Straight Preinsulated Bonded Pipes

Quality Tests on Preinsulated Bonded Pipe System Components

Following the decision of the German District Heating Association (AGFW) to perform an annual quality test on preinsulated bonded pipe system components, the corresponding activities were initiated for the first time in 2006/2007 as commissioned by the AGFW. Straight preinsulated bonded district heating pipes were tested at the District Heating Institute in Hanover in this first round of tests. The results of 8 of the 9 pipe systems tested were rated as »good« to »satisfactory«.

To determine the quality of straight preinsulated bonded district heating pipes, samples of pipes were taken in 2006 from project-specific deliveries. The tests on these randomly selected system components are sampling tests.

1 Quality Management and Quality Assurance

For the most part the quality of delivered preinsulated bonded pipe system components (e.g. pipes, fittings and underground valves) can only be visually inspected as part of project-parallel quality assurance activities. Mechanical-technological tests with incoming goods and on building sites are quick tests and only enable limited conclusions to be drawn on long-time suitability. Inspections to define the minimum requirements for materials and bonding properties can only be performed in appropriately equipped test labs.

AFGW guideline FW 401 proposes to use only preinsulated bonded pipe system components with proof of a type test. It is assumed here that all requirements of the product standards, EN 253, 448, 488, 489 and 14419 are met. To date there has not been any requirement to repeat type tests at specific intervals; if no significant product changes are made, the type test does not have to be repeated.

With the certificates presented by the manufacturers, however, usually only a limited amount of all requirements are verified. The results of trials that last longer in particular, and are therefore more expensive, are only presented in a few cases. Various tests at various test institutes will also be commissioned, and then the customer or network operator will not be able to retrace to find out if pipes from the same batch were tested at the test institutes. It is often impossible to retrace the initial values that the pipes had. Only specialists that have experience or are involved in the product standards and the corresponding expert discussions can to some degree evaluate the certificates presented using type tests, etc.

The tests defined for quality assurance in the informative addenda to EN 253 are declared obligatory with AGFW guideline FW 401. Compliance with the internal and external tests and their frequencies can be checked in the future based on EHP/001 »Certification guidelines for quality assessment of district heating pipes« of Euroheat & Power, Brussels. The manufacturers of preinsulated bonded pipe systems can have their production sites checked regularly for compliance with EHP/001, and if the inspection is passed, they receive the right to place a quality mark on pipes and fittings from these production sites. Customers and network operators are recommended to only purchase and use pipes and fittings from appropriately proven quality production.

2 Checking the Quality of Preinsulated Bonded District Heating Pipes

The quality status of preinsulated bonded pipe system components will be defined in the future with an independent, recurring random sampling quality check with annual tests on the basis of EN product standards and AGFW guideline FW 401.

As commissioned by AGFW, in the first round of tests in 2006/2007, straight preinsulated bonded district heating pipes – two 6 m long pipes and one 12 m long pipe, DN 50/125 – of the following manufacturers and suppliers were tested in the District Heating Research Institute in Hanover (FFI).

- Brugg Rohrsysteme GmbH, Wunstorf/Germany (hereinafter referred to as »Brugg«).
- GermanPipe Industrie- und Fernwärmetechnik GmbH, Nordhausen/Germany (hereinafter referred to as »GermanPipe«).
- Isoplus Fernwärmetechnik Gesellschaft m.b.H., Hohenberg/Austria (hereinafter referred to as »Isoplus-H«).
- Isoplus Fernwärmetechnik Gesellschaft m.b.H., Sondershausen/Germany (hereinafter referred to as »Isoplus-S«).
- KE Kelit Kunststoffwerk Gesellschaft m.b.H., Linz/Austria (hereinafter referred to as »KE Kelit«).
- Logstor Ror Polska Sp. Zo.o., Zabrze/Poland (hereinafter referred to as »Logstor-Z«).
- Starpipe A/S, Fredericia/Denmark (hereinafter referred to as »Starpipe«).

The following utilities provided pipes for the test from building site deliveries:

- Drewag Stadtwerke Dresden GmbH, Dresden/Germany,
- RheinEnergie AG, Cologne/Germany,
- Stadtwerke Hannover AG, Hanover/Germany,
- MVV Energie AG, Mannheim/Germany,
- Fernwärme Wien GmbH, Vienna/Austria,

Rolf Besier, German District Heating Association (AGFW), Frankfurt am Main/Germany; ***Armin Böhm***, Vattenfall Europe Berlin AG & Co KG, Berlin/Germany; ***Thomas Grage***, District Heating Research Institute in Hanover (FFI), Hemmingen/Germany; ***Hans-Otto Meyer***, Stadtwerke Hannover AG, Hanover/Germany; ***Peter Rührer***, Fernwärme Wien GmbH, Vienna/Austria; ***Alexander Wagner***, Eon Bayern Wärme, Munich/Germany

