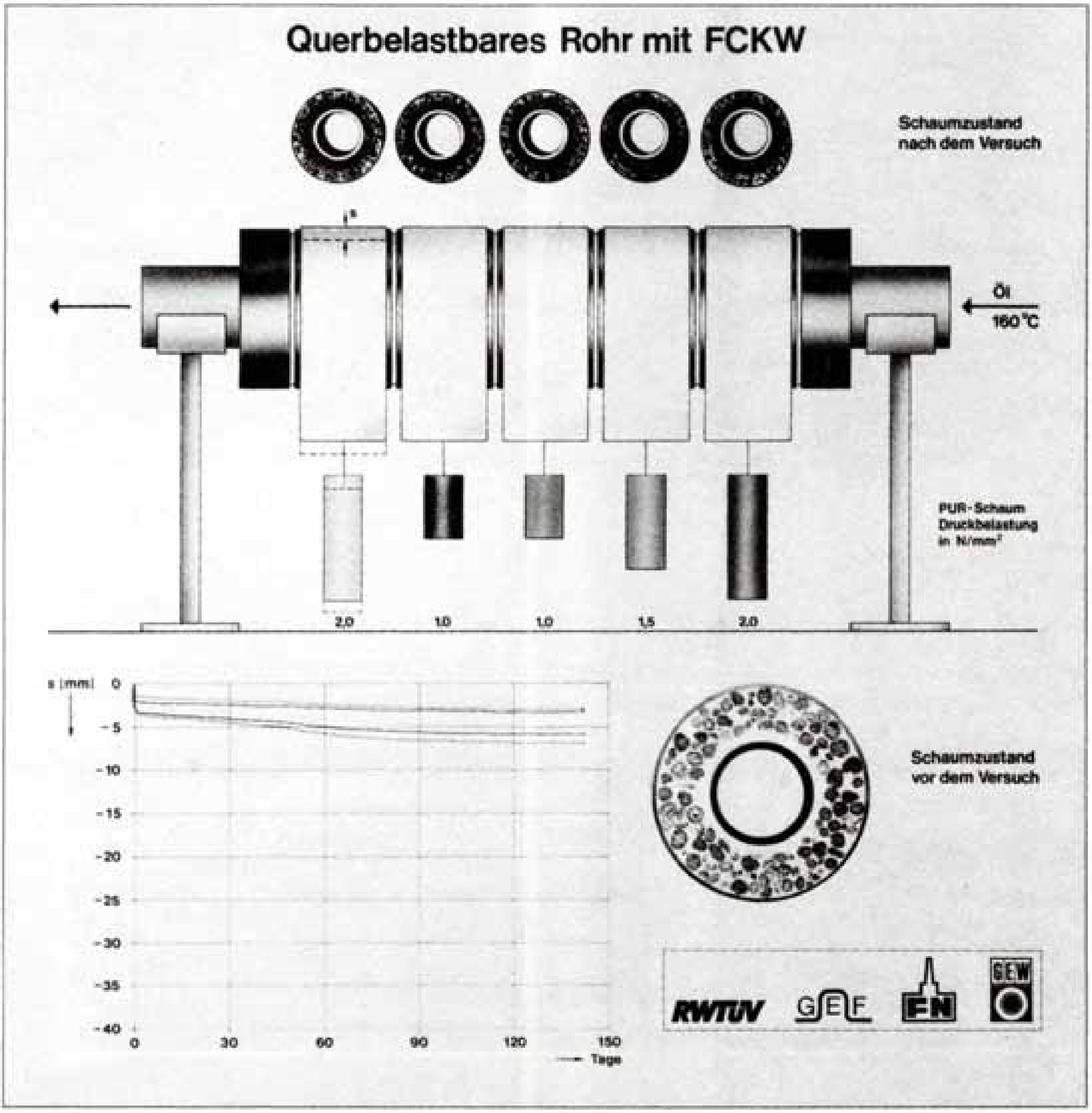
ERSTE ZWISCHENERGEBNISSE
BEI 160° CELSIUS

RADIALE ZEITSTAND-DRUCKVERSUCHE VON KUNSTSTOFF-MANTELROHREN



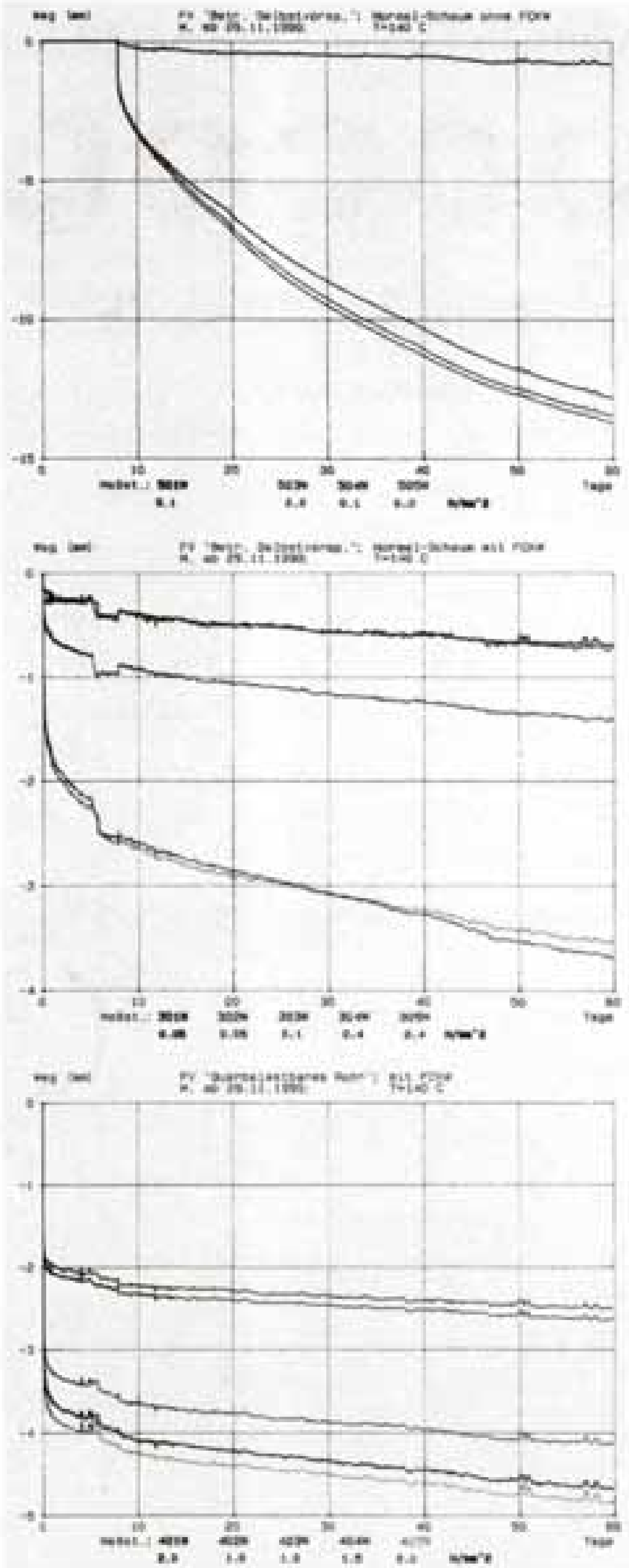
ERSTE ZWISCHENERGEBNISSE BEI 160° CELSIUS

Radiale Zeitstand-Druckversuche von Kunststoff-Mantelrohren



ERSTE ZWISCHENERGEBNISSE
BEI 160° CELSIUS

Radiale Zeitstand-Druckversuche von Kunststoff-Mantelrohren



ERSTE ZWISCHENERGEBNISSE
BEI 140° CELSIUS

RWTÜV
Steubenstraße 53
W-4300 Essen 1
Tel. (02 01) 825 - 26 13
Fax. (02 01) 825 - 25 41

GEW
Gas-, Elektrizitäts- und Wasserwerke Köln AG
Parkgürtel 24
W-5000 Köln 30 (Ehrenfeld)
Tel. (02 21) 178-0
Fax. (02 21) 178-33 22

GEF
Ingenieurgesellschaft für Energietechnik
und Fernwärme GmbH
Ferdinand-Porsche-Str. 4 a
W-6906 Leimen
Tel. (0 62 24) 7 60 81
Fax.(0 62 24) 7 71 31

FN
Fernwärme Niederrhein
Gerhard-Malina-Str. 1
W-4220 Dinslaken
Tel. (0 21 34) 605 - 0
Fax. (0 21 34) 605 -129

Bild 31: Tabellarische Zusammenstellung der untersuchten Rohre mit den Versuchsparametern

Rohr		T = 140 °C Versuchszeit 230 Tage			T = 150 °C Versuchszeit 120 Tage			T = 160 °C Versuchszeit 142 Tage		
Nr.	Abschn.	Schaum Bez.	Belastungsdruck [N/mm²]	Durchbieg. nach 120 Tagen [mm]	Schaum Bez.	Belastungsdruck [N/mm²]	Durchbieg. nach 120 Tagen [mm]	Schaum-bez.	Belastungsdruck [N/mm²]	Durchbieg. nach 120 Tagen [mm]
I	101	Normal-	0,05	0,45	Normal-	0,05	0,89	Normal-	0,05	4,52
	102	schaum	0,05	0,49	schaum	0,05	2,06	schaum	0,05	6,29
	103	mit	0,1	0,88	mit	0,1	4,96	mit	0,1	10,86
	104	FCKW	0,4	3,59	FCKW	0,4	11,87	FCKW	0,4	17,55
	105		0,4	3,19		0,4	11,60		0,4	27,09
II	201	Normal-	0,05	0,29	Normal-	0,05	1,04	Normal-	0,05	3,14
	202	schaum	0,05	0,53	schaum	0,05	2,65	schaum	0,05	3,01
	203	mit	0,1	1,22	mit	0,1	4,53	mit	0,1	3,32
	204	FCKW	0,4	3,54	FCKW	0,4	11,17	FCKW	0,4	22,58
	205		0,4	3,28		0,4	10,31		0,4	25,47
III	301	Normal-	0,05	0,72	Normal-	0,05	1,3	Normal-	0,05	3,35
	302	schaum	0,05	0,78	schaum	0,05	1,43	schaum	0,05	4,10
	303	mit	0,1	1,63	(M90)	0,1	2,58	mit	0,1	6,00
	304	FCKW	0,4	4,20		0,4	5,22	FCKW	0,4	22,40
	305		0,4	3,99		0,4	4,88		0,4	21,60
IV	401	Blähglas-	2,0	5,02	Normal-	0,05	3,88	Blähglas-	2,0	11,65
	402	schaum	1,0	2,62	schaum	0,05	4,46	schaum	1,0	7,17
	403	mit	1,0	3,07	(R142B)	0,1	5,07	ohne	1,0	8,07
	404	FCKW	1,5	4,45		0,4	5,69	FCKW	1,5	12,56
	405		2,0	5,08		0,4	4,82		1,5	12,44
V	501	Normal-	0,1	0,72				Normal-	0,1	22,04
	502	schaum	-	-				schaum	-	-
	503	ohne	0,3	16,15	keine Auswertung			ohne	0,3	35,54
	504	FCKW	0,1	16,47				FCKW	0,1	35,68
	505		0,3	15,68					0,3	35,97
VI	601	Blähglas-	2,0	2,44	Blähglas-	2,0	2,57 (63 Tage)	Blähglas-	2,0	4,90
	602	schaum	1,0	2,34	schaum	1,0	1,98	schaum	1,0	3,15
	603	mit	1,0	1,47	mit	1,0	2,17	mit	1,0	2,90
	604	FCKW	1,5	2,17	FCKW	1,5	2,46	FCKW	1,5	5,72
	605		2,0	2,00		2,0	3,29		2,0	6,75

APPENDIX 2

CHALMERS UNIVERSITY OF TECHNOLOGY
Div. of Building Technology
Ulf Jarfelt

CFC-FREE POYURETHANE

RESEARCH WORK

at

Chalmers University of Technology

Gothenburg, Sweden

A short presentation of research project being completed 1987-1991

by

Ulf Jarfelt

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CHALMERS UNIVERSITY OF TECHNOLOGY
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INTRODUCTION

Research work about CFC-free alternatives was started at Chalmers University of Technology in the end of 1987. Knowledge about the possibilities of reducing or excluding the use of CFC as blowing agent when producing polyurethane foam became important due to regulation concerning environmental protection. So far a number of project financially supported by The National Energy Agency in Sweden have been performed in order to find out the thermomechanical and insulating capacity of carbon dioxide blown foam and HCFC ("soft freon") blown foams.

In 1991 and interdisciplinary group of scientists was formed at Chalmers University of Technology involving scientists from Chemical Department and Building Physics Department. The hypothesis was, that by using the right combination of blowing agent, polyol, surface material and additives, it should be possible to produce a poyurethane foam with adequate insulation and mechanical properties without the use of CFC. The environmental consequences of this modified poyurethane foam will also be investigated. The group of scientists has been enlarged and experts in Material Physics from The Swedish National Testing Institute have been included to deal with questions concerning mechanical properties. The research group is financed by the Swedish Government for a period of three years 1991-1993, and will probably be supported for another three years period 1993-1996.

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CFC-FREE POLYURETHANE FOAM
Research work at Chalmers University of Technology

An interdisciplinary group of scientists from Chemical Department, Building Physics Department and Swedish National Testing Institute

Tests according to EN253

The stipulated tests have been performed for straight pipes and for joint. Both carbon dioxide and "soft freons" have been tested. Tests on aged pipes have also been perfomed

Thermomechanical analysis

The development of test equipment for axial shear strength at operating temperature (140°C) and creep behavior of the foam in radial direction.

Insulating capacity and ageing behavior

Test equipment for gas analysis and the diffusion rate of air and blowing agent in order to predict the change in λ-value of the foam. (gas mixture in the cells) The influence of surface materials of the diffusion.

CONTENT

- Composition of the gas phase in polyurethane foam. The thermal conductivity of the foam as a function of time is attributable to gas diffusion. A method of determination of the mixture of gas in the cells have been developed.

- Axial shear strength. Test equipment to determine the axial shear strength at elevated temperature. A number of test results obtained from different types of CFC-free foams.

- Radial creep. Method for testing the creep behavior at elevated temperature on PUR-foam. Test results from CFC- and CO_2-blown foams.

- Specifications and requirements of polyurethane foam for joints. The blowing agent CFC11 is replaces by carbon dioxide.

- Specifications and requirements of polyurethane foam manufactured without CFC for joints. Further investigations. Test results from aged joints at 170°C for 2 months.

- Test results of compressive strength and axial shear strength on district heating pipes after exposure to operating conditions. A study of three different makes and blowing agents, 100% CFC11, 25% CFC+75% CO_2 and 100% CO_2.

- Tests according to EN253 of products available on the Swedish market from different pipe manufacturer. All products CFC-free.

APPENDIX 3

CHALMERS UNIVERSITY OF TECHNOLOGY
Div. of Building Technology
Ulf Jarfelt

ABSTRACT

Ulf Jarfelt
Chalmers University of Technology
S-412 96 GÖTEBORG, SWEDEN

Specifications and requirements of rigid polyurethane foam for joints. The blowing agent CFC11 is replaced by carbon dioxide (CO_2).

The aim of the project has been, partly to modify the foam mixing equipment used for foams with other blowing agents than CFC and partly to develop and test new foams applicable for joints in district heating networks. The modification of the foam equipment for in situ foaming and all foaming used in the laboratory test has been done by PIPE-ISOL AB, MALMÖ, SWEDEN. Laboratory test and supervision of foaming procedure has been done by the staff of CHALMERS UNIVERSITY OF TECHNOLOGY, GÖTEBORG, SWEDEN. Supplier of raw material and the ratio of mixing has been developed by SHELL, SWEDEN.

The project started in March 1989 with a first test in order to be able to modify the foam equipment to the new poyols used. At this stage 12 joints were made and tested. The results of this first try implicated that some modifications had to be done partly to the foaming equipment and partly to the ratio of the mixing. The second and third stage of the project involved a total number of 24 joints. Only small changes were made after the second stage to the foaming equipment to be able to reach a better mixing. The results presented in table 1 are results obtained in the third stage of the project. The project was completed in November 1989.

Different temperature conditions of the surrounding air and of the carrier pipe were chosen to study if the quality of the foam was influenced by the temperature chosen. The CEN-document prEN 489 gives a guideline of what temperatures to be accepted during in situ foaming. In that document states that the temperature at the steel service pipe and the outer casing should be between 15 and 45°C. Temperature of the PUR-components shall be kept between 15 and 25°C.

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In order to fulfill this recommendation and to go a little further the temperatures chosen were, steel pipe temperature 8 to 60°C and casing pipe temperature 12 to 47°C.

The test were carried out in accordance with EN253 and the following results were obtained:

TABLE 1: Test results.

	A	B	C	D	E
Temperature (C°)					
Steel pipe	8	20	30	45	60
Casing pipe	12	20	23	24	27
Ambient air	20	20	20	20	20
Density(Kg/m^3)					
Top	70	66	70	69	78
Bottom	72	68	72	73	78
Compressive strength (MPa)					
Top	0,49	0,47	0,56	0,60	0,70
Bottom	0,37	0,31	0,38	0,51	0,55
Water absorption (%)	10	13	7	14	8
Closed cells (%)	95,6	94,4	97,8	97,3	96,4

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ABSTRACT

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Specifications and requirements of PUR-foam manufactured without CFC for joints. Further investigations.

The aim of the project has been to investigate the quality of the CFC-free foam alternatives available at this time for in situ foaming of joints. This project is an extension of an earlier project were foam equipment and foam mixing ratio were developed for a carbon dioxide blown foam with raw materials from Shell.

In this project raw materials from three different manufacturers were investigated and compared with CFC-blown foams. The raw material suppliers were Shell, Bayer and BASF and the formulations were based on carbon dioxide as the blowing agent for all three makes.

The foaming was done with the same type of equipment that are being used for in situ foaming of joints. Temperatures at the steel service pipe, the polyethylene casing and the ambient air were recorded. The project was carried out under the period, october 1989 to May 1990 at Chalmers University of Technology.

Three pipes, 6 meter long, were provided with four joints each. Pipe dimensions DN 125/250. Tests were made in accordance with EN253 to establish density, water absorption, compressive strength, axial sheer strength and rate of closed cells for the different makes both before and after ageing at 170°C for 1450 hours. The test results are shown in TABLE 1 and 2.

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TABLE 1. Test results of three different CO_2-blown foams and one CFC-blown foam for joints. Unaged foam.

	Bayer	Shell	BASF	CFC
Density (Kg/m^3)	58	64	71	63
Water absorption (%)	12,7	6,4	9,1	7,0
Compressive strength (MPa)	0,22	0.30	0,43	0,41
Axial shear strength (MPa)	0,06	0.17	0,08	0,12
Closed cells (%)	99,0	95,0	99,9	99,9

TABLE 2. Test results. Aged foam 170°C for 1450 hours.

	Bayer	Shell	BASF	CFC
Density (Kg/m^3)	47	62	66	58
Water absorption (%)	23,0	6,5	6,6	9,9
Axial shear strength (MPa)	0,09	0.15	0,29	0,31
Closed cells (%)	97,4	98,0	96,3	97,9

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APPENDIX 4

CHALMERS UNIVERSITY OF TECHNOLOGY
Div. of Building Technology
Ulf Jarfelt

Axial shear strength

1991-12-02

The aim of the project has been to develop a test equipment to determine the axial shear strength at operating temperature. The development work has been carried out as a joint venture between Chalmers University of Technology, Göteborg, Sweden and The Swedish National Testing Institute. The test equipment coincides with the requirement stated in EN253 rev.3, where the service pipe temperature are kept at 140±2°C. This temperature is reached within 30 minutes and maintained for 30 minutes before applying the force.

After the development work a number of tests on various test samples have been performed. The axial shear strength at room temperature and operating temperature for CFC-blown, HCFC-blown and CO_2-blown foams have been performed. Also unaged and aged foams (in accordance with EN253 170°C for 1450 hours) have been tested.