	Property	Brugg	German Pipe	Isoplus-H	Isoplus-S	Isoplus-S DN 65/140	KE Kelit	Logstor-Z	Logstor DN 40/110	Starpipe
2.1	Other applicable documents			Acceptance test certivicates 3.1 in accordance with EN 10204						
2.2	**Identification**	+	+	+	+	+	+	+	+	+
2.2.1	Steel medium pipe	–	–	+	+	+	+	–	+	+
2.2.2	PE casing pipe	+	+	–	+	+	+	+	–	–
2.2.3	Bonded pipe	–	–	–	–	–	–	–	–	–
2.3	**Steel medium pipe**									
2.3.1	Welded steel pipes	+	+[1]	+	+	+	+	+	+	+
2.3.2	Diameter tolerance	+	–	+	–	+	+	–	+	–
	Wall thickness tolerance	+	+	+	+	+	+	+	+	+
2.3.3	Surface conditions	+	+	+	+	+	+	+	+	+
2.4	**PE casing pipe**									
2.4.1	Density	+	+	+	+	○	+	+	○	+
	Composition	○	○	○	○	○	○	○	○	○
2.4.2	Melt flow rate	+	+	–	+	+	+	+	+	+
2.4.3	Heat resistance	○	○	○	○	○	○	○	○	○
2.4.4	Raw material mech. long-time behaviour	○	○	○	○	○	○	○	○	○
2.4.5	Appearance, surface condition, pipe ends	+	+	+	+	+	+	+	+	+
2.4.6	Elongation at break	–	+	–	–	+	–	–	+	–
2.4.7	Change after heat treatment	○	○	○	○	○	○	○	○	○
2.4.8	Mechanical long-time behaviour	#	+	–	#	○	–	+	○	+
2.4.9	Resistance to stress cracking	+	+	–	+	○	–	+	○	+
2.5	**PUR rigid foam insulation**									
2.5.1	Composition	○	○	○	○	○	○	○	○	○
2.5.2	Cell structure	+	+	+	+	+	+	+	+	+
2.5.3	Density	+	+	+	+	+	+	+	+	–
2.5.4	Compression strength	+	–	+	+	+	+	–	–	–
2.5.5	Water absorption	+	+	+	+	+	+	+	+	–
2.6	**Bonded pipe**									
2.6.1	Insulation thickness	+	+	+	+	+	+	+	+	+
2.6.2	Pipe ends	+	+	+	+	+	+	+	+	–
2.6.3	PE casing pipe diameter	+	+	+	+	+	+	+	+	+
	PE casing wall thickness	+	+	+	+	+	+	+	+	–
2.6.4	Centerline deviation	+	–	+	–	+	+	–	+	+
2.6.5	Foam end areas in acc. with FW401	+	+	+	+	+	+	+	+	+
2.6.6	Shear strength	+	+	+	+	+[2]	+	+	+[2]	–
2.6.7	Heat conductivity	+	+	+	+	+	+	+	+	+
2.6.8	Impact resistance	+	+	+	+	+	+	+	+	+
2.6.9	Creep behaviour ΔS_{100}	+	+	+	+	○	+	+	○	+
	$\Delta S_{1\,000}$	#	#	#	#	○	#	#	○	#
	Extrapolation (30 years)	–	–	–	–	○	+	–	○	–
2.6.10	Surface conditions at delivery	+	+	+	+	+	+	+	+	+
2.7	**Surveillance and leak detection systems**									
	Distance of wires to medium pipe	–	+	+	+	+	+	+	+	–
	Grinding	+	+	+	+	+	+	+	+	+
	Freedom from contact	+	+	+	+	+	+	+	+	+
	Lengths of wires at pipe ends	+	+	+	+	+	+	+	+	+
	Wire protection	+	+	+	+	+	+	+	+	+

Table 1. *Summary of the results (+ test passed; – test failed; # measured values determined; ○ requirement was not checked); [1] Steel quality deviates from EN 253; [2] Test only in delivery status)*

• Vattenfall Europe Berlin AG & Co KG, Berlin/Germany.

The tests were performed under identical conditions. The DN 50/125 pipe dimension was chosen to enable a direct comparison with the dimensions that are usually used in type tests.

Parallel to this, Steag Fernwärme GmbH, Essen/Germany, carried out limited tests on pipes from Logstor (DN 40/110) and Isoplus-S (DN 65/140) at the FFI. The results were provided for this publication and are also presented in the following.

All pipes tested are discontinuously produced pipes.

The tests were monitored by the AGFW working group »Network Construction Technology, as commissioned by the AGFW »Heat Distribution« expert committee.

The results must be assessed as specific point tests; a statement on the quality of pipes from other batches, production sites, or the like, is not possible. The results of all tested pipes permit a statement on the quality standard of »usual« deliveries.

The requirements in accordance with EN 253:2006, EN 14419:2004 and AGFW guideline FW 401 were checked with the tests – to the extent that this was possible on the available pipes after production.

The essential, summarized results are shown in *table 1*. Weighting the individual test requirements was intentionally dispensed with here.

2.1 Other Applicable Documents

With the delivery of the pipes at FFI and in accordance with EN 10204, copies of the acceptance test certificates 3.1 were submitted or filed later on.

The production date, production site and further information on the bonded pipes can only be obtained from the numbers and codes on the pipes by asking the manufacturers.

The manufacturers were not asked any questions in this regard about identifiers as part of this inspection.

2.2 Identification

The pipes can be identified in any suitable way, as long as it in no way impairs the functional properties of the pipe casing and is suitably configured to withstand all handling, storage and usage stresses.

All pipes met the requirements.

2.2.1 Steel Medium Pipe

In accordance with amendment 2 of EN 253, the steel pipes of the tested diameter must comply with steel pipe standards, EN 10216-2, 10217-1 and 2. The steel pipes must be identified, i.e. with an external diameter >51 mm, a permanent identifier must be provided on at least one of the pipe ends.

Manufacturer	specified dimension	Tolerances D according to	Tolerances T according to
Brugg	60,3 · 2,9[1]	EN 253	EN 253
GermanPipe	60,3 · 3,2	EN 10217-1	EN 253
Isoplus-H	60,3 · 3,2	EN 253	EN 253
Isoplus-S	60,3 · 3,2	EN 10217-1	EN 253
Isoplus-S DN 65/140	76,1 · 2,9[1]	EN 253	EN 253
KE Kelit	60,3 · 3,2	EN 253	EN 253
Logstor-Z	60,3 · 3,2	EN 10217-1	EN 253
Logstor DN 40/110	48,3 · 2,6[1]	EN 253	EN 253
Starpipe	60,3 · 3,2	EN 10217-1	EN 253

Table 2. *Pipe dimensions in accordance with the specified technical regulations.* [1]*Corresponds with the ordered wall thickness*

A complete identifier was not provided on the Brugg, GermanPipe and Logstor-Z steel pipes.

2.2.2 PE Casing Pipe

The PE casing pipe manufacturer must provide the following details on the casing pipe:

- *PE raw material, either with trade name or code.*
- *MFR table value (Melt Flow Rate) as provided by the raw material manufacturer.*
- *Nominal diameter and nominal section thickness of the casing pipe.*
- *Year and week of production (code where applicable).*
- *Manufacturer's logo/mark.*

The nominal section thickness was missing on the pipe from Starpipe; with Isoplus-H the MFR value details were missing; and with Logstor DN 40/110 the nominal wall thickness and the manufacturer's logo/mark were missing.

2.2.3 Bonded Pipe

The bonded pipe manufacturers must provide the following on the PE casing pipe:

- *Nominal diameter and nominal wall thickness of the medium pipe.*
- *Steel name and steel quality.*
- *Manufacturer's logo/mark.*
- *Number of the European Standard, EN 253.*
- *Year and week of foaming (code where applicable).*

Supplementary requirements in accordance with AGFW guideline FW 401-3:

- *Foam type with foaming agent details.*
- *Foaming technology.*
- *Production site.*

There was no steel quality information on the pipes from Brugg and GermanPipe; »EN 253« information was missing on the pipes from Logstor-Z and Starpipe.

Identifiers for the supplementary requirements in accordance with AGFW guideline FW 401-3 were not provided on any of the pipes.

According to AGFW guideline FW 401-3, the make of the measuring wires of the surveillance and leak detection systems must not be provided on the pipes. The system-specific measuring wires can be recognized by the different materials and wire insulations.

2.3 Steel Medium Pipe

2.3.1 Quality

According to EN 253/A2, steel quality P235GH is required for seamless pipes; the steel qualities P235TR1, P235TR2 or P235GH must be used for welded pipes.

The acceptance test certificates 3.1 in accordance with EN 10204 were used to test the quality of straight bead welded steel pipes. The following qualities were certified herein:

- The pipes from Isoplus-H, Isoplus-S, Isoplus-S DN 65/140, KE Kelit, Logstor DN 40/110 and Starpipe comply with P235TR1 quality in accordance with European standard EN 10217-1. The high-temperature yield strength was certified for St 37.0 in accordance with DIN 1626:1984.
- The seamless pipe from Brugg complies with St 37.0 quality in accordance with DIN 1626:1984 and P235TR2 in accordance with EN 10217-1.
- The pipe from GermanPipe complies with St 37.0 quality in accordance with DIN 1626:1984.
- The pipe from Logstor-Z complies with the St 37.0 qualities in accordance with DIN 1626:1984 and P235TR1 in accordance with EN 10217-1.