Pipes from the following manufactures are included:

CFC: IC Möller
Lögstör

HCFC IC Möller
Ecopipe
Tarco

CO_2 Lögstör
Stjärnrör
Powerpipe

Ulf Jarfelt
Project leader

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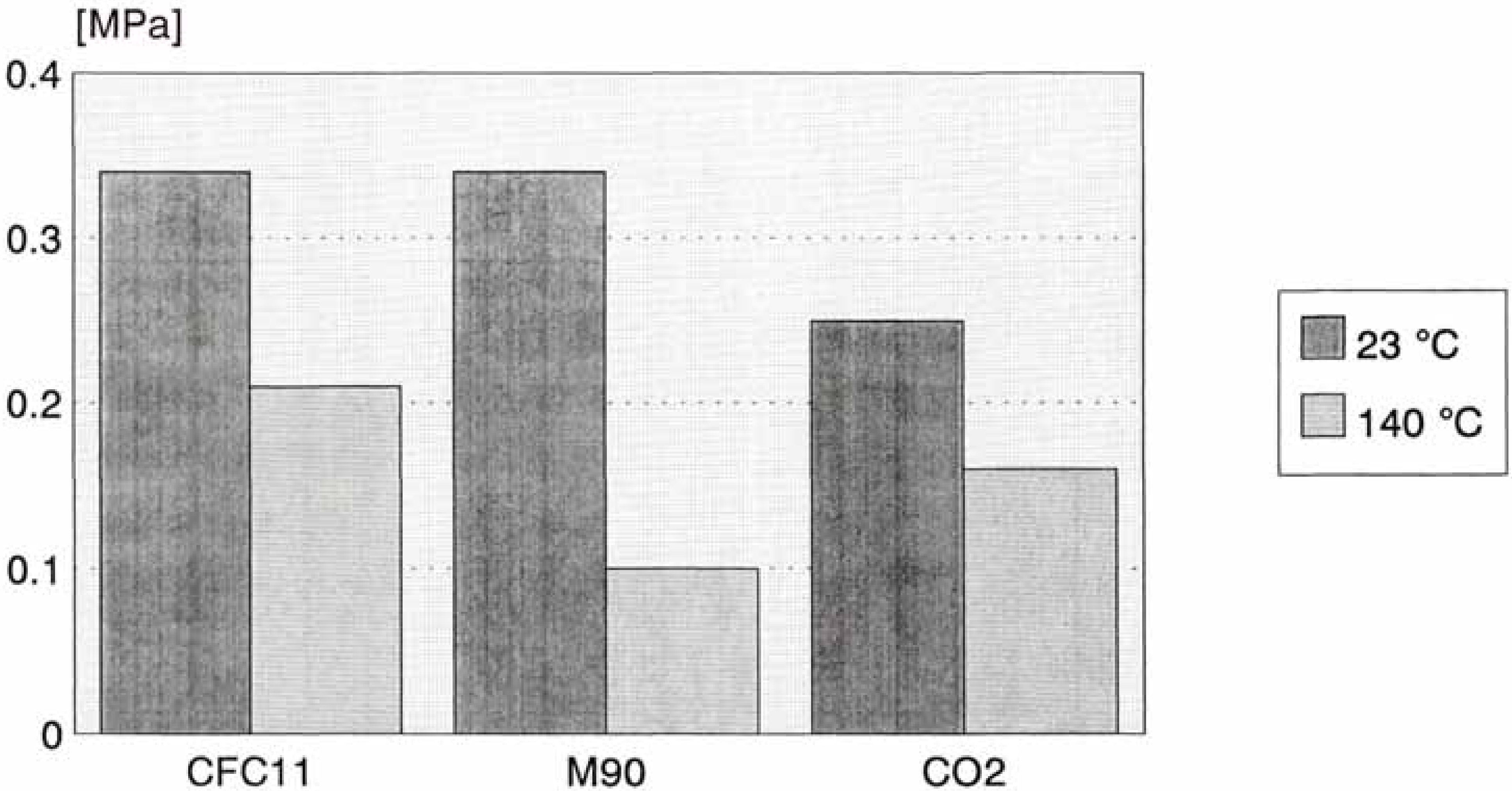
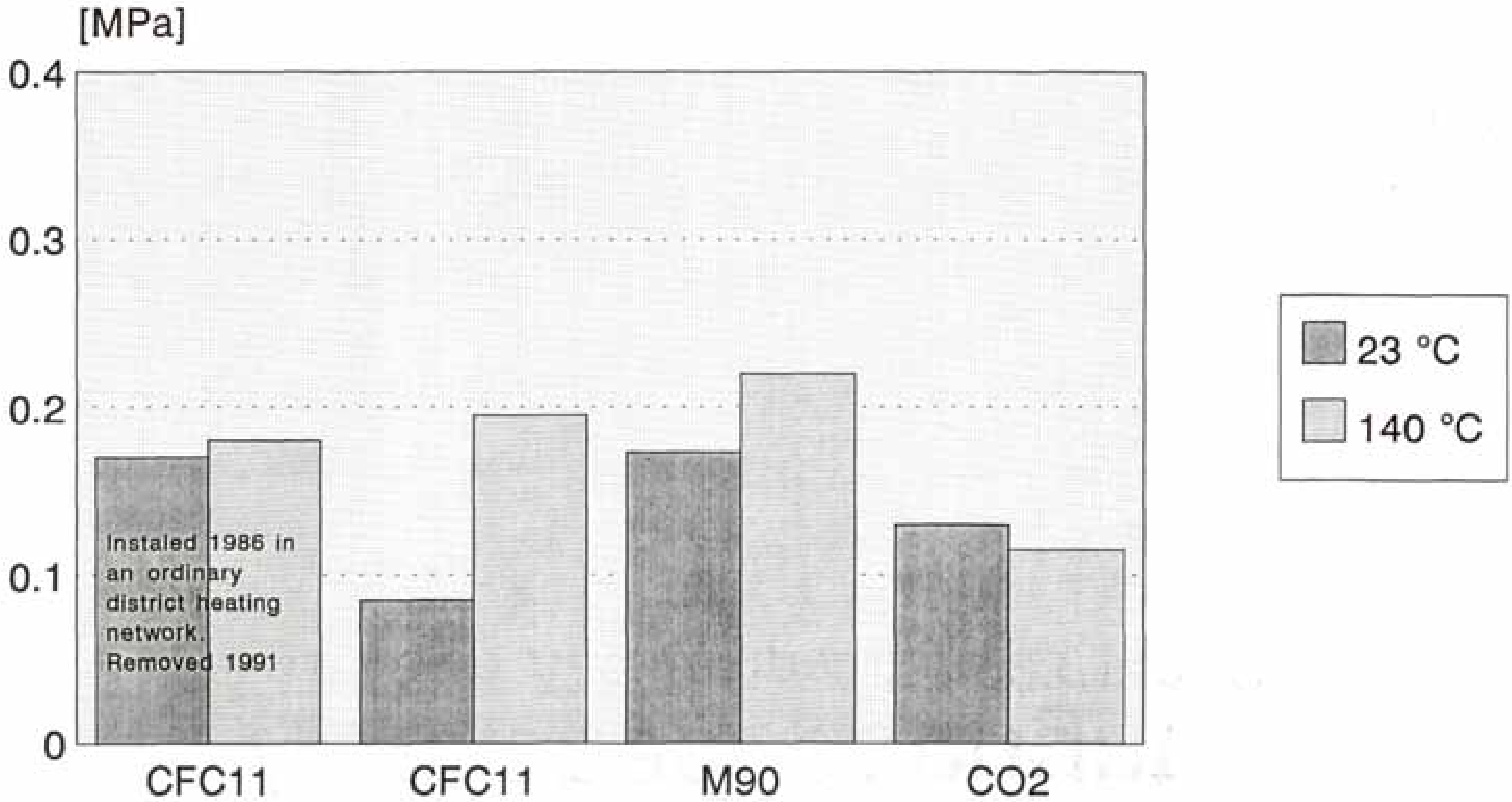
Axial sheer strenght