According to the acceptance test certificates, eight pipes comply with the steel qualities in accordance with EN 253/A2. The pipe from GermanPipe complies with a steel pipe standard that is permissible in accordance with EN 253/A2. The material quality was agreed with the party that placed the order.

All pipes meet the increased requirements of EN steel pipe standards for high-temperature limits of elasticity in accordance with EN 253 and AGFW guideline FW 401. The limits of elasticity at room temperature ($R_{p0.2}$) proven in accordance with the acceptance test certificate in the tensile test were between 285 and 383 N/mm², i.e. more than 20 % above the minimum value required in accordance with EN 253 and AGFW guideline FW 401.

2.3.2 Diameter and Wall Thickness

To minimize the stresses on pipes during pipe network operation caused by temperature differences and displacement at weld seam connections, the tolerances required by EN 253 are tougher than those required by EN 10216 and EN 10217; all tolerances comply with the tolerances of the withdrawn standards, DIN 1626:1984 and DIN 1629:1984.

AGFW guideline FW 401 proposes an increased minimum wall thickness of 3.2 mm for the inspected pipe dimension in comparison with EN 253 in order to increase the safety of workmanship (tightness of the weld connections) under building site conditions.

The pipes comply with the technical regulations for the tolerances provided in *table 2*.

- Diameter: The pipes from Brugg, Isoplus-H, Isoplus-S DN 65/140, KE Kelit and Logstor DN 40/110 meet the requirements in accordance with EN 253, which have been increased with regard to the steel pipe standards.

We do not know if the customers were informed accordingly that the requirements of EN 253 are not met with the pipes from GermanPipe, Isoplus-S, Logstor-Z and Starpipe.

• Wall thickness: The pipes from GermanPipe, Isoplus-H, Isoplus-S, KE Kelit, Logstor-Z and Starpipe were delivered with 3.2 mm wall thicknesses in accordance with AGFW guideline FW 401.

The pipes from Brugg, Isoplus-S DN 65/140 and Logstor DN 40/110 comply with the minimum wall thickness ordered by the network operators.

All pipes met the wall thickness tolerances in accordance with the standard EN 253.

2.3.3 Surface Conditions

The external pipe surface must be cleaned before the foaming, so that it is free of rust, mill scale, oils, grease, dust, coating materials, moisture and other contaminants. Before cleaning, the external surface of the pipe must comply with rust grades A, B or C in accordance with ISO 8501-1:1988; there must be no pitting corrosion.

A visual inspection of the steel pipe surfaces was made at the free pipe ends and at the points at which the medium pipes could be examined after the destructive tests. Pitting corrosion was not found.

2.4 PE Casing Pipes

Separately produced PE casing pipes were used with the production of the semi-finished products, as all pipes tested are discontinuously produced pipes.

2.4.1 Density and Composition

EN 253 notwithstanding, the density was checked using samples from the foamed PE casing pipes. The mean value from measurements on three test pieces was decided as the test result.

Seven tested PE casing pipes had a density of more than 944 kg/m^2.

The composition of the initial material and the carbon black content, distribution and mixing were not checked.

2.4.2 Melt Flow Rate

The manufacturer provided the MFR factor for the PE pipe to facilitate proper welding. The melt flow rates of the pipes to be welded – e.g. casing pipe segment moulded parts or welded sleeves – may not differ by more than 0.5 g per 10 min.

As already pointed out in section 2.2.2, the pipe from Isoplus-H does not have any melt flow rate information.

The information on the other pipes shows permissible melt flow rates.

2.4.3 Heat Resistance

The induction time of the pipe material must be at least 20 minutes if the test is performed in accordance with EN 728 at 210 °C.

This test was not performed within this quality test.

2.4.4 Mechanical Long-time Behaviour of the Raw Material

This test could not be performed on the raw material.

2.4.5 Appearance, Surface Conditions, Pipe Ends

The internal and external surfaces of the extruded PE casing pipes must be clean and must be free of any unevenness or other imperfections that could impair proper use. The pipe ends must be clean cut and at right angles to the pipe axis with a tolerance of 2.5°.

In accordance with EN 253, the external surfaces of the bonded pipe underwent a visual inspection without magnification. All pipes met the requirements.

2.4.6 Elongation at Break

For the casing pipe dimensions provided, five test pieces were cut lengthwise and evenly spaced over the circumference of the PE casing pipe on the same cross-section and tested in the tensile test. The elongation at break to be verified on each test piece must be at least 350 %.

The pipes from GermanPipe, Logstor DN 40/110 and Isoplus-S DN 65/140 met the requirements with all individual tests. With the pipes from Brugg, Isoplus-S, KE Kelit, Logstor-Z and Starpipe, one test piece of each did not achieve the required elongation at break; with the pipe from Isoplus-H, two test pieces did not achieve the minimum requirement.

2.4.7 Change After Heat Treatment

This test could not be performed on the bonded pipes.

2.4.8 Mechanical Long-time Behaviour of PE Casing Pipes

With the test for mechanical long-time behaviour (CLT Test = Constant Load Tensile Test), 6 test pieces cut lengthwise and evenly spaced over the circumference of the PE casing pipe on the same cross-section are tested at a temperature of 80 °C with a constant tensile stress of 4 MPa in a watery solution with 2 % tenside content.

The geometric mean value of the time of the 6 samples until they reach fracture failure is calculated and must be at least 2,000 h. An individual test value that deviates by more than double from the standard deviation need not be considered here. If the test pieces do not show fracture failure after 2,000 h, the test can be stopped, as the result has met the respective requirements.

The mechanical long-time behaviour tests were suspended with all test pieces with a test time of 2,000 h, although a series of test pieces would have required longer test times to achieve the geometric mean value per pipe.

None of the 6 test pieces of the pipes from GermanPipe, Logstor-Z and Starpipe failed with the 2,000 h test time. They all met the requirement.

With the pipes from Brugg and Isoplus-S, 4 test pieces reached the test time of 2,000 h; 2 test pieces of each failed earlier. To achieve the required geometric mean value, each of the still intact 4 test pieces from Brugg would have to have reached the 2,200 h test time without failing, and those from Isoplus-S would have to have reached a test time of 2,403 h without failing. A definitive statement on meeting the requirement cannot be made for these pipes.

All 6 test pieces of the pipes from KE Kelit and Isoplus-H failed significantly before the minimum time of 2,000 h. Assuming that the PE material for the pipe extrusion came from a qualified production, problems with the pipe extrusion and/or the mixture of the processed material must be expected.

The requirement for the mechanical long-time behaviour of PE casing pipes will no longer apply with the revision of the European standard EN 253 [2]. Only the material composition will still be specified. This means that corresponding normative tests on the PE materials can no longer be carried out on the finished preinsulate bonded district heating pipe system components. Proof of the significantly varying long-time behaviour determined in this inspection would therefore no longer be possible.

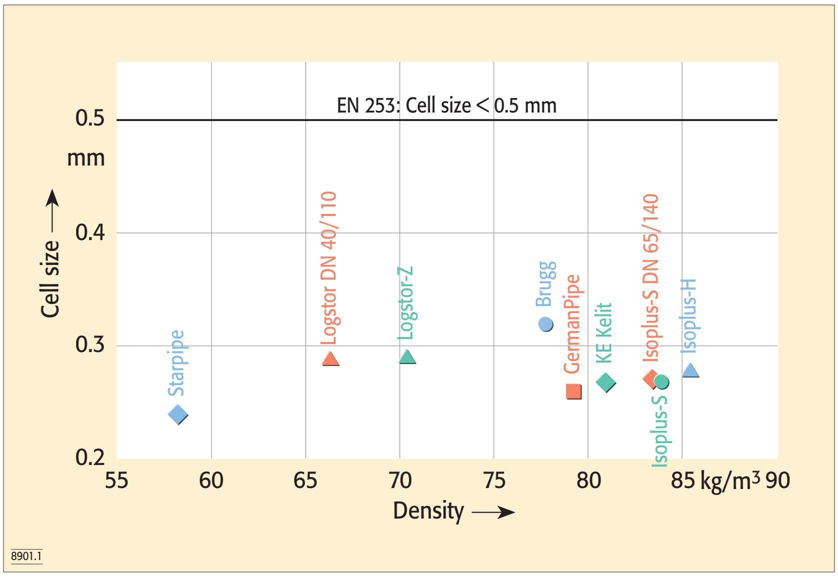

Figure 1. *Average heat insulation cell sizes*

2.4.9 Resistance to Stress Cracking

Under the same test conditions as those for determining the mechanical long-time behaviour, four test pieces cut lengthwise and evenly spaced over the circumference of the PE casing pipe on the same cross-section are provided with circumferential notches and tested for resistance to stress cracking (NCLT = Notch Constant Load Tensile Test).

The time it takes for all test pieces to fail must exceed 300 h.

With the pipes from Isoplus-H and KE Kelit, not one of the test pieces achieved the required minimum values. With the five other pipes tested, all test pieces met the requirements.