Unaged pipe. Test temperature 23/140 °C



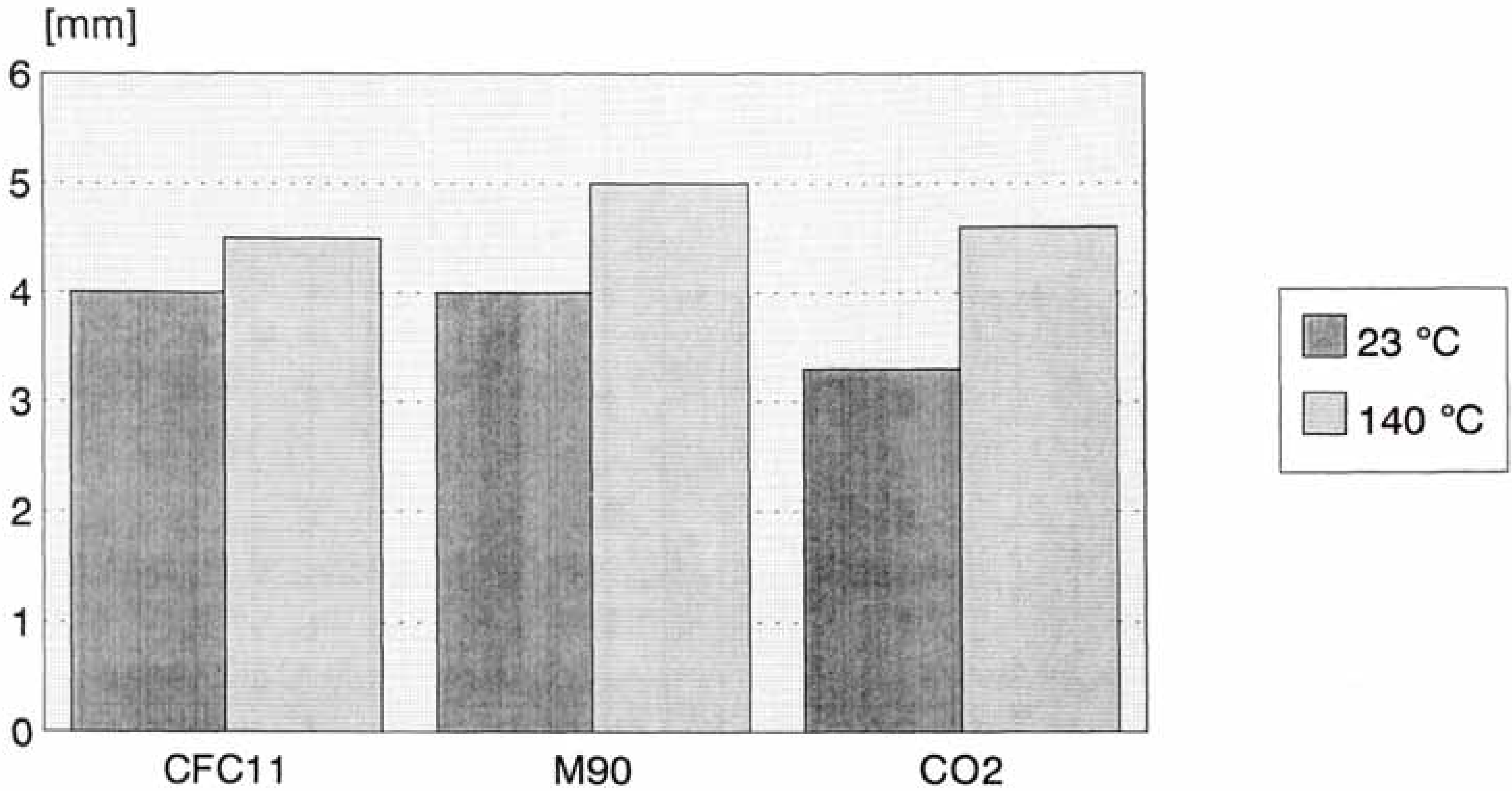
Axial sheer strength

Aged pipe (170 °C for 1450 hours). Test temperature 23/140 °C



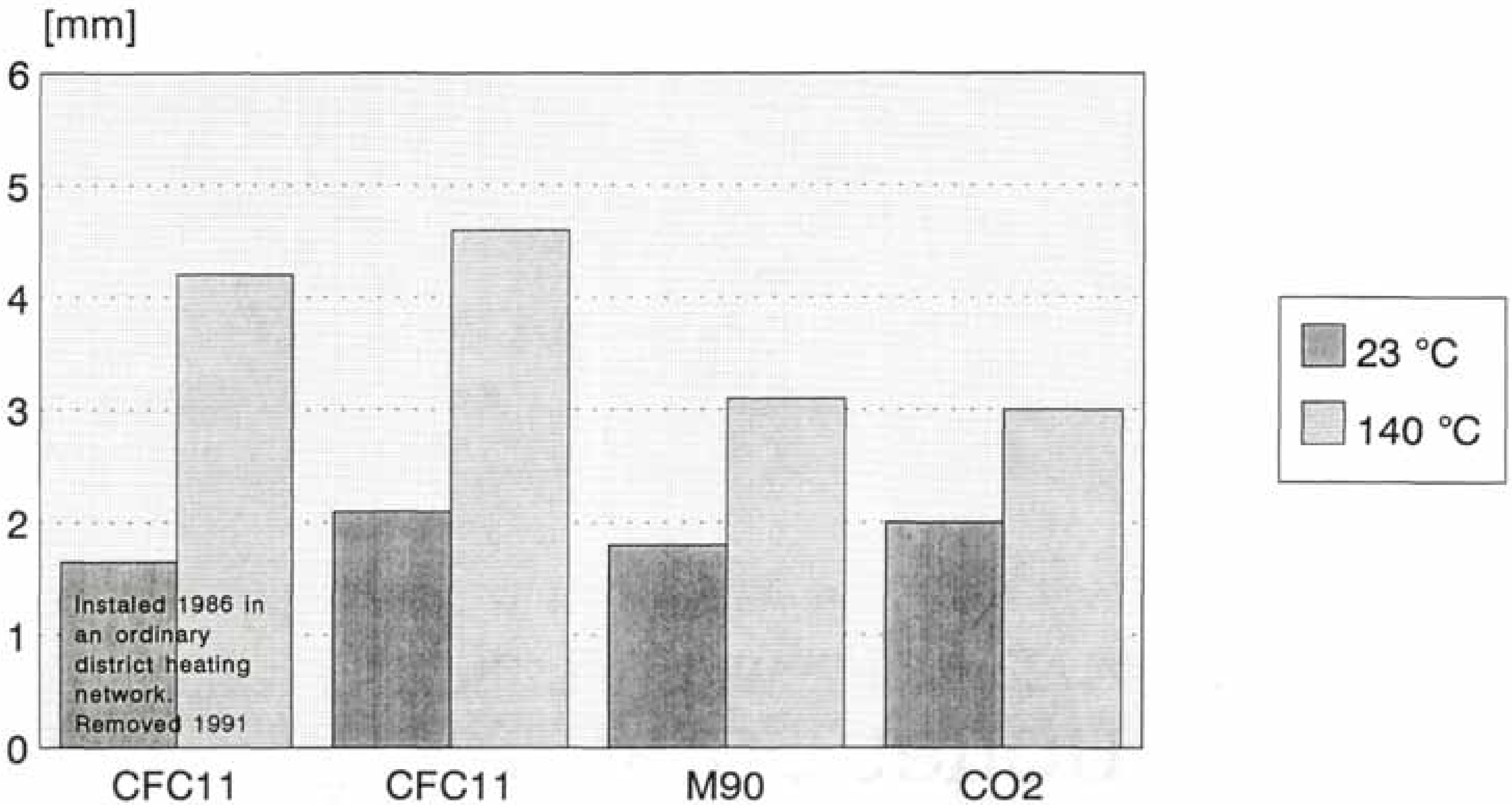
Axial deformation

Unaged pipe. Test temerature 23/140 °C



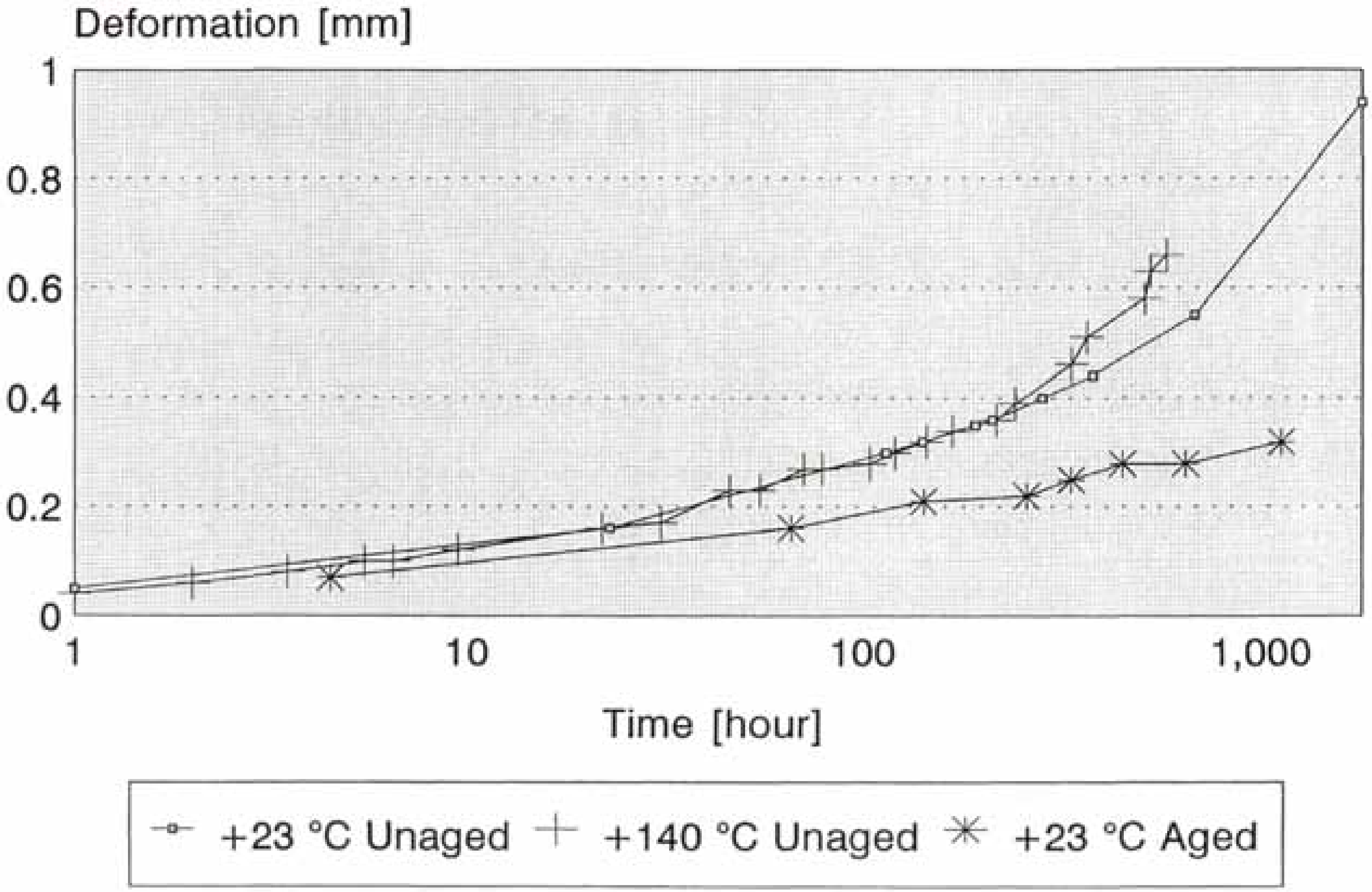
Axial deformation

Aged pipe (170 °C for 1450 hours). Test temerature 23/140 °C



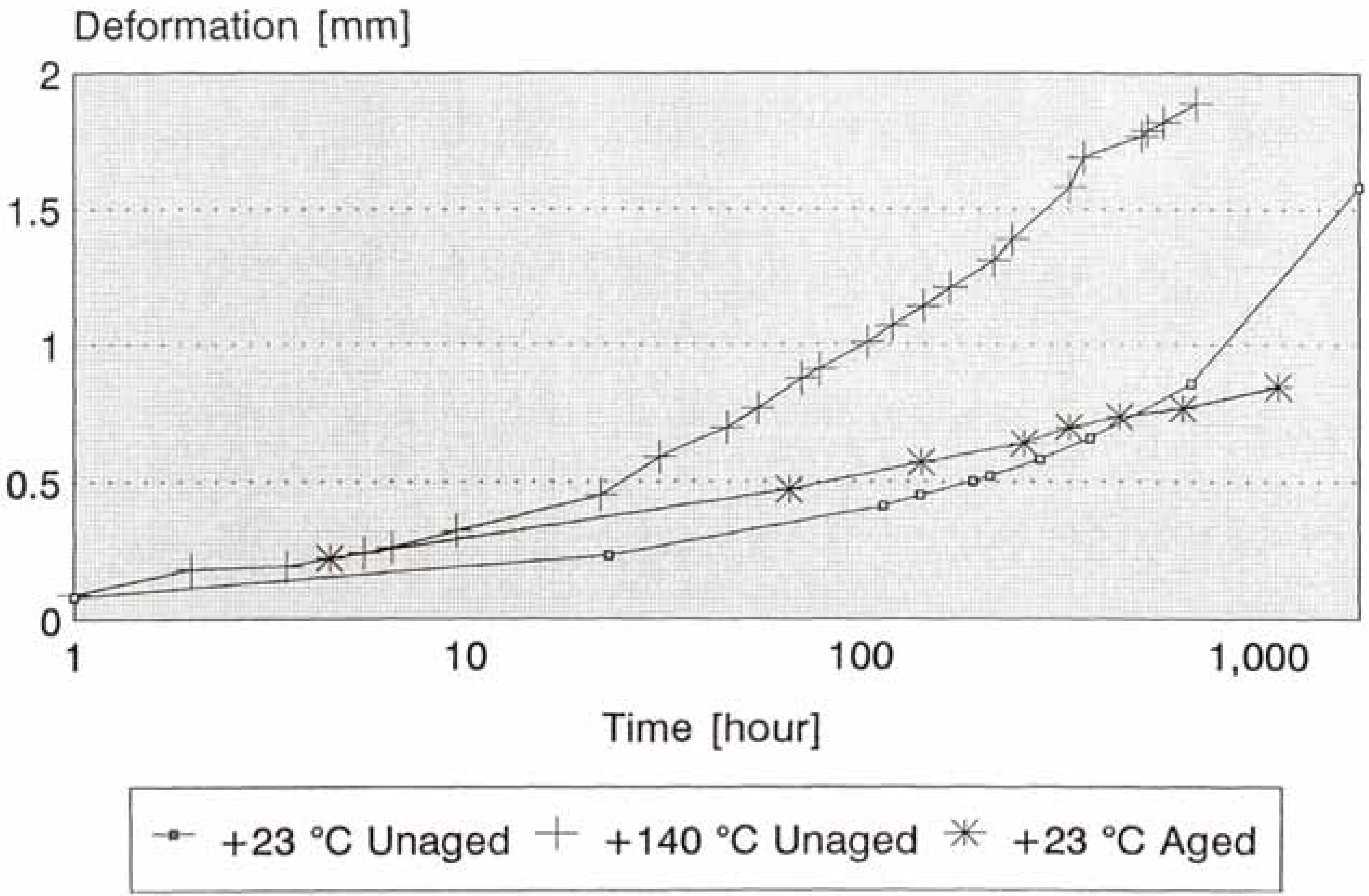
APPENDIX 5

Load 0.1 MPa



Deformation [mm]
1
0.8
0.6
0.4
0.2
0
1
10
100
1,000
Time [hour]
+23 °C Unaged
+140 °C Unaged
+23 °C Aged

Load 0,3 MPa


Deformation [mm]
2
1.5
1
0.5
0
1
10
100
1,000
Time [hour]
+23 °C Unaged
+140 °C Unaged
+23 °C Aged

APPENDIX 6

COMPOSITION OF THE GAS PHASE IN POLYURETHANE FOAM

by

Ulf Jarfelt
Olle Ramnäs

Chalmers University of Technology

ABSTRACT

The thermal conductivity of polyurethane foam as a function of time is attributable to gas diffusion. To be able to predict long term behavior, e.g. thermal conductivity, it is vital to know the gas content of the cells at any given time. This paper discusses the method of direct determination of the gas phase composition using gas chromatography.

INTODUCTION

The value of the thermal insulation of polyurethane foam is governed by the type of polymetric material in the walls and struts of the cellular structure and the type of gas or gas mixture within the closed cell structure. The gas content of the cells at any given time depends on diffusioncoefficents of the individual gases and for the polyurethane foam as well as type of facers which are bonded to the surface to restrict the diffusion processes.

Transfer of gases through a cellular plastic material takes place by a number of processes. The gas is absorbed into the surface of the cell wall and into the struts, diffuses through the wall, vaporises from the opposite surface of the cell wall, diffuses through the next gas filled cell, and so on. The gas transfer is dependent both to diffusion through cell walls and on the ability of the gas to be absorbrd in the cell wall.

Under a period of a few years the use of chlorofluorocarbon (CFC) will be band in several cuntries and be raplaced by more environmentally acceptable alteratives, e.g. HCFC123, HCFC141b, CO_2.

Replacing CFC as blowing agent is a complex problem and requires different types of knowledge. It is therefore necessary to treat the problem interdisciplinarily. At Chalmers University of Technology, Gothenburg, Sweden a number of scientists have formed a project group for basic studies of heat transfer and gas diffusion in cellular plastics. The project is being financed by the National Energy Administration of Sweden for a period of 3 years.

STATEMENT OF THE OBJECTIVE AND DEFINITIONS

Heat transfer through the material is generally governed by conduction in the enclosed gas or gas mixture, conduction in the solid polymer and radiation. The total thermal conductivity can be written

$$\lambda=\lambda_{gas}+\lambda_{cond.\ solid}+\lambda_{rad.}$$

where

$\lambda_{gas}=$ thermal conductivity of the gas mixture.

$\lambda_{cond.\ solid}=$ thermal conductivity of the solid polymer

$\lambda_{rad}=$ thermal conductivity due to radiation

The thermal conductivity of the gas mixture has been treated by a large number of reseaschers and a number of expressions have been proposed. In all these expressions the thermal conductivity of the gas mixture is governed by information about the partial pressur of each gas and the thermal conductivity of each gas.

Since the total thermal conductivity of the foam is largely dependenton the conductivity of the enclosed gas mixture, it is of vital to know the compsition of the gas phase in the cells. Diffusion of gas in a homogeneous material can be written

$$\frac{dp}{dt} = D_{eff} \frac{d^2p}{dx^2}$$

where p = partial pressure (kPa)
t = time (s)
D_{eff}= diffusion coefficient (m^2/s)

Gas transfer through cell structure has been analysed by a number of researchers, and different methods for the derivation of permeability and conversion into diffusion coefficients are presented. Examples which may be mentioned are Cuddihy and Moacanin (1967), Norton (1982) Valenzuela and Glicksman (1983) and Glicksman et al (1986).

The litterature also contains a number of works in which equivalent diffusion coefficients for the gases used in polyurethane foam have been directly determined, Norton (1967), Brandreth and Ingersoll (1980). This has been done by determination of the gas concentration as a function av time, after which the effective diffusion coefficient D_{eff} could be calculated.

APPENDIX 7

CHALMERS UNIVERSITY OF TECHNOLOGY
Div. of Building Technology
Ulf Jarfelt

ABSTRACT

Ulf Jarfelt
Chalmers University of Technology
S-412 96 GÖTEBORG, SWEDEN

Test result of compressive strength and axial shear strength on district heating pipes after exposure to operating conditions.

The project has been carried out as a joint venture between Chalmers University of Technology, the local energy supplier of Göteborg and a pipe manufacturer, Powerpipe AB SWEDEN, in order to compare three different makes of polyurethane foams for district heating pipes. A test plant was built in 1988 and the pipes being tested were connected to a heat plant. The design of the test plant is shown in Figure 1.

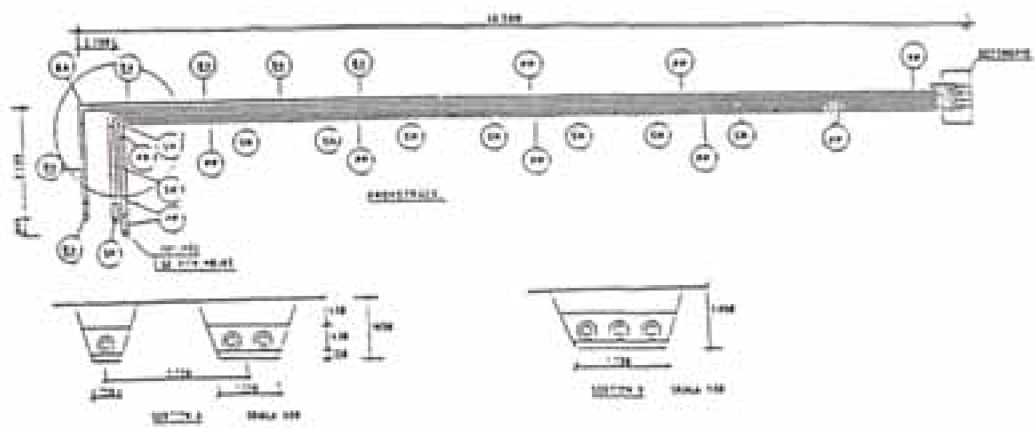


FIGURE 1. Design of test plant i Göteborg, Sweden. Pipe dimensions: steel service pipe 168 mm, polyethylene casing pipe 273 mm.

By supplying the test pipes with hot and cold water alternatively twice a day an accelerated axial shear stress situation has been simulated. Hot water temperature 80-100°C and cold water temperature 25-30°C. After 180 temperature cycles the soil has been removed and parts of the pipes have been removed and taken to the laboratory for investigations.

The compressive strength and axial shear strength have been studied for the following types of polyurethane foams:

* 100% CFC
* 25% CFC + 75% CO_2
* 0% CFC + 100% CO_2

TABLE 1. Test results from three different polyurethane foams for district heating pipes. Aged by influence of temperature changes between 25-90°C. Compressive strength and axial shear strength have been tested in accordance with EN253.

	Density(Kg/m³)	Compressive strength MPa	Axial Shear strength Mpa
100% CFC			
Straight pipe	66	0,46	0,16
Bend	53	0,27	0,01
Joint	65	0,38	-
25% CFC			
Straight pipe	70	0,43	0
Bend	54	0,17	0
Joint	66	0,28	-
0% CFC			
Straight pipe	73	0,60	0,23
Bend	59	0,34	0,13
Joint	68	0,52	-

As a result of the tests a combination of CFC11 and CO_2 as blowing agent for foam is not suitable for the moment. If the test results are combined with the demands from the Swedish government to reduce the use of CFC the only solution, for the moment, is to change production to use CO_2 blowing agent.

APPENDIX 8

CHALMERS UNIVERSITY OF TECHNOLOGY
Div. of Building Technology
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ABSTRACT

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Chalmers University of Technology
S-412 96 GÖTEBORG, SWEDEN

Test results in accordance with EN253 of products available on the Swedish market from different pipe manufacturer. All products CFC-free.

The test work has been done at Chalmers University of Technology and at the Swedish National Testing Institute. The work has been initiated be the Swedish District Heating Assisiation and carried out in 1991.

TABLE 1. Test results in accordance with EN253.

	Spec. EN253	PP	IC	LR	DR	TR	EP
Celldiameter	<0,5 mm	0,4	0,3	0,2-0,6	-	-	0,4
Closed cells	≥88 %	98,0	99	98	99	-	98,8
Core density	≥60 Kg/m³	72,6	84	78	80,7	83,2	72
Mean density	≥80 Kg/m³	82,4	96	80	86,7	91,9	85
Compressive strength	≥0,3 MPa	0,57	0,52	0,41	0,53	0,52	0,46
Water absorp-tion	≤10 %	3,4	5,2	4	4,9	-	4,1
Axiel shear strength. Unag-ed.	≥0,12 MPa	0,27	0,41	0,26	0,34	0,58	0,35
Axiel shear strength. Aged.	≥0,12 MPa	0,12	0,16	0,12	0,15	0,37	0,17
Thermal con-ductivity	≤0,027 W/mK	0,031	0,028	0,030	0,032	0,029	0,030

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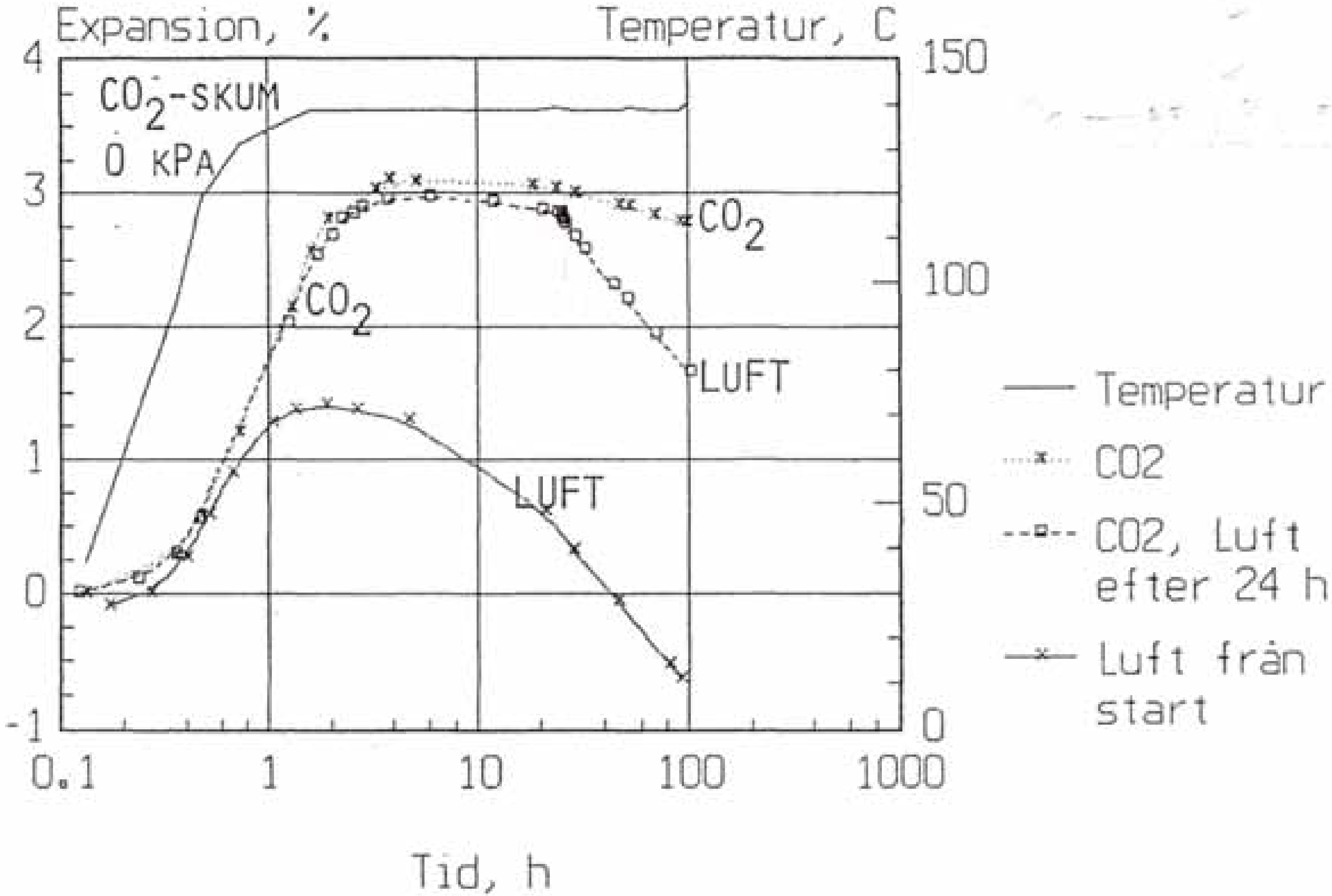
Ulf Jarfelt

TABLE 2. Test results in accordance with EN253 draft 3. Axial shear strength at operating temperature are studied.

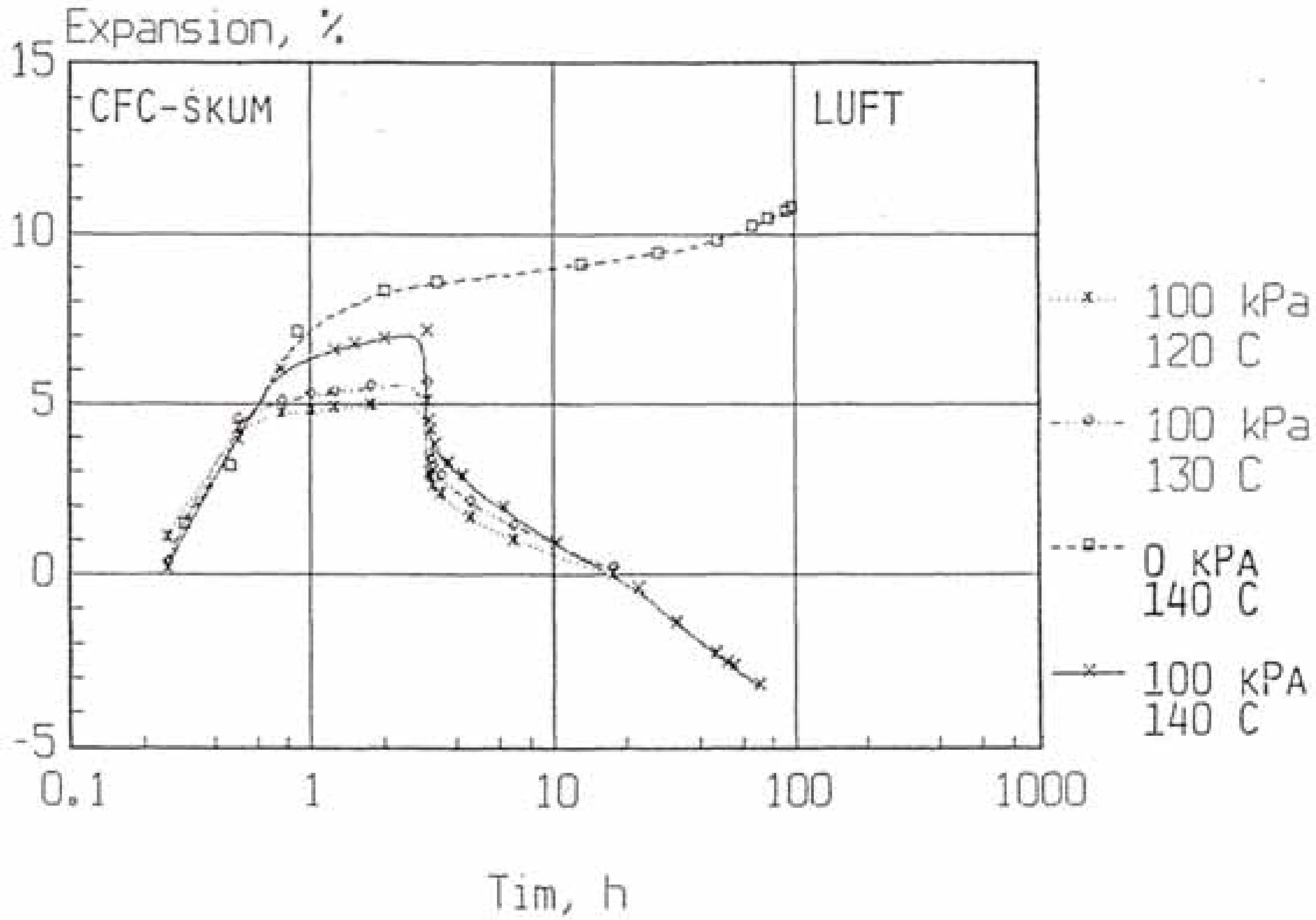
	Spec. EN253	PP	IC	LR	DR	TR	EP
Celldiameter	≈0,5 mm	0,4	0,3	0,2-0,6	-	-	0,4
Axiel shear strength at 140°C. Un-aged	≥0,12 MPa	0,20	0,11	0,13	0,14	0,30	0,10
Axiel shear strength at 140°C. Aged.	≥0,08 MPa	-	-	0,11	-	-	0,22
Thermal con-ductivity	≤0,033 W/mK	0,031	0,028	0,030	0,032	0,029	0,030

PP = Powerpipe AB
IC = ABB IC Möller
LR = Lögstör
DR = Dansk Rörindustri
TR = Tarco
EP = Ecopipe

APPENDIX 9



Expansion, %
Temperatur, C
CO2-SKUM
0 KPA
CO2
CO2
LUFT
LUFT
150
100
50
0
4
3
2
1
0
-1
0.1
1
10
100
1000
Tid, h
Temperatur
CO2
CO2, Luft efter 24 h
Luft från start



Expansion, %
15
10
5
0
-5
CFC-SKUM
LUFT
0.1
1
10
100
1000
Tim, h
100 kPa
120 C
100 kPa
130 C
0 kPA
140 C
100 kPA
140 C

APPENDIX 10

Lämpölaitosyhdistys ry.