2.5 PUR Rigid Foam Insulation

2.5.1 Composition

The manufacturer of the bonded pipes is responsible selecting the raw materials, their composition and the production conditions. The manufacturer must retain all documentation and records that document the raw materials used, the mixture ratios applied and the tests performed.

Proof that these requirements had been met was not requested from the manufacturers.

2.5.2 Cell Structure

The PUR rigid foam must have a uniform cell structure free from smears.

The average size of the cells must be <0.5 mm in the radial direction. This is determined on a 10 mm long sample lying radial in the centre of the heat insulation and the number of cells counted along sample. The mean value of the measurements on 3 test pieces is calculated and specified.

The ratio between the open and closed cells must be calculated on cubes with 25 mm edge length.

The closed cells percentage must be at least 88 %.

Cavities and bubbles are found on 5 cross-sections of the heat insulation. At least 1.5 m from the pipe end; 5 cuts are made through the jacket and insulation layer over a total length of 400 mm at 100 mm intervals. The 4 rings of jacket and heat insulation are removed one after the other and the cross-section surfaces are examined for cavities and bubbles. All holes that are bigger than 6 mm in any direction are measured in 2 perpendicular directions, and the product from the two measurements is defined as the area of the hole. Holes that are smaller than 6 mm are not assessed. The amount of voids and bubbles with this test may not be more then 5 % of the cross-section surface. Not a single pore may leave more than 1/3 of the nominal thickness of the heat insulation between the steel medium pipe and the PE casing pipe open.

All pipes met the cell size requirements (*figure 1*). The range of the cell size differences per cross-section and pipe system is low.

Voids and bubbles were not found on any pipe.

The closed cell content was not tested.

2.5.3 Density

To test the foam density, three test pieces evenly spaced over the circumference are taken from the radial centre of the heat insulation. Each cube must have the dimensions, 30 mm · 30 mm · t, whereby t is the maximum possible thickness, which, however, may not exceed 30 mm.

The density may not be less than 60 kg/m³ at any point.

As part of this inspection, the density was determined on two cross-sections of each pipe on all pipe systems, i.e. on 6 test pieces.

With the pipe system from Starpipe, the density of 4 test pieces was below the minimum value. All other pipes met the requirements.

Figure 2 shows that the individual results per cross-section differ by up to 30 kg/m³. The mean values of the density of individual cross-sections also differ by up to approximately 20 kg/m³ per pipe. This therefore confirms the assumption that the density of the heat insulation of discontinuously produced pipes is subject to significant fluctuations along the pipe axis and over the pipe cross-section. In the results presented in the following, further property values are used, depending on the mathematical mean values from the 2 cross-sections inspected.

The results allow conclusions to be drawn on the different product philosophies of the manufacturers. While to all appearances Logstor and Starpipe endeavour to optimise density with a view to reducing heat conductivity, the other manufacturers appear to focus on ensuring mechanical properties.

2.5.4 Compression Strength

The compression strength in the radial direction is determined with cubes with the dimensions 30 mm · 30 mm · t, which are removed evenly spaced over two cross-sections of a pipe. t here is the greatest possible dimension in the pipe's radial direction, which, however, may not exceed 20 mm.

The compression strength or compressive load with 10 % relative deformation in the radial direction may not be less than 0.3 MPa. None of the cubes may have inadmissibly low compression strength.

With all pipe systems the compression strength was determined with three cubes on 2 cross-sections of a pipe.

With the pipes from Brugg, Isoplus-H, Isoplus-S, Isoplus-S DN 65/140 and KE Kelit, all test pieces met the requirement (*figure 3*).

The pipes from GermanPipe, Logstor-Z and Logstor DN 40/110 did not meet the requirement with 1 to 3 test pieces – on 1 pipe side. Starpipe only met the requirement with 1 out of a total of 6 test pieces.

As the regression line in *figure 3* illustrates, according to this inspection, pipes with an average foam density of approximately 65 kg/m³ and over will meet the requirement.

2.5.5 Water Absorption

The water absorption is determined on 3 cubes with 25 mm edge lengths, which are removed evenly spaced over the circumference. The test pieces with the initial mass m_0 are submerged for 90 minutes in boiling water and then cooled off for 1 h in a container with 23 °C water. The water on the surface of the cubes is very carefully removed before the m_1 mass is determined. The water absorption may not exceed 10 % of the initial volume.

The water absorption was determined with all pipe systems on 2 cross-sections per pipe, i.e. on 6 test pieces.

This test enables an initial qualitative assessment of the heat insulation. Adequate quality can be expected if the water absorption value is below 10 %. If the value is higher, there may be problems with the components or processing work.

A total of 8 pipes had mean water absorption values between approximately 3 and 5 % with a narrow tolerance range for the individual values. The pipe from Starpipe (*figure 4*) had a water absorption level significantly above the limit value.