Enclosure 2.

Veli-Pekka Sirola 11.9.1991

SUMMARY OF FINNISH TYPE TEST RESULTS OF CFC-FREE DH-PIPES

The CFC-free pipes of five pipe manufacturers (four CO_2, one HCFC) have been tested in Lappeenranta Technical University according to the requirements of the national quality assurance system. Also one pipe with 50 % R11/50 % CO_2 has been tested. All samples were of size DN 80/200. The results are as follows:

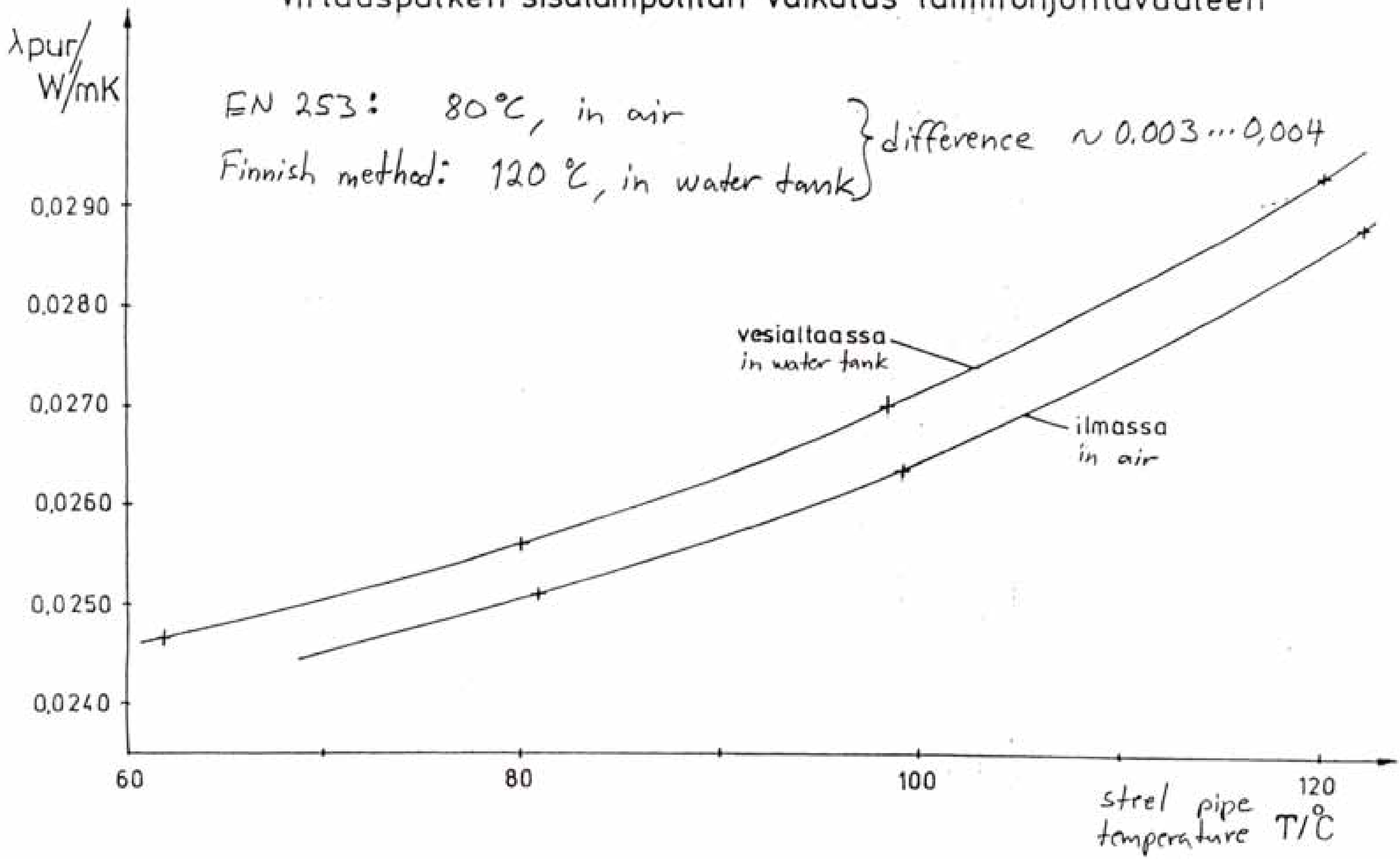
	pipe 1 CO_2	pipe 2 CO_2	pipe 3 CO_2	pipe 4 CO_2	pipe 5 R11/CO_2	pipe 6 HCFC
λ-value[1], W/mK						
- unaged	.0308!	.0327	.0301!	.0328	.0294	.0308
- aged[2]	.0323	.0339	.0312	.0346	.0301	.0319
Axial shear strength[3], kPa						
- unaged	334	361	308	330	288	370
- aged[2]	168	278	224	174	227	260
Compressive strength, kPa						
- axial	858	746	746	820	619	650
- radial	710	712	596	557	589	630
Overall density, kg/m³	80,9	81,3	82,7	84,7	78,7	86,9

1) Finnish method, comparison to EN 253 enclosed

2) 1000 h in 130 °C

3) tested in 20 °C

Virtausputken sisälämpötilan vaikutus lämmönjohtavuuteen



APPENDIX 11

Institut für Kunststoffprüfung
und Kunststoffkunde
Universität Stuttgart

UNIVERSITÄT
IKP
STUTTGART

PRÜFBERICHT

Nr. M 2232

vom 31.10.1990

über Untersuchung von PUR-umschäumten Fernwärmemantelrohren

1. Ausfertigung

Auftraggeber Arbeitsgemeinschaft Fernwärme e.V.
Stresemannallee 23
6000 Frankfurt/Main 70

Auftrag vom 16.07.1990

Der Prüfbericht umfaßt insgesamt	68	Seiten
darin sind enthalten	59	Bilder
	2	Tabellen

Schaum	Treibgas	Erweichungstemperaturen °C				Masseabnahme Temperaturen °C	Temperaturen bei denen ein exothermer Abfall auftritt °C	
		mech. Spektroskopie N_2	TMA stat N_2	TMA stat CO_2	TMA dyn N_2	TGA N_2	DDK, N_2 1.Lauf	DDK, N_2 2.Lauf
Shell water type 1	CO_2	183	142/234	144/237	138	-/322	203	217
Shell water type 2	CO_2	120	89/220	*	91	-/320	198	227
Shell CFC blown system	FCKW	200	193/230	*	180	200/333	203	220
Shell CFC blown system X	FCKW	197	190/230	*	154	194/333	187	224
BAYER ESN 1011	FCKW	153	154/204	*	*	158/328	155	211
BAYER ESN 1012	CO_2	174	132/220	*	*	-/318	220	223
Elastogran I	FCKW	180	116/175	*	*	195/335	-	-
Elastogran II	CO_2	182	129/224	*	*	-/324	-	205
Elastogran III	CO_2	204	155/233	*	*	-/326	-	212
Logstor I	FCKW	215	162/187/>230	*	*	-/330	-	218
Logstor II	CO_2	195	141/ 240	*	*	-/333	-	-

Tabelle 1: Erweichungstemperaturen
*) keine Messungen durchgeführt, -) keine Umwandlung gefunden

APPENDIX 12

Untersuchungsvorhaben

Vorversuche an Kunststoffmantelrohren mit FCKW-freien Schäumen

Durchführung:	Technische Werke der Stadt Stuttgart AG (TWS) Hauptabteilung Rohrnetze für Gas, Wasser, Fernwärme Lautenschlagerstraße 21 7000 Stuttgart 1
Laufzeit:	01.03.1991 bis 31.12.1991
Berichtsabfassung:	Dipl.-Ing. A. Zeller (TWS)
Projektleitung:	Dipl.-Ing. P. Hofer (TWS)

Stuttgart, im April 1992

1. Aufgabenstellung

Die endgültige Bewilligung des Antrages über das beabsichtigte TWS-FE-Vorhaben (A 6.1) "Entwicklung eines Prüfverfahrens und Bestimmung der Zeitstand-Scherfestigkeit von FCKW-freiem Polyurethan-Schaum in Fernwärmerohren" stand im Frühjahr 1991 immer noch aus. Um die Zeitspanne bis zur Erteilung des Förderbescheides sinnvoll zu nutzen, sollten in Vorversuchen

- die Grenzen der thermisch mechanischen Festigkeiten der zu untersuchenden Schäume getestet werden und

- die Technik der Temperaturaufbringung über elektrische Aufheizung erprobt werden.

2. Technik des Versuchsstandes

Der Prüfstand (Bild 1) war so konstruiert, daß ein 2 m langes Prüfrohr mit insgesamt zehn Prüfscheiben bis maximal 170 °C temperiert werden konnte. Es wurden jeweils 5 Prüfscheiben mit gleicher Scherbeanspruchung beaufschlagt.

Da das für die elektrische Aufheizung verwendete Gerät üblicherweise für die Vorwärmung von Leitungen in KMR-Technik eingesetzt wird und deshalb für wesentlich längere Rohrstrange ausgelegt wär, wurde an das Prüfrohr beidseits ein 3 m langes Rohr angesetzt, um so die Aufheizstrecke zu verlängern.

Bei der gewählten Versuchsanordnung (Bild 2) konnte ein weitgehend konstanter Temperaturanstieg beim Aufheizen und eine bis auf ± 0,5 ° ausgeregelte Versuchstemperatur erreicht werden.

Die PUR-Schaum-Schnittflächen wurden während der Versuchszeit gegen Oxydation durch Spülen mit inertem Gas geschützt.

Die Krafteinleitung (Scherbeanspruchung) erfolgte über Rohrschellen und Mitnehmerbolzen (Bild 3).

Die Torsionsbelastung wurde über eine zweiseitige Hebelkonstruktion auf die Prüfscheiben aufgebracht (Bild 4).

Über einen Datenlogger wurden folgende Versuchsparameter aufgenommen:

- Mediumrohrtemperatur
- Mantelrohrtemperatur
- Lufttemperatur
- Verdrehung am Außenmantel von 4 Prüfscheiben.

Im Hinblick auf die hohen Kosten für die Wegaufnehmer mit automatisiertem Erfassungssystem (Bild 5) wurde die Verdrehung einiger Prüfscheiben manuell abgelesen.

3. Versagenskriterien

Eine Probe versagt, wenn der Verbund Stahlrohr/Schaum/Mantelrohr zerstört ist. Im Hinblick auf die langen Standzeiten bei niedrigen Belastungen war zu untersuchen, ob es im Verlauf der Kriechkurven vorzeitige Hinweise auf das Eintreten des Bruchvorganges gibt.

Bei den zunächst eingestellten hohen Belastungen mit entsprechend kurzen Standzeiten waren vor dem Bruch z.T. deutliche Veränderungen in den Kriechkurven zu erkennen.

4. Versuchsprogramm

Die Versuche 1 und 2 wurden mit kontinuierlich geschäumten, Versuch 3 mit diskontinuierlich geschäumten Rohren, durchgeführt (DN 50 Normreihe 3). Auf jedem Prüfrohr waren 2 x 5 Prüfscheiben angeordnet. Die Versuchstemperaturen waren bedingt durch den Versuchsstand für alle Prüfscheiben gleich. Für jeweils 5 Prüfscheiben wurde eine gleiche Prüfspannung vorgegeben.

Die in der Praxis vorkommenden axialen Scherspannungen (zwischen 0,01 und 0,03 N/mm^2) wurden in den Versuchen mit tangentialen Scherversuchen simuliert. Bei einem Umrechnungsfaktor der tangentialen in die axiale Scherbelastung mit dem Faktor 1,67 entspricht die axiale Spannung von 0,03 N/mm^2 damit einer tangentialen Scherspannung von 0,05 N/mm^2. Beim ersten Versuch wurden hohe Scherspannungen von 0,2 und 0,1 N/mm^2 (Sicherheiten von s 0 4 bzw. 2) gewählt: In den Versuchen 2 und 3 mußten die Spannungen auf 0,1 und 0,05 N/mm^2 (s = 2 bzw. 1) herabgesetzt werden, da die hochbelasteten Prüfscheiben des ersten Versuches bereits beim Vortempern mit 100 ^{o} versagten.

Nach dem bisherigen Kenntnisstand gibt es eine Nachverfestigung des Schaumes durch eine Temperaturvorbelastung. Da Leitungen überlicherweise vor der Heizperiode angefahren und bei Fahrweise mit gleitenden Vorlauftemperaturen erst über einige Wochen mit reduzierten Betriebstemperaturen beaufschlagt werden, wurde jedes Versuchsrohr über einen Zeitraum von 14 Tagen bei 100 °C beaufschlagt. Die Vortemperung erfolgte dabei unter mechanischer Last, da auch in der Praxis an kritischen Leitungspunkten von Anbeginn mit der vollen Scherspannung zu rechnen ist.

Gegenüber den Versuchen 1 und 2, bei denen nach der Vortemperierung bei 100 °C sofort auf höhere Temperaturen (160 °, 150 °) gefahren wurden, wurden im Versuch 3 die Temperaturen wie folgt stufenweise erhöht (Bild 12):

- 14 Tage Vortemperung bis 100 °C
- 4,5 Wochen Aufheizung auf 130 °C
- tägliche Temperaturerhöhung um 2 °C bis 140 °C
- 1,5 Wochen Aufheizung auf 140 °C
- 2 x tägliche Temperaturerhöhung um 2 °C bis auf 144 °C
- 7 Wochen Temperierung auf 144 °C
- Abschaltung nach insgesamt 109 Versuchstagen.

Im Versuch 1 wurde unter mechanischer Last aufgeheizt, in den Versuchen 2 und 3 wurde die mechanische Last bei Erreichen von 100 ° aufgebracht.

5. Ergebnisse

Ergebnisse Versuch 1 (Prüfling 3/A) 160 °

Torsionsspannung 0,2 N/mm²: Versagen während des Temperns bei 100 ° nach 2 bis 7 Tagen Standzeit

Torsionsspannung 0,1 N/mm²: Versagen nach der Vortemperung während des Aufheizens kurz vor bzw. nach Erreichen von 160 ° (Bild 7)

In den Kriechkurven sind deutliche Anstiege beim Aufbringen der mechanischen Last sowie beim Erreichen von ca. 75 ° festzustellen (Bild 6). Nach dem 14-tägigen Tempern standen nur noch die Prüfscheiben mit 0,1 N/mm^2 Diese zeigten während des Aufheizens auf 160 ° deutliche Wegzunahmen ab 135 °. Dies durfte den Beginn des Erweichungsvorganges kennzeichnen.

Ergebnisse Versuch 2 (Prüfling 2/B) 150 °

Torsionsspannung 0,1 N/mm^2: Versagen aller 5 Proben nach Erreichen von 150 ° innerhalb von 34 Minuten (Bild 10)

Torisonsspannung 0,05 N/mm^2: Versagen von 2 Proben bei 150 ° nach 4 bzw. 8 Tagen. 3 Proben wurden nach 13 Tagen abgebrochen (Bild 11)

Die Kriechkurven zeigen bei 130 ° wieder einen deutlichen Anstieg als Folge des Erweichungsvorganges.

Ergebnisse Versuch 3 (Prüflinge 2/G) 130 °/140 °/144 °

Torsionsspannungen 0,1 N/mm^2: Versagen von 3 Prüfscheiben nach Abschalten des Heizaggregates beim Abkuhlen (Bilder 12 und 13)

Torsionsspannungen 0,05 N/mm^2: kein Versagen, Torsionsverdrehungen bei Versuchsabbruch zwischen 7,5 ° und 9,5 ° (Bild 12)

Die Kriechkurven zeigen Unstetigkeiten kurz nach Erreichen von 100 °C, sowie nach Erhöhen der Temperatur auf 130 °. Beim weiteren schrittweisen Erhöhen der Temperatur auf 140 °C zeigte sich bei 138 °C ein deutlicher Knick in der Kriechkurve (Bild 12).

Nach dem Abschalten des Heizaggregates fiel innerhalb von fünf Stunden die Mediumtemperatur um ca. 103 °C auf T = 41 °C ab. Dabei versagten drei Prüfscheiben. Die automatisch erfaßte Prüfscheibe 9 scherte beim Abkühlen auf 41 °C ab (Bild 13).

6. Beurteilung der Ergebnisse aus den Versuchen

Versuche 1 und 2

Schon bei den kurzen Standzeiten zeigen die mit 160 ° und 150 ° belasteten Prüflinge leichte Braunverfärbungen im Schaum. Das läßt darauf schließen, daß der Schaum bereits einer unzulässig hohen Temperatur ausgesetzt war.

Das Versagen bereits bei Torsionsspannungen von 0,1 bzw. 0,05 N/mm^2 wurde nach so kurzen Standzeiten nicht erwartet. Beim Abmanteln der Rohre wurden Fehler im Schaum entdeckt, welche die geringe Belastbarkeit erklären können. Im oberen Teil war deutlich eine radial ausgerichtete, axial verlaufende Naht zu erkennen, die auf eine zu kurz eingestellte Topfzeit schließen läßt. Auch am Stahlrohr waren Zonen mit unzureichender Vernetzung mit dem Schaum zu erkennen. Im Versuchsrohr 1 zog sich an der Oberfläche des Stahlrohres über die ganze Länge des Prüfrohres ein Streifen ohne Haftungsverbund.

Die Prüfspannungen bezogen sich auf homogenen und über die volle Oberfläche haftenden Schaum. Unter Berücksichtigung der festgestellten Fehlstellen ergaben sich am Übergang Stahlrohr/Schaum tatsächlich wesentlich höhere Spannungen. Die Prüfergebnisse dürfen deshalb nur qualitativ bewertet werden.

Die Versuche lassen auf eine reduzierte mechanische Festigkeit ab 130 bis 135 ° schließen. Dies deckt sich nicht mit den in Laborversuchen beim Institut für Kunststoffprüfung Stuttgart festgestellten Erweichungstemperaturen des kontinuierlich hergestellten Schaumes (150 °). Nur für diskontinuierlich eingebrachten CO_2-getriebenen Schäume wurden Erweichungstemperaturen von ca. 130 ° angegeben.

Versuch 3

Nach insgesamt 109 Tagen und Aufheizung bis maximal 144 °C zeigten die Prüfscheiben sehr starke Braunverfärbungen im Schaum. An den Stirnseiten zweier Prüfscheiben waren die dort eingebauten Abstandhalter aus Kunststoff im Bereich bis 1 cm um das Mediumrohr infolge der Temperaturbeaufschlagung vollkommen aufgelöst. Das läßt darauf schließen, daß sowohl der Schaum als auch der Abstandhalter bereits einer unzulässig hohen Temperatur ausgesetzt waren.

Deutliche Zunahmen der Verformungen sind jeweils bei Temperaturerhöhungen zu erkennen (Bild 12). Die Kriechkurven flachen bei Anhalten der Temperatur wieder ab. Beim schrittweisen Erhöhen der Temperatur von 130 °C auf 140 °C ist bei 138 °C ein deutlicher Knick in der Kriechkurve zu erkennen. Bei Erhöhen der Temperatur auf 144 °C ist sogar ein deutlicher Sprung in der Verformungszunahme ersichtlich.

Der stete Zuwachs auch noch nach 4 Wochen Temperaturhaltung auf 130 ° weist darauf hin, daß der Schaum bereits haltlose Verformungen aufweist. Der endgültige Erweichungspunkt dürfte bei ca. 136 °/138 °C liegen. Dies deckt sich in etwa mit den Untersuchungen am IKP, die den Erweichungspunkt bei T = 129 °C festgestellt haben.