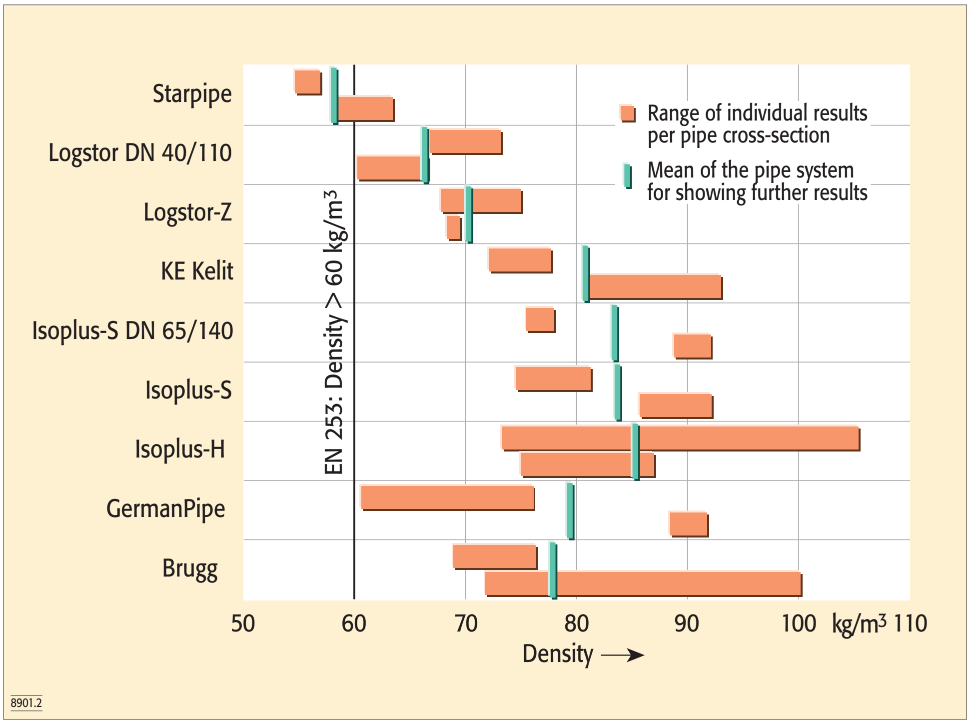

***Figure 2.** Heat insulation density*

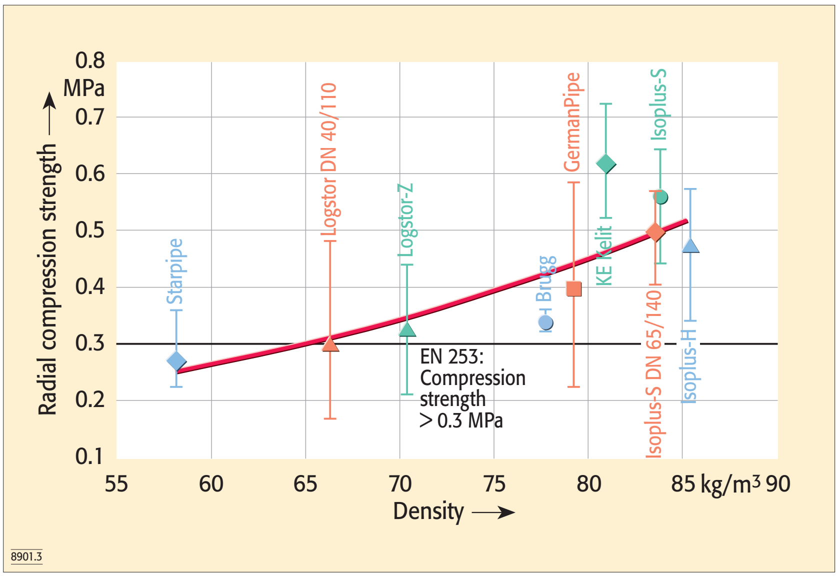

***Figure 3.** Radial compression strengths*

2.6 Bonded Pipe

2.6.1 Insulation Thickness

All pipes complied with the standard insulation thickness in accordance with the AGFW guideline FW 401-3.

2.6.2 Pipe Ends

EN 253 stipulates that the ends of the medium pipes must be free of insulation material for at least 150 mm. The tolerance of the defined value must be ±10 mm. AGFW guideline FW 401-3 stipulates free medium pipe ends of 200 ±50 mm.

The ends of the medium pipes must be prepared for welding.

One pipe end of each of the two pipes from Starpipe did not meet the minimum length. All other pipes met the requirements.

All medium pipe ends were provided with protective caps.