Das Versagen nach der Abschaltung der Heizvorrichtung wurde nicht erwartet. Sie ist wohl darauf zuruckzuführen, daß der Schaum in der Grenzfläche am Mediumrohr nach der Temperaturbelastung schon sehr ausgehärtet war und das sprödere Schaummaterial die die Durchmesserreduzierung infolge Temperaturabsenkung von ca. 0,07 mm unter Last nicht mehr ertrug. Im Hinblick auf die gleitende Fahrweise im praktischen Fernwärmebetrieb kommt diesem Versagensbild jedoch eine wichtige Bedeutung zu, die noch weiterer Untersuchungen bedarf.

7. Vergleich zu KMR mit FCKW-haltigem PUR-Schaum

Zu Beginn der Versuche war auch eine vergleichende Untersuchung zu einem Kunststoffmantelrohr mit FCKW-haltigem PUR-Schaum vorgesehen. Diese Vergleichsprüfung konnte aufgrund der begrenzten Mittel nicht mehr durchgeführt werden.

Radiale Zeitstand-Druckversuche an Kunststoffmantelrohren beim RW TÜV Essen im Rahmen der FE-Vorhaben "Betriebliche Selbstvorspannung/Unterverteilung" der Fernwärmeversorgung Niederrhein GmbH und "Neue Prüftechniken und Systemkomponenten beim Kunststoffmantelrohr" der Gas-, Elektrizitäts- und Wasserwerke Köln AG zeigten auf, daß die radialen Druckfestigkeiten des FCKW-freien Schaumes bei den untersuchten Temperaturen deutlich unter den Werten des Normalschaumes liegen. Im Hinblick auf die Parallelität der Kriechkurven aus den TWS-Vorversuchen und den Einsenkungsmessungen der radialen Zeitstand-Druckversuchen wurde auf eine weitere Prüfung mit R-11-getriebenem Schaum verzichtet.

Bildunterschriften:

Bild 1 Prüfstand zur Aufnahme eines 2 m langen Prüfrohres mit insgesamt zehn Prüfscheiben.

Bild 2 Schaltschema des Versuchsaufbaues mit Schaltung Aufheizgerät, Regelkreis Überhitzungsschutz und Temperaturmeßwertaufzeichnung.

Bild 3 Einbringung der Scherspannung in das Mantelrohr mit Rohrschellen und Mitnehmerbolzen.

Bild 4 Aufbringung der Torsionsbelastung über eine zweiseitige Hebelkonstruktion. Die Prüfscheiben 7 und 8 haben bereits versagt.

Bild 5 Anordnung der vier Wegaufnehmer mit automatischem Erfassungssystem.

Bild 6 Prüfrohr 3/A. Kriechkurvenverlauf bei Aufbringung der Last und Aufheizen auf 100 °C.

Bild 7 Prufrohr 3/A. Kriechkurven bei Temperaturerhöhung von 100 °C auf 160 °C. Versagen der Prüfscheiben 4 und 2 (0,1 N/mm^2) kurz nach Erreichen der Temperatur von 160 °C.

Bild 8 Prüfrohr 3/A. Verlauf der Kriechkurven über die gesamte Versuchszeit

Bild 9 Prufrohr 2/B. Vergleich der manuell und der automatischen erfaßten Meßwerte für Prüfscheiben 2 und 4. Bei längerdauernden Veranderungen kann der Kurvenverlauf auch ohne automatisierte Aufzeichnung hinreichend genau erfaßt werden.

Bild 10 Prufrohr 2/B. Aufheizvorgang von T = 100 °C auf T = 150 °C. Versagen der Prüfscheiben 7 und 9 (0,1 N/mm^2) kurz nach dem Erreichen der Temperatur von 150 °C.

Bild 11 Prüfrohr 2/B. Verlauf der Kriechkurven über die gesamte Prüfzeit.

Bild 12 Prüfrohr 2/G. Verlauf der Kriechkurven über die gesamte Prüfzeit.

Bild 13 Prufrohr 2/G. Abschalten des Aufheizgerätes nach 109 Tagen. Prüfscheibe 9 versagt beim Abkühlen nach 4,5 Stunden bei T = 41 °C.

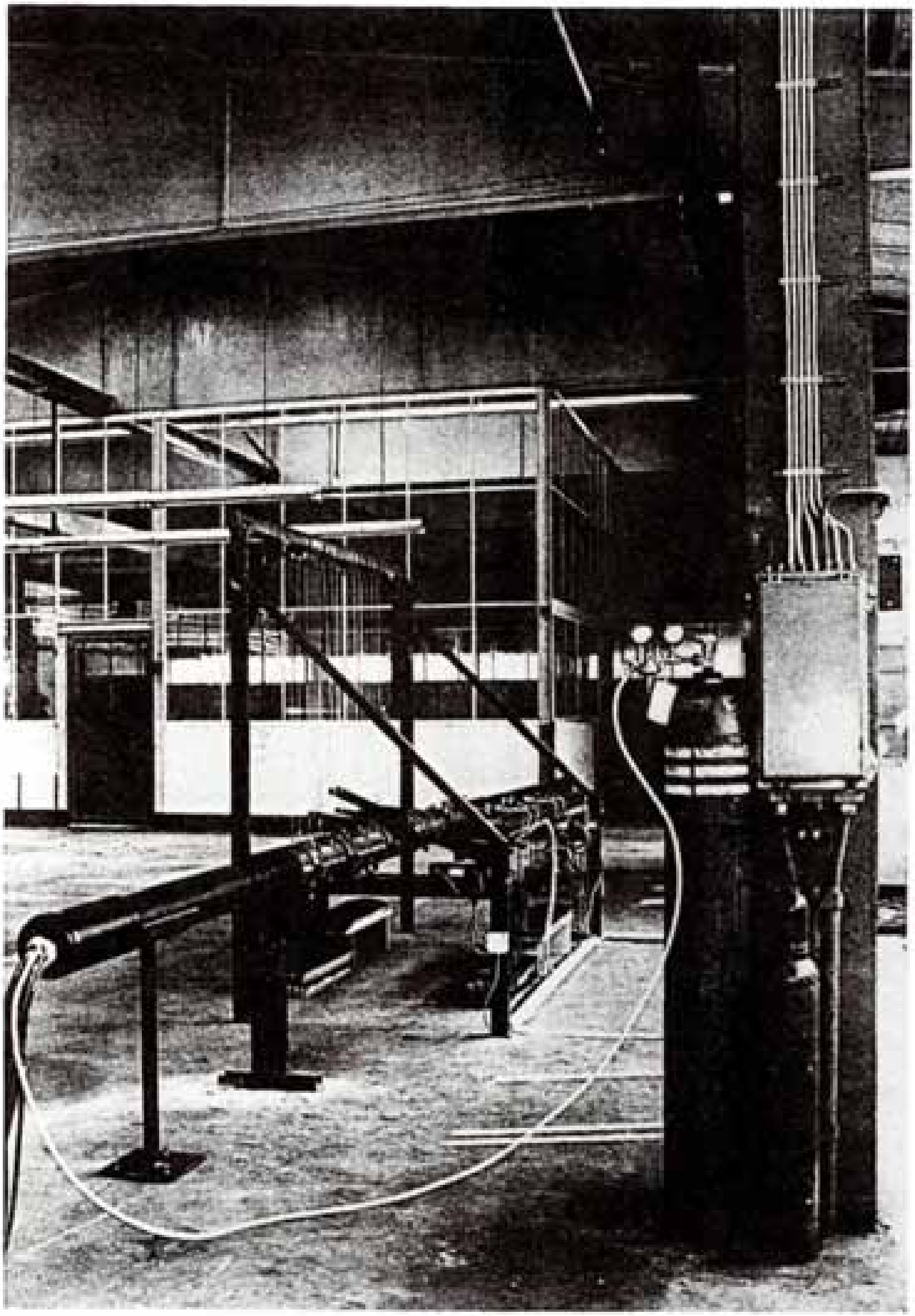
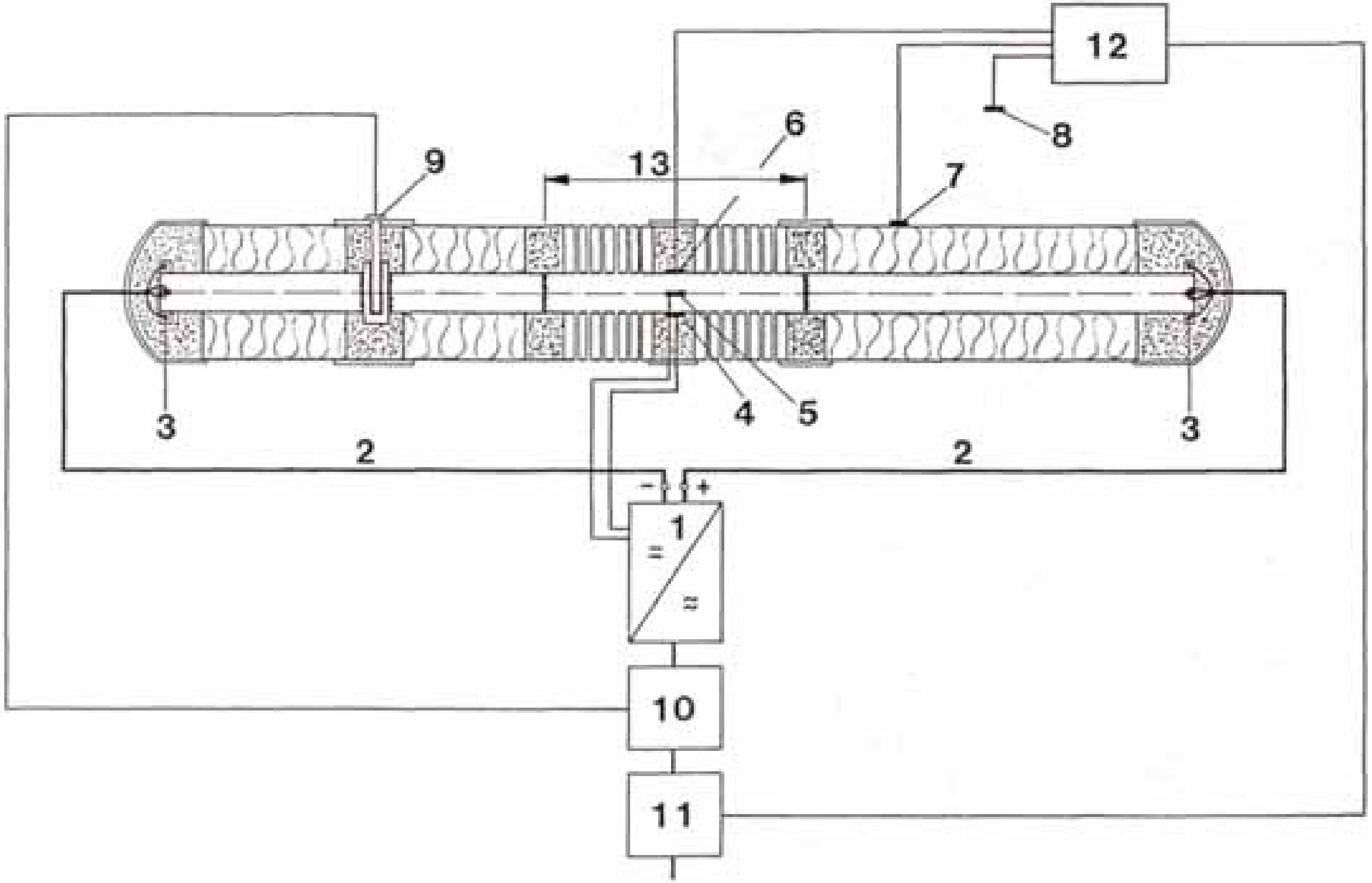


Bild 1



1 Aufheizgerät mit Temperaturregelung (Resitherm Gerät Typ LHF 630)

2 Stromzuführung vom Aufheizgerät zum Mediumrohr mit 2 x 10 Kabel Typ NSL FFöu 50 mm² (Gesamtquerschnitt 500 mm²)

3 Anschluß der Stromzuführungskabel mit Cu-Preßkabelschuhe, je 2 Kabel an einer am Mediumrohr angeschweißten Fahne (nachträglich ausgeschäumt)

4 am Mediumrohr befestigter Temperaturfühler Pt 100 für Temperaturregelung am Aufheizgerät (Istwert)

5 am Mediumrohr befestigter Sicherheitstemperaturfühler SM für die automatische Abschaltung des Aufheizgerätes bei Erreichen der auf T = 180 °C festgelegten Sicherheitstemperaturbegrenzung am Mediumrohr

6 am Mediumrohr befestigter Temperaturfühler Pt 100 für die Aufzeichnung der Mediumtemperatur über Datenlogger

7 am Mantelrohr befestigter Temperaturfühler Pt 100 für die Aufzeichnung der Mantelrohrtemperatur über Datenlogger

8 Temperaturfühler Pt 100 für die Aufzeichnung der Umgebungstemperatur über Datenlogger

9 Überhitzungsschutz: Eintauchtemperaturfühler in eingeschweißter Stahlplatte am Mediumrohr für automatische Abschaltung der gesamten Anlage bei Erreichen der auf T = 180 °C festgelegten Sicherheitstemperaturbegrenzung

10 Steuerschrank für Sicherheitsabschaltung

11 Verteilerschrank mit Anschluß an das Stromversorgungsnetz

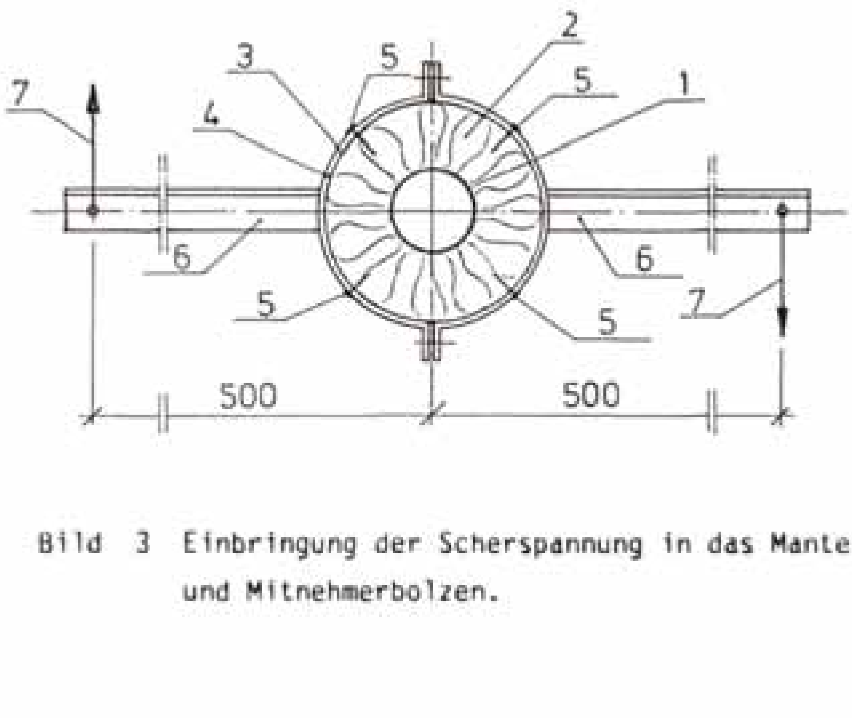
12 Datenlogger

13 2 m langes Prüfrohr mit 10 Prüfscheiben

werkseitig hergestellter Rohrschaum

Ortschaum

Bild 2 Schaltschema des Versuchsaufbaues mit Schaltung Aufheizgerat, Regelkreis Uberhitzungsschutz und Temperaturmeßwertaufzeichnung.



1 Mediumrohr DN 50
2 PUR-Schaum
3 Mantelrohr, $Ø_a$ = 160,00 mm
4 Rohrschelle, $Ø_i$ = 168,3 mm, B = 60 mm
5 Mitnehmerbolzen M 8
6 Hebel (T 30)
7 Gewicht

Bild 3 Einbringung der Scherspannung in das Mantelrohr mit Rohrschellen und Mitnehmerbolzen.

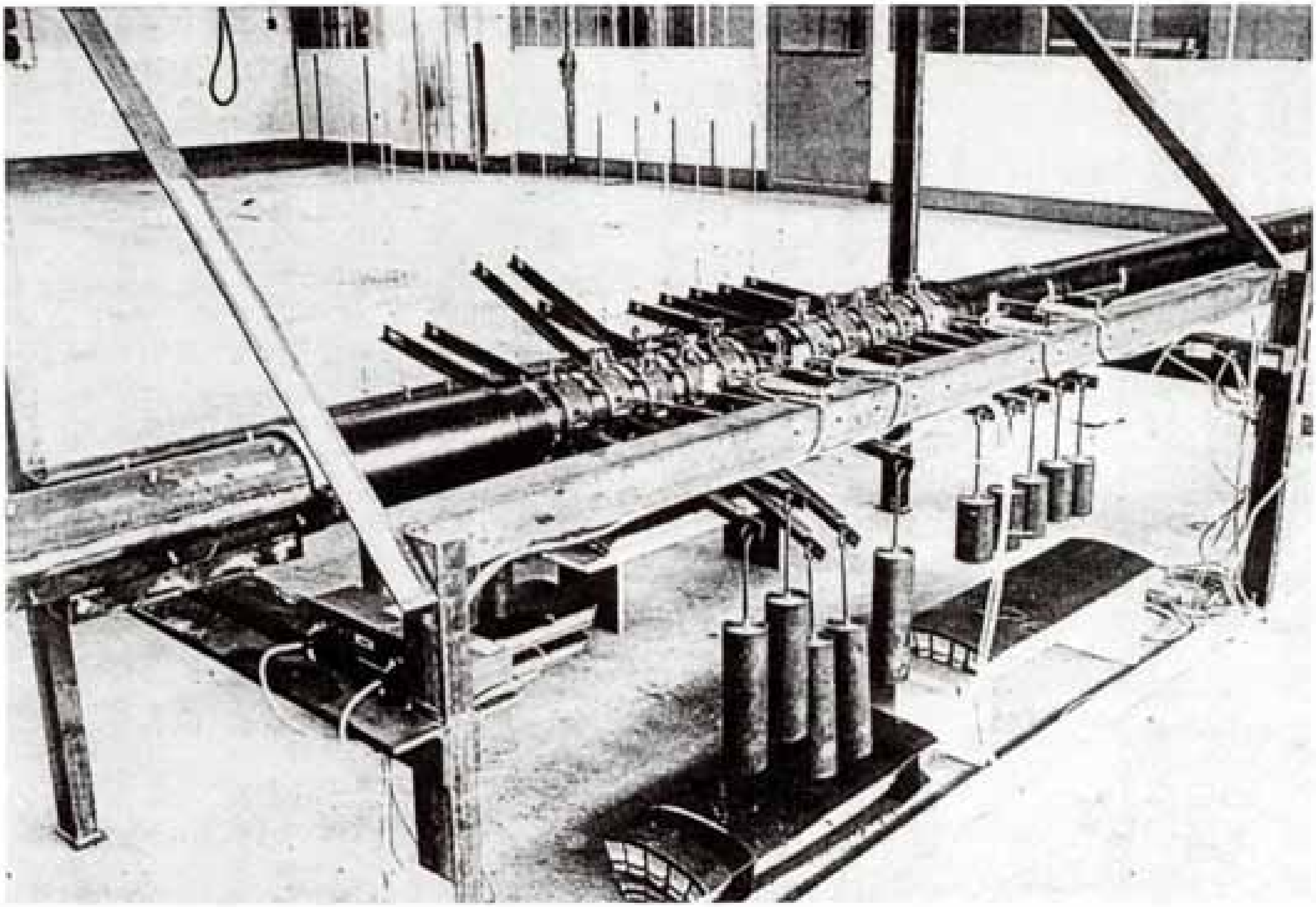


Bild 4

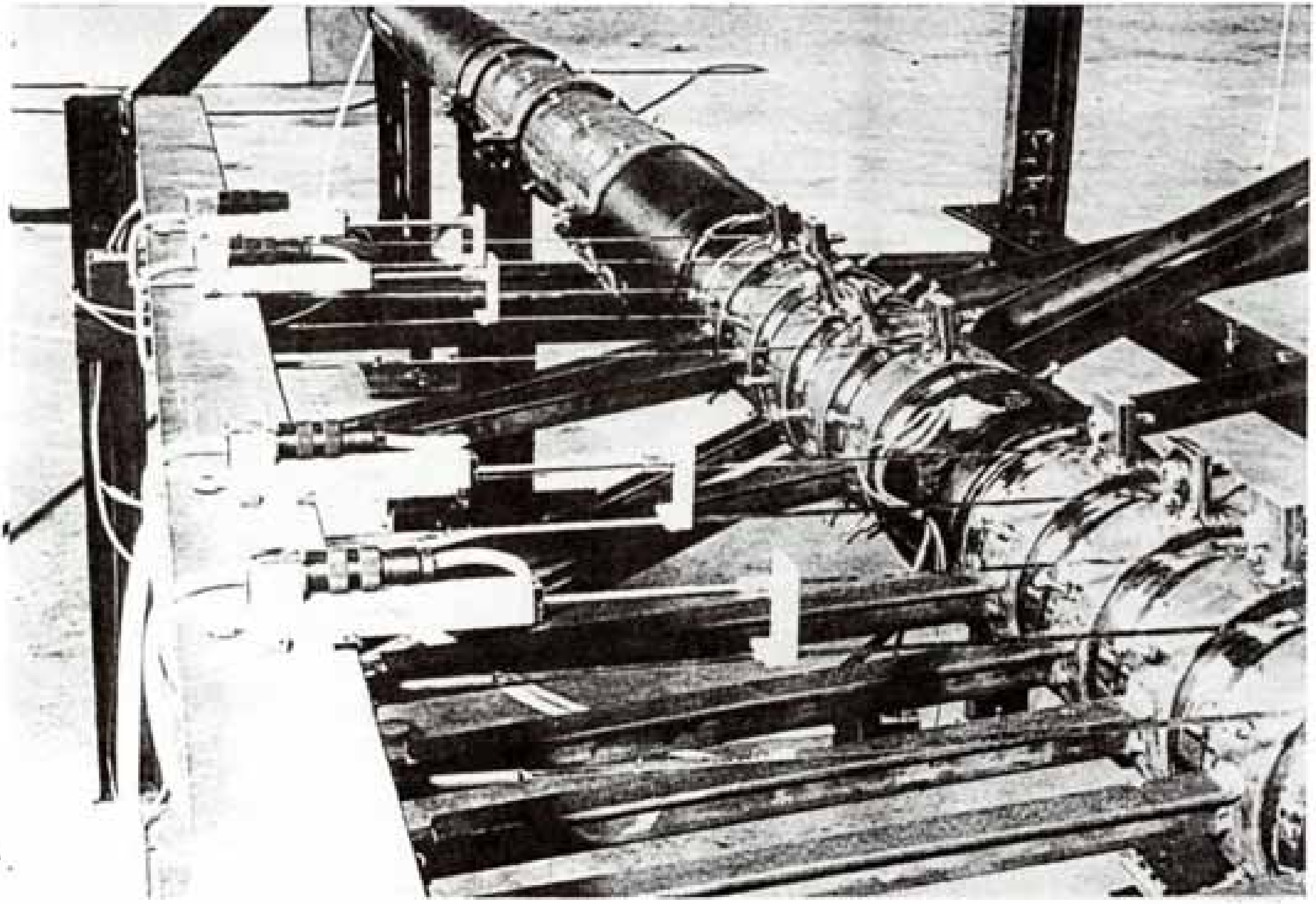


Bild 5

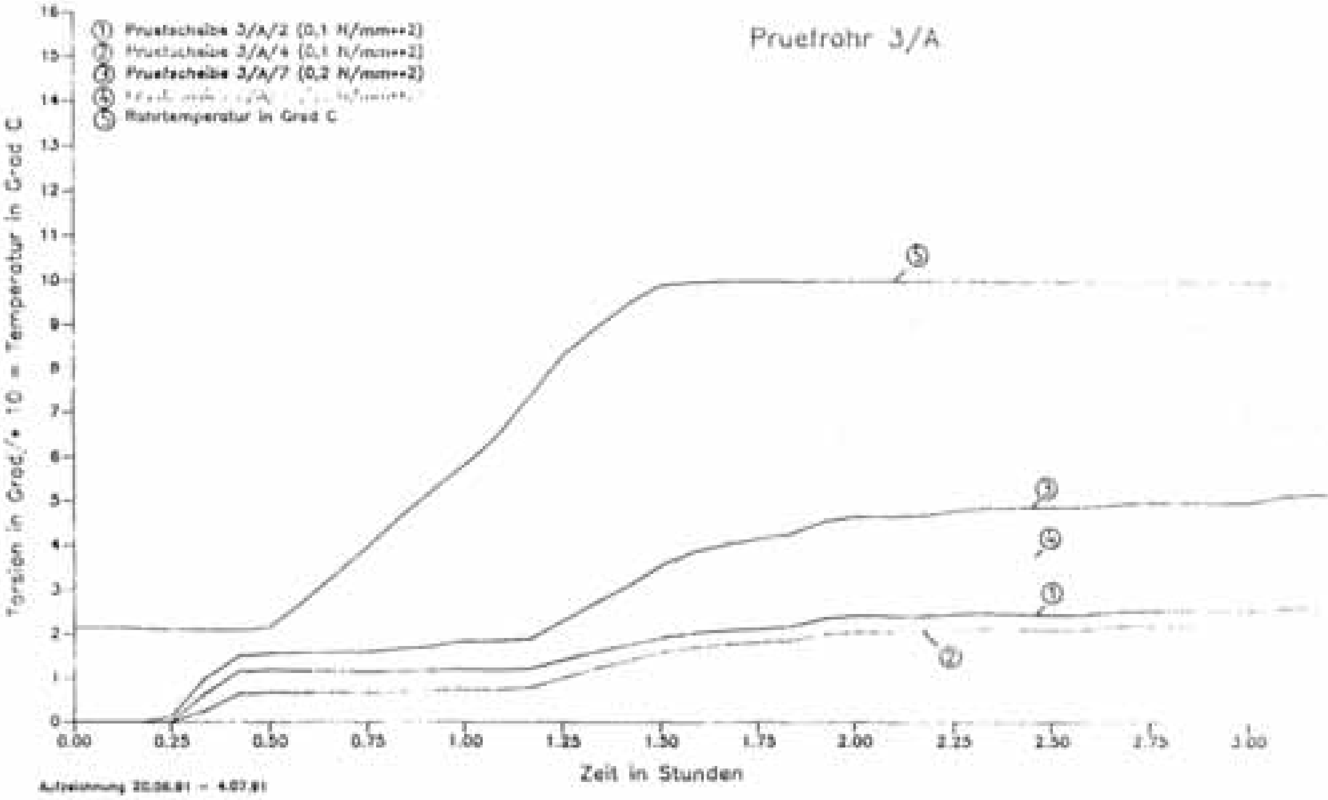


Bild 6 Prüfrohr 3/A. Kriechkurvenverlauf bei Aufbringung der Last und Aufheizen auf 100 °C.

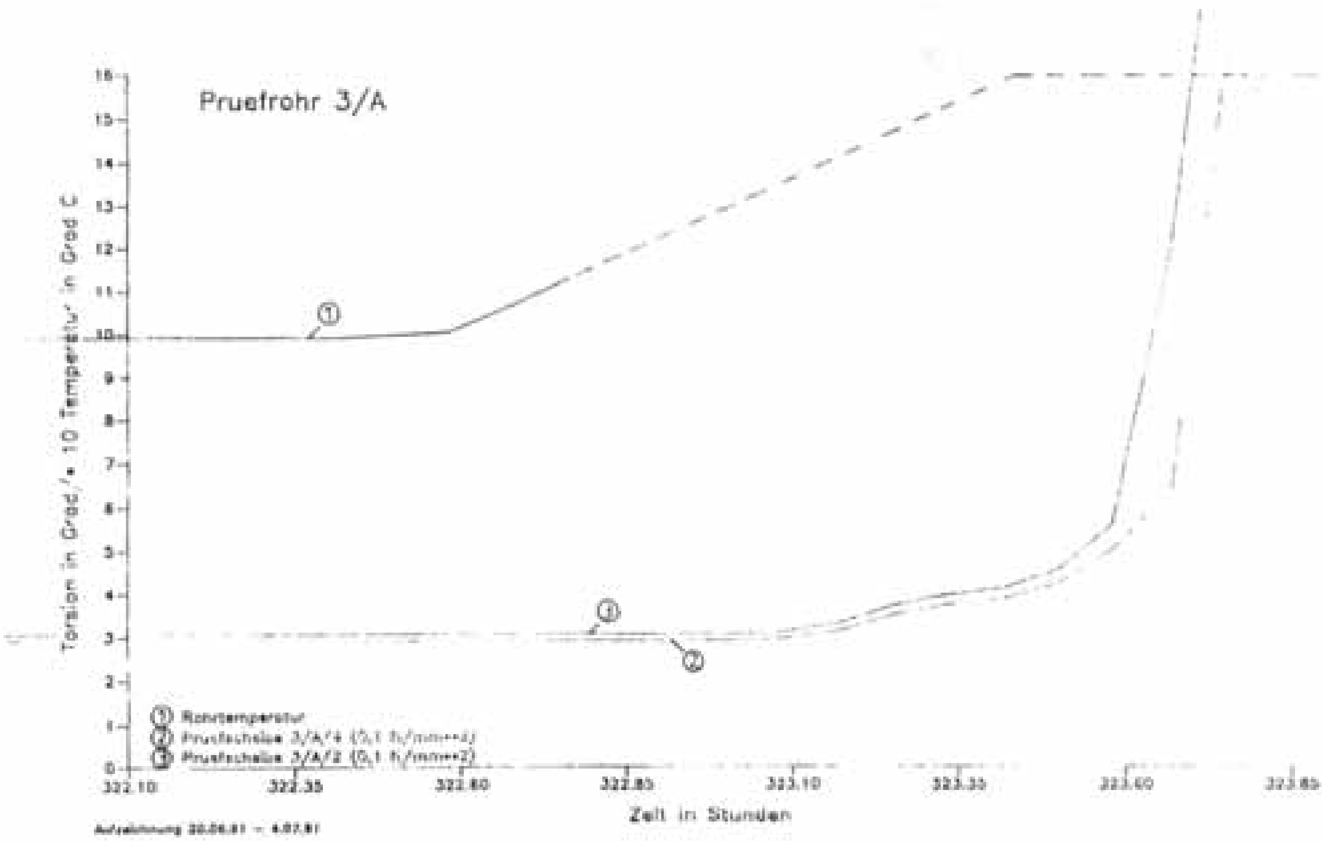


Bild 7 Prüfrohr 3/A. Kriechkurven bei Temperaturerhohung von 100 °C auf 160 °C. Versagen der Prüfscheiben 4 und 2 (0,1 N/mm²) kurz nach Erreichen der Temperatur von 160 °C.

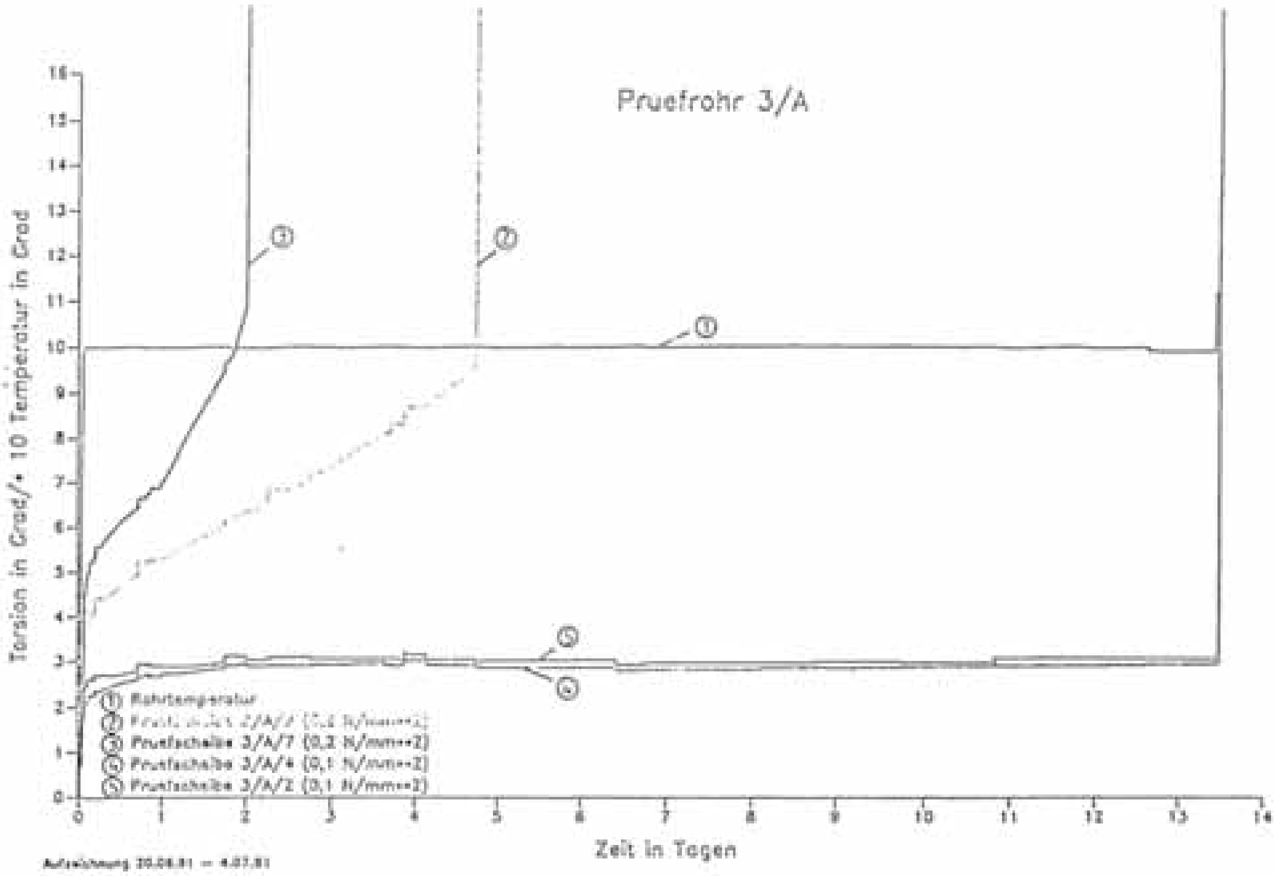


Bild 8 Prüfrohr 3/A. Verlauf der Kriechkurven über die gesamte Versuchszeit

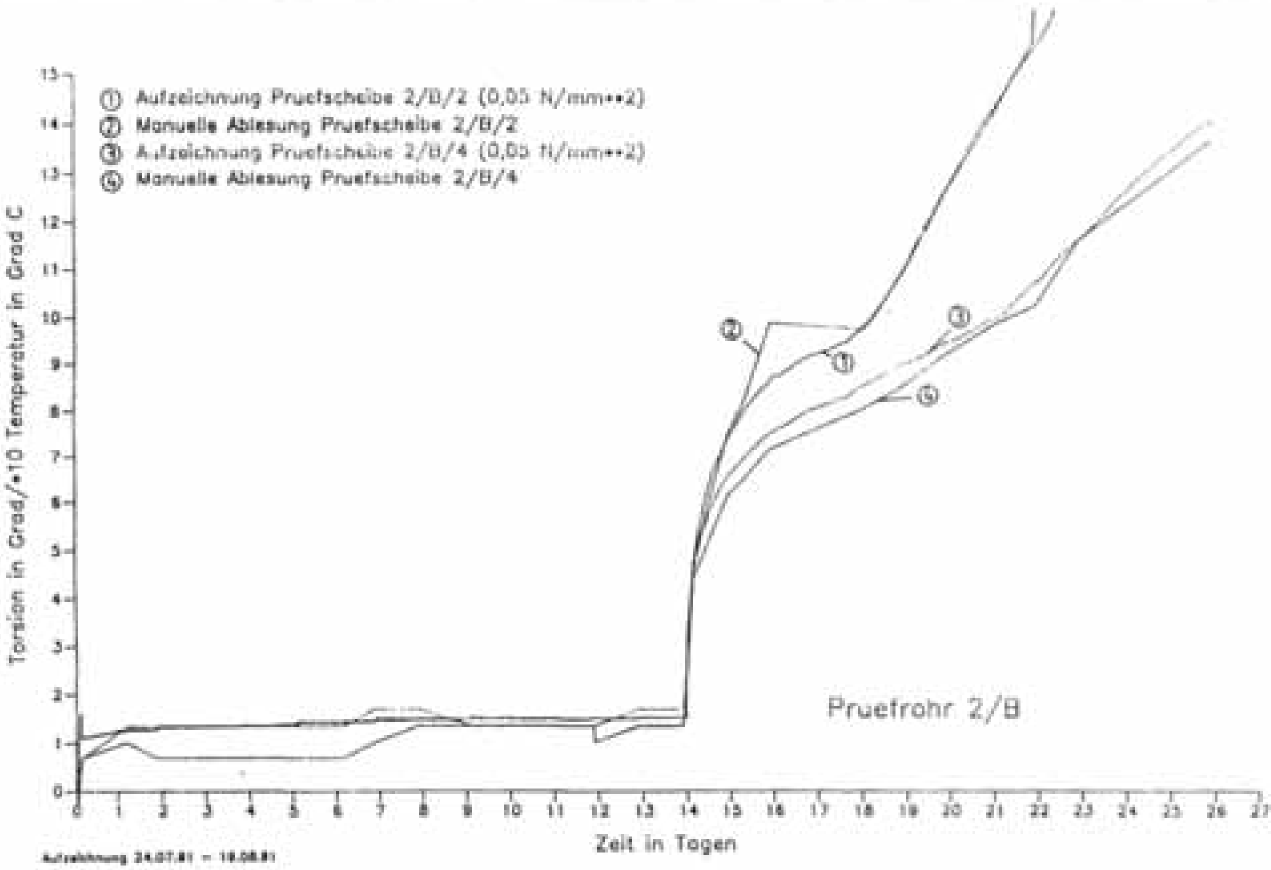


Bild 9 Prufrohr 2/B. Vergleich der manuell und der automatischen erfaßten Meßwerte für Prüfscheiben 2 und 4. Bei längerdauernden Veränderungen kann der Kurvenverlauf auch ohne automatisierte Aufzeichnung hinreichend genau erfaßt werden.

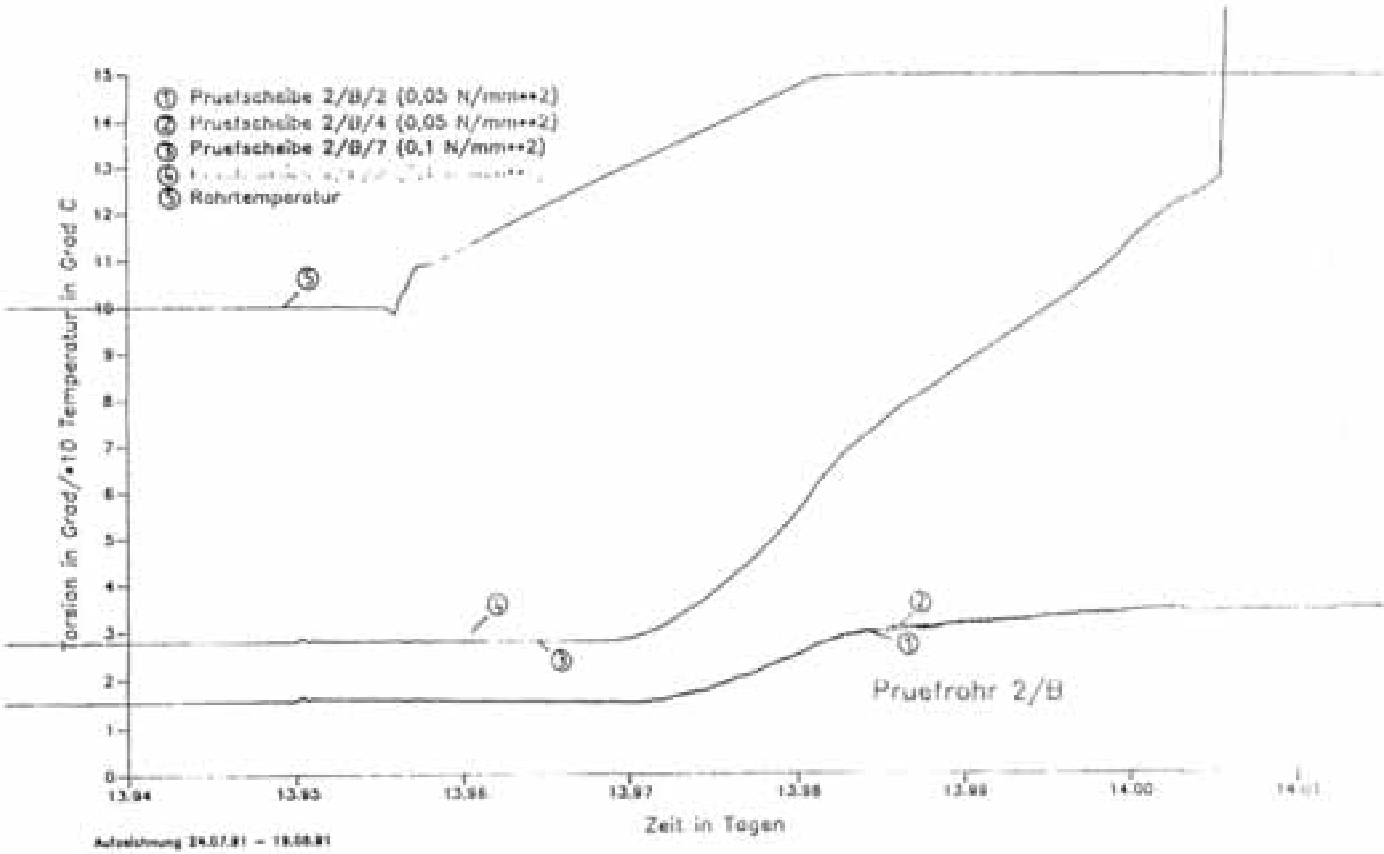


Bild 10 Prufrohr 2/B. Aufheizvorgang von 1 - 100 °C auf 1 - 150 °C. Versagen der Prufscheiben 7 und 9 (0,1 N/mm²) kurz nach dem Erreichen der Temperatur von 150 °C.

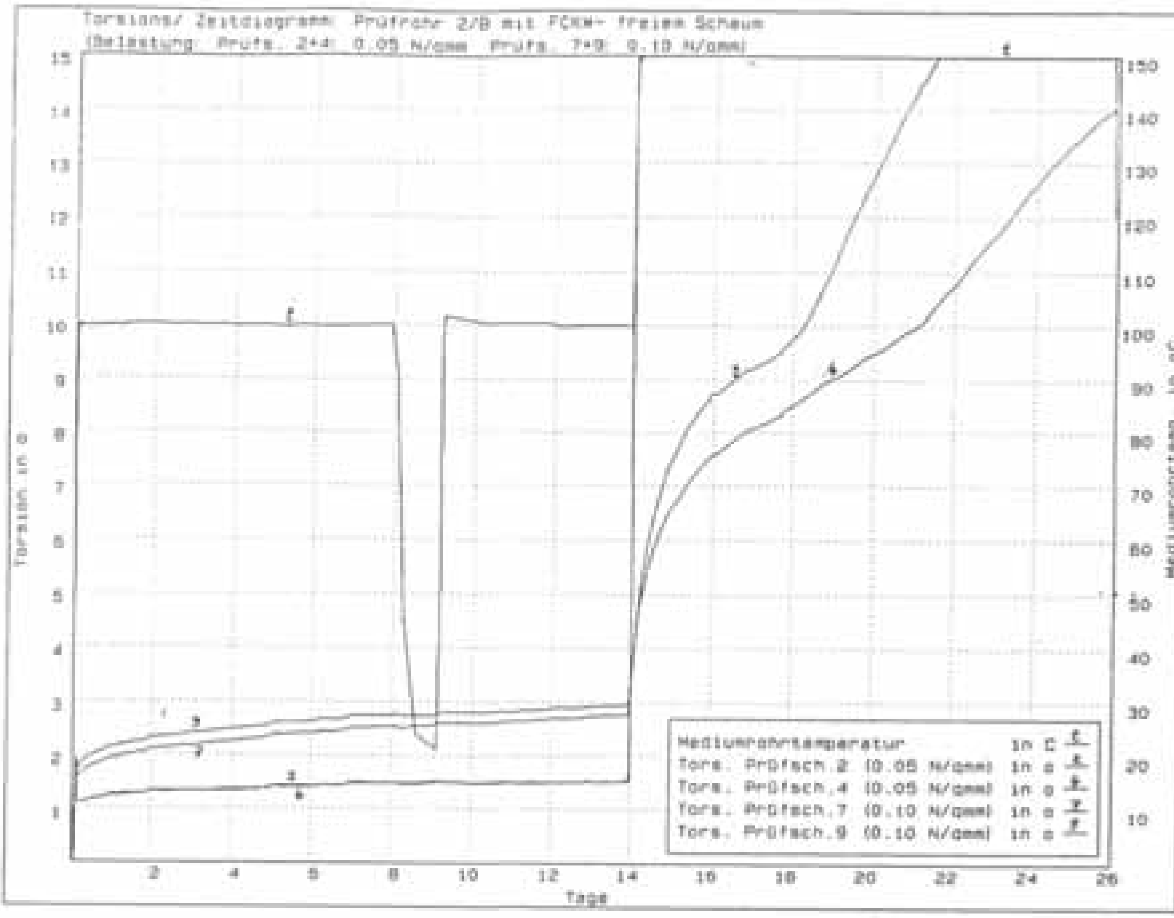


Bild 11 Prüfrohr 2/B. Verlauf der Kriechkurven über die gesamte Prüfzeit.

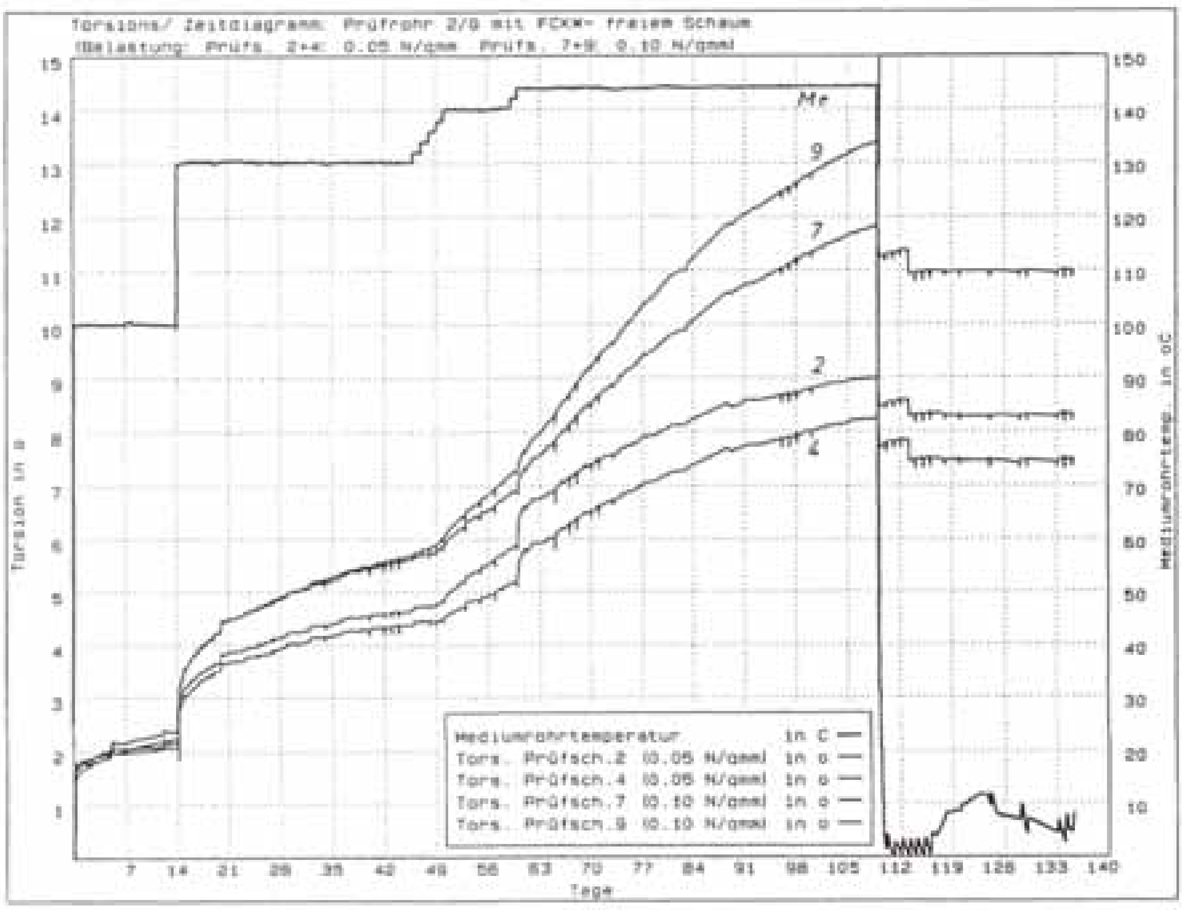


Bild 12 Prufrohr 2/G. Verlauf der Kriechkurven uber die gesamte Prufzeit.

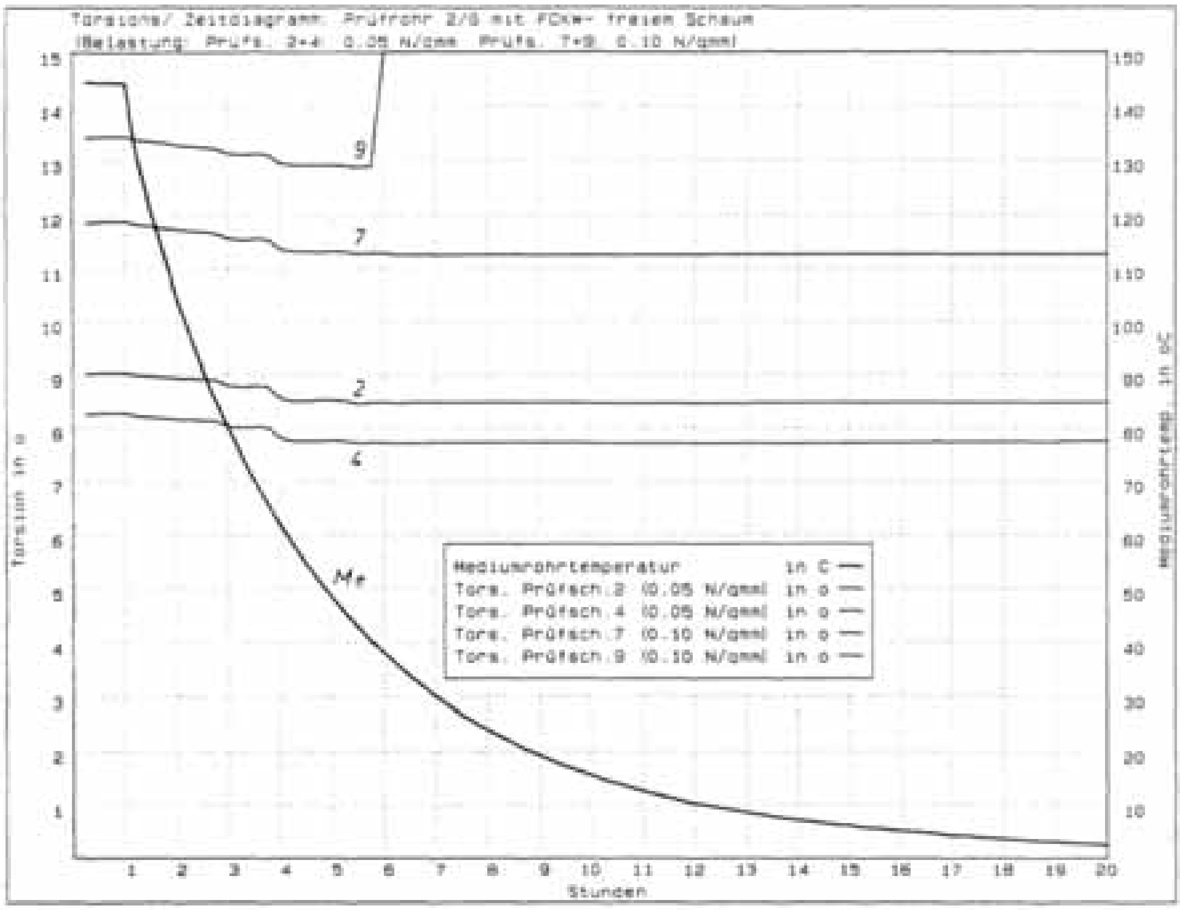


Bild 13 Prufrohr 2/G. Abschalten des Aufheizgerates nach 109 Tagen. Prufscheibe 9 versagt beim Abkuhlen nach 4,5 Stunden bei t - 41 °C.

APPENDIX 13

Vorliegende Ergebnisse: Neues R11-System von Stadtwerken Hannover

	Axiale Scherfestigkeiten								
	ungealtert τ_{ax} in ~~[MPa]~~ bei Prüftemperatur N/mm²			gealtert 170 °C / 1450 h τ_{ax} in ~~[MPa]~~ bei Prüftemperatur N/mm²			gealtert 160 °C / 3600 h τ_{ax} in ~~[MPa]~~ bei Prüftemperatur N/mm²		
	20 °C	130 °C	140 °C	20 °C	130 °C	140 °C	20 °C	130 °C	140 °C
Mindest-anforderung	0,12	0,12	0,12	0,12		0,08 (?)	0,12		0,08 (?)
FCKW 11	0,39	0,13	0,13	-	-	-	-	-	-
H-FCKW	>0,12	>0,12	>0,12	>0,12	>0,12	>0,12	>0,12	>0,12	>0,12
CO2	>0,12	>0,12	>0,12	≥0,12	>0,12	>0,12	<0,12	<0,12	<0,12

	Tangentiale Scherfestigkeiten								
	ungealtert τ_{tan} in ~~[MPa]~~ bei Prüftemperatur N/mm²			gealtert 170 °C / 1450 h τ_{tan} in ~~[MPa]~~ bei Prüftemperatur N/mm²			gealtert 160 °C / 3600 h τ_{tan} in ~~[MPa]~~ bei Prüftemperatur N/mm²		
	20 °C	130 °C	140 °C	20 °C	130 °C	140 °C	20 °C	130 °C	140 °C
Mindest-anforderung	0,20	0,20	0,20	0,20			0,20		
FCKW 11	0,51	0,24	0,23	-	-	-	-	-	-
H-FCKW	>0,2	>0,2	>0,2	>0,2	>0,2	>0,2	>0,2	>0,2	>0,2
CO2	>0,2	<0,2	<0,2	>0,2	>0,2	>0,2	>0,2	<0,2	<0,2

Klünder 26.2.92

~~Besier 18.9.1991~~

FCKW-freier PUR-Hartschaum in Kunststoff-Mantelrohren

AGFW

Vorliegende Ergebnisse: Bisheriges R11-System

	Axiale Scherfestigkeiten								
	ungealtert τ_{ax} in ~~[MPa]~~ bei Prüftemperatur N/mm^2			gealtert 170 °C / 1400 h τ_{ax} in ~~[MPa]~~ bei Prüftemperatur N/mm^2			gealtert 160 °C / 3600 h τ_{ax} in ~~[MPa]~~ bei Prüftemperatur N/mm^2		
	20 °C	130 °C	140 °C	20 °C	130 °C	140 °C	20 °C	130 °C	140 °C
Mindest-anforderung	0,12	0,12	0,12	0,12		0,08 (?)	0,12		0,08 (?)
FCKW 11	0,36	0,09	0,08	0,17 -	0,19 -	0,13 -	-	-	-
H-FCKW	>0,22	>0,12	>0,12	>0,12	>0,12	>0,12	>0,12 -	>0,12	>0,12
CO2	>0,12	>0,12	>0,12	>0,12	>0,12	>0,12	<0,12	<0,12	<0,12

	Tangentiale Scherfestigkeiten								
	ungealtert τ_{tan} in ~~[MPa]~~ bei Prüftemperatur N/mm^2			gealtert 170 °C / 1400 h τ_{tan} in ~~[MPa]~~ bei Prüftemperatur N/mm^2			gealtert 160 °C / 3600 h τ_{tan} in ~~[MPa]~~ bei Prüftemperatur N/mm^2		
	20 °C	130 °C	140 °C	20 °C	130 °C	140 °C	20 °C	130 °C	140 °C
Mindest-anforderung	0,20	0,20	0,20	0,20			0,20		
FCKW 11	0,46 -	0,15 -	0,15 -	0,39 -	0,33 -	0,32 -	-	-	-
H-FCKW	>0,2 -	>0,2	>0,2 -	>0,2 -	>0,2 -	>0,2 -	>0,2 -	>0,2 :	>0,2 :
CO2	>0,2 -	<0,2	<0,2	>0,2 -	>0,2 -	>0,2 -	>0,2 :	<0,2 :	<0,2

KLüncler 26.2.92 ~~Besier 16.9.1991~~	FCKW-freier PUR-Hartschaum in Kunststoff-Mantelrohren	AGFW

APPENDIX 14

APPENDIX 14

Radial Creep Behaviour of PUR-cellular plastic in pre-insulated pipes (DTI, Denmark)

This research project is simliar to the radial creep rupture pressure tests carried out by FN Dinslaken, GEW Köln and GEF at the RWTÜV. The tests refer to pipes with two different reference foams:

FEBIS I (CFC-11 blown)
FEBIS II (CO_2-blown)

Aim of the project is the development of a test method for measuring the radial creep behaviour of PUR foamed plastic jacket pipes. On this occasion the creep behaviour of both reference foams is documented on a broad stastic basis.

Test temperature will be 90°C, 110°C, 130°C and 150°C.
Test loads will be 0.05 MPa, 0.15 MPa, 0.25 MPa and 0.35 MPa.
Test pipes are da/Da = 60.3 mm/125 mm.

Investigations are divided into 3 steps:

a) Preliminary Tests
Aim of the preliminary tests is to determine the optimum sizes of the samples as well as the general conditions for the test. In detail it will have to be investigated:

- optimum width of the specimen

In order to be able to carry out rational tests an interior heatable pipe bar is divided into several specimen segments. If at this point only the jacket pipe is cut through, the lateral supporting effect of the foam can be maintained, although different test loads laying next to each other have a mutual influence. Cutting through also the foam inbetween the single specimens down to the medium pipe a mechanic de-coupling is reached, but the lateral support effect of the foam is lost and a diffusion lining becomes more difficult.

For the present study the foam samples are cut down to the medium pipe. That is why a minimum width has to be determined for the test, under which the lateral buckling and therewith the missing lateral support effect does not play an important role anymore. This has to be calculated with the help of FEM-calculations.

- Avoiding unacceptable diffusion of oxygen

  In case of stress-rupture tests with PUR-foams the measuring result might be vitiated, so that it is most important that inadmissible diffusion of oxygen is avoided. Especially the CO_2 cell gas tends to diffuse quickly.

  The preliminary tests serve to find out, if the diffusion can be impeded sufficiently by a diffusion lining or if the tests will have to be carried out under CO_2-atmosphere (rinsing).

- Load Deposit

  First, the actual load distribution on the earth-bedded plastic jacket pipes is determined with the help of a FEM-calculation, so that afterwards the mechanic loads may be distributed in a realistic manner. Tempering of the pipes is done from the interior with the help of thermo oil.

b) Reference Tests

Regarding time and costs factors not all of the possible combinations of testing voltages and temperatures can be carried through as long-time tests.

At least for one testing temperature, i.e. probably 130° C, the 4 testing voltages should act on both of the reference foams for the minimum period of 1 year.

On one hand it is not very probable that the foam's creep behaviour decays under temperature and load, on the other hand the long-term effects, like those which occured with the green TARCO-foam during the TÜV-test also have to be registered.

c) Main tests

Main tests comprise all possible combinations of loads and temperatures. Each combination of testing voltage and temperatures is repeated 5 times in order to allow a statistical evaluation. The total program comprises 160 tests. In order to observe the time as well as the cost factors, the tests are interrupted after 1000 hours by the latest, i.e. if a hubbing of 20% of the insulating thickness has not been reached until then.

The foams's thickness is measured at the intermediary pieces. At the same time TMA-investigations are carried through. The results are imitated for FEM-calculations.

Titel:

Einfluß halogenfreier PUR-Isolierungen auf das Langzeitverhalten von Kunststoffmantelrohren

Beginn:	voraussichtliches Ende:
07/91	12/92

Projektvorschlag/Projektbearbeitung durch:

Institut für Materialforschung und Anwendungstechnik GmbH Dresden
Fernwärme-Forschungsinstitut in Hannover e. V.

Ziel:

Ermittelt wird das Temperatur-Zeitverhalten für die mechanischen und thermischen Eigenschaften der PUR-Dämmschicht und insbesondere für die Festigkeit des Verbundes zwischen Stahlrohr und Deckschicht. Die bekannten Methoden für die Abschätzung der Lebensdauer frongeschäumter Kunststoffmantelrohre sind auf ihre Anwendbarkeit für die neuen Schaumsysteme zu überprüfen und falls erforderlich, weiterzuentwickeln.

Parameter:

- Alterungstemperaturen von 140...170 °C
- Prüfzeiten, Prüftemperaturen, Prüfmethoden

Einflußgrößen:

Diffusion, Herstelltechnologie

Probenform:

Rohre DN50/160 und Prüfkörper

vorgeschlagene Systeme:

R11- und CO_2-Referenzschaumsysteme

Kosten:	Finanzierung durch:
400.000 DM	Arbeitsgemeinschaft industrieller Forschungsvereinigungen

Bemerkungen:

Die MPA wird sich an den Arbeiten beteiligen.

APPENDIX 16

Enclosure 2 1992-02-18

Forschungsprojekte zum Thema "Neue Schäume für KMR" Stand Februar 1992

Titel:

Creep properties. Radial creep

Beginn:
1992-03-01

voraussichtliches Ende:
1993-12-31

Projektvorschlag/Projektbearbeitung durch:

Chalmers University of Technology
Gothenburg, Sweden
Swedish National testing and Research Institute
Gothenburg, Sweden

Ziel:

Test equipment and test procedure to evaluate the creep data for polyurethane foam have been developed in an earlier project. By using this knowledge the creep data of PUR-foam will be investigated. Influence of gas type and cellular size as well as temperature dependence will be considered.

Parameter:

Temperature: 23, 100, 120, 140, 160°C
Load: 50, 100 kPa
Type of foam: FEBIS-CFC11, FEBIS-CO_2, CO_2, HCFC

Einflußgrößen:

Blowing agent CFC11, CO_2, HCFC;s
Cellular size and structure

Probenform:

Test samples of PUR-material taken from district heating pipes.
Dimensions 50x50x25 mm^3

vorgeschlagene Systeme:

Kosten:
105 000 ECU

Finanzierung durch:
40% NUTEK
60% open

Bemerkungen:

This project will be carried at Chalmers University of Technology, Swedish National Testing and Research Institute and in close contact with Danish testing Institute (DTI), where radial creep on pipe samples are to be tested.

APPENDIX 17

Enclosure 3 1992-02-18

Forschungsprojekte zum Thema "Neue Schäume für KMR" Stand Februar 1992

Titel:

Creep properties, Axial creep

Beginn: **voraussichtliches Ende:**

Part 1:	1992-09-01	1993-03-31
Part 2:	1993-04-01	1993-12-31

Projektvorschlag/Projektbearbeitung durch:

Chalmers University of Technology
Gothenburg, Sweden
Swedish National Testing and Research Institute
Gothenburg, Sweden

Ziel:

Part 1: To develop test procedure and test equipment to evaluate the creep properties for polyurethane foam exposed to axial shear forces.

Part 2: Measuring the axial creep and its dependence on temperatures, loads and cell structures.

Parameter:

Temperature: 23, 100, 120, 140, 160°C
Load: 40, 80 kPa
Type of foam: FEBIS-CFC11, FEBIS-CO_2, CO_2, HCFC

Einflußgrößen:

Blowing agent CFC11, CO_2, HCFC;s
Cellular size and structure

Probenform:

Test samples of PUR-material taken from district heating pipes.

---

vorgeschlagene Systeme:

Kosten: **Finanzierung durch:**

Part 1: 30 000 ECU	Part I: NUTEK
Part II: 80 000 ECU	Part II: open

Bemerkungen:

APPENDIX 18

Enclosure 4 1992-02-18

Forschungsprojekte zum Thema "Neue Schäume für KMR" Stand Februar 1992

Titel:
Model for creep behavior. FEM analysis.

Beginn:
1992-03-01

voraussichtliches Ende:
1992-09-30

Projektvorschlag/Projektbearbeitung durch:
Chalmers University of Technology
Gothenburg, Sweden

Ziel:
To simulate radial creep on district heating pipes by using FEM-model. Different models will be implemented and evaluated. The simulations will be compared with experimental results obtained at Chalmers University of Technology, Swedish National Testing and Research Institute and Danish Testing Institute.

Parameter:
Creep behavior at operating temperatures and for appropriate loads.

Einflußgrößen:

Probenform:
Theoretical analysis

vorgeschlagene Systeme:

Kosten:
26 000 ECU

Finanzierung durch:
Chalmers University of Technology

Bemerkungen:

APPENDIX 19

Enclosure 5 1992-02-18

Forschungsprojekte zum Thema "Neue Schäume für KMR" Stand Februar 1992

Titel:

Thermal conductivity and ageing of polyurethane foam.
Diffusion of gases through cell walls and through surface materials.

Beginn:
1991-01-01

voraussichtliches Ende:
1993-12-31

Projektvorschlag/Projektbearbeitung durch:

Chalmers University of Technology
Division of Building Technology
Chemical Environmental Science
Gothenburg, Sweden

Ziel:

The aim of the project is to form and maintain a group of scientists with an interdisciplinary quality in order to study CFC-free polyurethane foams. Basic studies of heat transfer and gas diffusion are vital to understand the mechanism, that influences the ageing of the foam with respect of thermal conductivity.

Parameter:

Gas mixtures CFC11, CO_2, HCFC;s and mixtures
Time
Temperatures
Surface materials

Einflußgrößen:

Probenform:

Pipe samples, sheets of PUR-material.

vorgeschlagene Systeme:

Kosten:
400 000 ECU

Finanzierung durch:
NUTEK

Bemerkungen:

APPENDIX 20

Anlage 1

Ausschreibung für tangentiale Scher-Kriechversuche an Kunststoff-Mantelrohren

Mit Schreiben vom 03.04.1992 wurden folgende Prüfinstitute zur Abgabe eines Angebots aufgefordert:

AMPA, Hannover	(D)
Chalmers University of Technology, Göteborg	(S)
DTI, Aarhus	(DK)
EMPA, Dübendorf	(CH)
FFI, Hannover	(D)
IKP, Stuttgart	(D)
IMA, Dresden	(D)
KEMA, Arnheim	(NL)
National Testing Institute, Göteborg	(S)
Studsvik	(S)
University of Technology, Lappenranta	(SF)

Be / 3.4.1992

Rahmenkonzept für die Untersuchung von KMR durch tangentiale Scher-Kriechversuche

- Entwurf -

1. Allgemeines

Um die FCKW-freien PUR-Hartschaumsysteme in KMR auch hinsichtlich ihres Scher- und Kriechverhaltens beurteilen zu können, ist es notwendig tangentiale Scher-Kriechversuche durchzuführen. Das Ziel der tangentialen Scher-Kriechversuche ist, in Abstimmung mit weiteren parallel laufenden Untersuchungen, ein treibmittelunabhängiges und normungsfähiges Prüfkonzept für die "neuen" Schaumsysteme zu entwickeln.

Die Untersuchungen sind an Probekörpern durchzuführen, die aus bereitgestellten KMR herzustellen sind. Diese KMR enthalten PUR-Hartschäume, die als sogenannte "Referenz"-Schaumsysteme die bisherigen FCKW11-geblähten und die "neuen" CO_2-geblähten Schaumsysteme repräsentieren. Die "Referenz"-Schaumsysteme wurden von den Schaumherstellern Bayer, Elastogran und Shell gemeinsam für die - im Rahmen der Erarbeitung von Prüfkonzepten zum Nachweis der Eignungsfähigkeit - notwendigen Untersuchungen erarbeitet.

Die quantitativen Ergebnisse der Untersuchungen der "Referenz"-Schaumsysteme sind dabei von sekundärem Interesse, da diese Formulierungen nicht in dem Maße optimiert werden konnten, wie dies bei den am Markt angebotenen Produkten der Fall ist.

Der Endtermin der Untersuchungen ist September 1993.

Die im Rahmen der nachfolgend beschriebenen Untersuchung durchzuführenden Arbeiten sind nach bestem Wissen und dem aktuellen Stand der Technik bzw. der diesbezüglichen Fachdiskussion auszuführen. Eine enge Abstimmung mit weiteren an der Gesamtproblematik arbeitenden Prüfinstituten und Fachleuten ist hinsichtlich des sich rasch weiterentwickelnden Erkenntnisstandes zu gewährleisten.

Als Auftraggeber der tangentialen Scher-Kriechversuche ist nach einer Auftragsvergabe die

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Die Koordination der Untersuchungen sowie die Bewertung der Ergebnisse wird von der europäischen Projektgruppe "Koordination / Controlling FCKW-freier Schaumsysteme in KMR" durchgeführt.

Die unter den Punkten 2 und 3 beschriebenen Einzelheiten zu den tangentialen Scher-Kriechversuchen beruhen auf Beschlüssen der o.g. europäischen Projektgruppe und zeigen das Rahmenkonzept dieser Untersuchungen auf. Die zur Abgabe von Angeboten aufgeforderten Prüfinstitute haben neben einer Referenzliste ähnlicher bzw. vergleichbarer in der Vergangenheit durchgeführter Untersuchungen und der Angabe der unter Punkt 4 näher zu untergliedernden Kosten auch ein detailliertes Untersuchungskonzept vorzulegen, das u.a. folgende Punkte enthält:

- zeitlicher Ablauf
- Versuchsaufbau
- Versuchsdurchführung
- Anzahl der benötigten KMR
- Dokumentation
- Auswertung der Ergebnisse und deren Interpretation im Rahmen der Gesamtproblematik

Der Auftragnehmer hat für die Dauer der Untersuchungen namentlich einen verantwortlichen Untersuchungsleiter zu benennen.

2. Versuchsbedingungen

2.1 Versuchsaufbau

Alle Untersuchungen am CO_2-"Referenz"-Schaumsystem sind unter einer CO_2-Athmosphäre, die in Form einer permanenten Spülung auszuführen ist, durchzuführen.
Bei den Untersuchungen des FCKW11-"Referenz"-Schaumsystemes genügt eine Abdichtung der offenen Schaumendbereiche.

Dem Angebot ist seitens des Anbieters der für die Untersuchungen gedachte Versuchsaufbau in Form von Skizzen und mit einer Beschreibung beizulegen.

Insbesondere sollten diese Informationen Aufschluß über die Realisierung der Prüfathmosphäre, die Erwärmung der Mediumrohre, die Reduzierung des Einflusses der Wärmestrahlung der Mediumrohre auf die Stirnseiten der Wärmedämmung, die Aufbringung der tangentialen Beanspruchung und der Meßwertaufnahme geben.
(In der Anlage zu diesem Rahmenkonzept haben wir Ihnen beispielhaft eine Beschreibung eines nicht mehr vorhandenen Versuchsstand von TWS Stuttgart beigefügt.)

Der Auftraggeber erhält alle Rechte am Versuchsaufbau. Dies betrifft insbesondere die Art und Weise der konstruktiven Ausbildung und die Versuchsdurchführung.

2.2 Versuchsdurchführung

2.2.1 Herstellen der Prüflinge

Die zu untersuchenden und bezüglich der darin enthaltenen Schaumsysteme (je ein FCKW11- und CO2-geblähtes Schaumsystem) gekennzeichneten Untersuchungsobjekte (KMR) werden für die Untersuchungen zur Verfügung gestellt.
Abmessungen: DN ~~80~~ 50 / 125, Länge 6 m (nach EN 253 - 2. Draft revision; 1991-04-25)

Aus den angelieferten KMR sind Prüflinge für die tangentialen Scher-Kriechversuche nach EN 253, 2. Draft revision (1991-04-25), herzustellen. Dabei ist darauf zu achten, das die herzustellenden Prüflinge zur weitgehenden Reduzierung von Diffusionsvorgängen nicht unnötig lange ungeschützt der Umgebungsathmosphäre (Luft) ausgesetzt werden.

2.2.2 Durchzuführende Untersuchungen

An den angelieferten KMR sind folgende Eigenschaftswerte im ungealterten Zustand nach EN 253 zu ermitteln:

- Zellstruktur
- Kernrohdichte
- Gesamtrohdichte
- Druckfestigkeit
- Wasseraufnahme

Die tangentialen Kriech-Scherversuche sind über die gesamte Versuchsdauer bei gleichbleibenden Versuchsparametern (thermische und mechanische Belastung) durchzuführen. Als Umgebungstemperatur wird - wie in EN 253 - Raumtemperatur festgelegt.
Während der Versuchsdurchführung sind dauerhaft die zeitabhängigen Kriechverformungen bzw. das Versagen des Verbund-Rohrsystems zu erfassen und in geeigneter Form darzustellen. Die entsprechenen Prüfathmosphären, wie in Kapitel 2.1 vorgegeben, sind einzuhalten.

Der Umfang der Untersuchungen pro Schaumsystem ergibt sich aus den nachfolgend aufgeführten Kombinationen der Parameter "Temperatur" und "Tangentiale Scherbeanspruchung":

Temperatur:	T = 90, 110, 130 und 150°C (Die Temperatur ist an der Oberfläche des Mediumrohres zu messen. Die zulässige Abweichung während der Untersuchungen beträgt ±0,5 °C.)
Tangentiale Scherbeanspruchung:	τ_t = 0,02; 0,04; 0,08; 0,16 N/mm^2 (Als tangentiale Scherspannung gilt die an der Oberfläche des Mediumrohres auftretende Beanspruchung.)

Die Prüftemperatur sollte ausgehend von der Raumtemperatur nach 30 Minuten erreicht sein und weitere 30 Minuten beibehalten werden, bevor die tangentiale Scherbeanspruchung stoßfrei und zügig aufgebracht wird.
Die Versuchszeit beginnt mit der Aufbringung der tangentialen Scherbeanspruchung.

Alle Kombinationen aus "Temperatur" und "tangentialer Scherbeanspruchung" sind mindestens fünfmal zu wiederholen, damit ein Minimum an statistischer Absicherung gewährleistet werden kann.
Die einzelnen Untersuchungen sollten über einen Zeitraum von 1000 h durchgeführt werden. Die Versuche sind beendet, wenn die Verbundwirkung des KMR versagt.
Ausgewählte Parameterkombinationen (nach Abstimmung mit anderen Untersuchungsprogrammen) sollten hinsichtlich einer besseren Zeitstandprognose über einen Zeitraum von einem Jahr laufen.

Vor Beginn der Untersuchungen ist seitens des Auftragnehmers ein detaillierter Untersuchungsplan - mit wesentlichen für den Aufbau, den zeitlichen Ablauf und die Durchführung der Untersuchung relevanten Informationen - vorzulegenden, der von der AGFW (in Abstimmung mit der europäischen Projektgruppe) genehmigt werden muß.
Dieser Untersuchungsplan enthält - nach Festlegung zwischen den Vertragspartnern - Kriterien bzw. "Meilensteine", zu denen ein schriftlicher Zwischenbericht vorzulegen ist und vom Auftraggeber hinsichtlich der Ergebnisse und der Einhaltung des Terminplanes bewertet wird. Der Auftraggeber entscheidet nach Erreichen der "Meilensteine" über die Art und Weise der weiteren Fortführung der Untersuchungen.

2.2.3 Dokumentation der Meßergebnisse

Die Aufzeichnung der Meßergebnisse ist versuchsbegleitend durchzuführen und dauerhaft zu dokumentieren. Die Dokumentation der Meßergebnisse sollte auf elektronischen Datenträgern erfolgen (ASCII-Code), um diese gegebenenfalls in einem mathematischen Modell - mit den Ergebnissen aus weiteren Untersuchungsprogrammen - korrellieren zu können.

3. Auswertung und Dokumentation der gesamten Untersuchung

3.1 Zwischenberichte

Wie unter Punkt 2.2.2 ausgeführt, sind Zwischenberichte anzufertigen und diese in schriftlicher Form dem Auftraggeber auszuhändigen.

In den Zwischenberichten sind die bis zu diesem Zeitpunkt erarbeiteten Ergebnisse auszuwerten und hinsichtlich der weiteren Versuchsdurchführung zu bewerten. Der Auftragnehmer ist verpflichtet, die aus seiner Sicht erkennbaren Probleme deutlich zu formulieren und dem Auftraggeber Verbesserungsvorschläge für die weitere Bearbeitung zu unterbreiten. Dazu ist in enger Abstimmung mit anderen relevanten Untersuchungen und Erkenntnissen vor allem die Auswirkung auf die Gesamtproblematik - Gebrauchstauglichkeit von KMR mit FCKW-freien Schaumsystemen - zu bewerten.

3.2 Abschlußbericht

Nach Beendigung der Untersuchungen ist ein schriftlicher Abschlußbericht anzufertigen, der Aufschluß über die gesamte Untersuchung gibt.

Der Abschlußbericht ist dem Auftraggeber vorzulegen und muß von diesem, nach einer Bewertung, schriftlich genehmigt werden.

3.2 Präsentation der Ergebnisse

Der Auftragnehmer ist verpflichtet, auf Wunsch des Auftraggebers diesem oder von ihm zu benennenden Personen jederzeit die Möglichkeit zu geben, sich am Ort der Untersuchungen über den Stand derselben zu informieren.
Der Auftragnehmer steht darüber hinaus in terminlicher Abstimmung mit dem Auftraggeber für Präsentationen und Diskussionen des Versuchsstandes, der Zwischen- und Endergebnisse etc. vor einem vom Auftraggeber festzulegenden Kreis von Fachleuten zur Verfügung.

3.3 Verfügbarkeit über die Ergebnisse

Für die Veröffentlichung von Ergebnissen bzw. Zwischenberichten (auch auszugsweise) ist die Zustimmung des Auftraggebers einzuholen.

4. Vergütung der erbrachten Leistungen

Leistungen seitens des Auftragnehmers können dem Auftraggeber nur dann in Rechnung gestellt werden, wenn diese in schriftlicher Form als Auftrag (bzw. Auftragserweiterung) vereinbart wurden.

Im Rahmen der gesamten Untersuchung kann der Auftragnehmer seine bis zum Zeitpunkt der Rechnungsstellung erbrachten Leistungen in Rechnung stellen. Der Nachweis der erbrachten Leistungen ist in Form eines Zwischenberichtes zu dokumentieren und dem Auftraggeber auszuhändigen. Die Beurteilung der erbrachten Leistungen erfolgt nach der unter Punkt 1 ausgeführten Vorgehensweise.

Werden im Rahmen der Versuchsdurchführungen Mehrleistungen des Auftragnehmers ersichtlich, die aufgrund nicht vom Auftragnehmer zu verantwortender Gründe autreten, sind diese unverzüglich in schriftlicher Form dem Auftraggeber bekanntzugeben. Eine Vergütung von Mehrleistungen kann nur dann erfolgen, wenn diese vom Auftraggeber in schriftlicher Form bestätigt werden.

5. Verrechnungssätze für die zu erbringenden Leistungen

Gemäß des unter Punkt 1 - 4 beschriebenen Leistungsumfanges für tangentiale Scher-Kriechversuche werden die zur Abgabe eines Angebotes aufgeforderten Prüfinstitute gebeten, ihren finanziellen Leistungsumfang wie nachfolgend aufgeführt, anzugeben.

Weitere Kosten, die im Umfang dieses Rahmenkonzeptes enthalten sind, sind in den nachfolgend aufgeführten Positionen zu berücksichtigen und können nach einem eventuellen Vertragsabschluß nicht gesondert in Rechnung gestellt werden (z.B. Personalkosten, Reisekosten, Berichte, Präsentationen etc.).

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