2.6.3 PE Casing Pipe Diameter and Wall Thickness

The external diameter of the PE casing pipes must be between the minimum diameter (nominal external diameter) and a permissible expansion after the foaming at every point (Ø110-116, Ø125-132, Ø140-147). The minimum wall thickness of the PE casing pipes must be at least 3 mm at every point.

All pipes met the requirements for diameter tolerances.

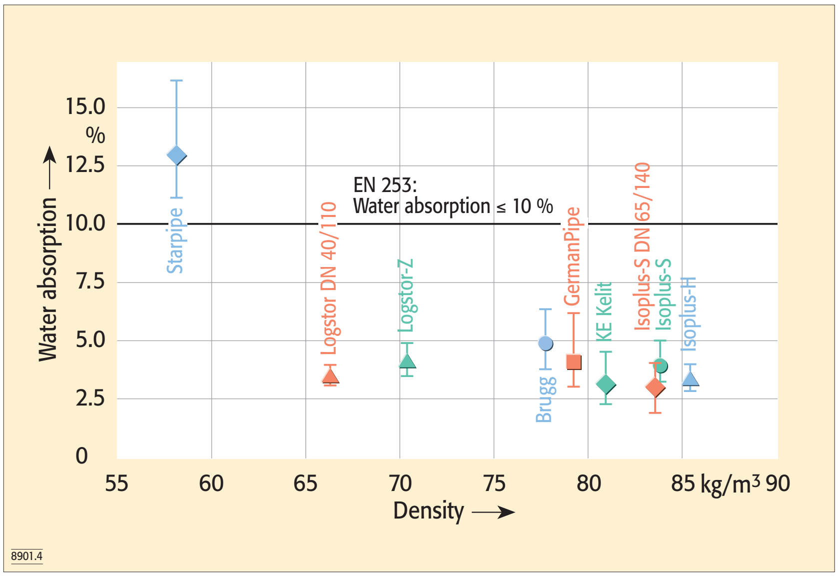

Figure 4. *Heat insulation water absorption*

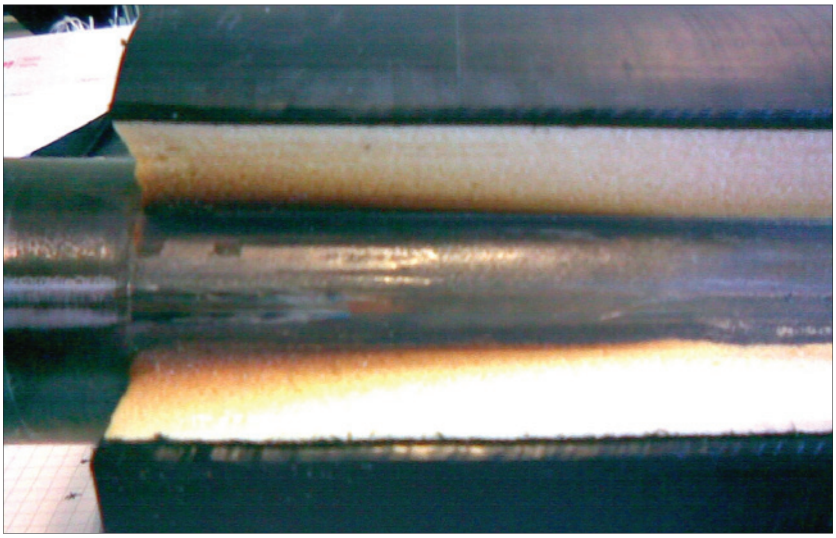

Figure 5. *Effect of the ambient atmosphere on the heat insulation at the pipe ends after thermal aging*

The minimum wall thickness of 8 pipes complied with the requirements. The pipe from Starpipe did not achieve minimum wall thickness.

2.6.4 Centerline Deviation

The distance between the centerline of the medium pipe and the PE casing pipe may not exceed 3 mm at any point.

With 6 pipe systems both pipes met the requirements.

One pipe from Isoplus-S exceeded the maximum value at one point; one pipe from both GermanPipe and Logstor exceeded the maximum value by approximately twice the limit value.

2.6.5 Foam End Areas

Shrinkage in the PUR rigid foam means that after production only limited signs of disbonding may appear at the pipe ends, both on the casing pipe and on the steel pipe. These must be so limited in the axial direction, that they can be completely removed at the foam ends to be cut out as part of the sleeve mounting.

Signs of disbonding were not found on any of the pipes.

2.6.6 Shear Strength

The shear strength is the capacity of the bonded pipe to resist a shearing force between the PE casing pipe and the medium pipe, which means the axial shear stresses that result from the temperature changes of the heating water must be withstood in the network operation, without the bond failing. Axial shear strength $\tau_{ax,23\,°C} \geq 0.12$ MPa must be verified with the test at room temperature, and with the test at 140 °C $\tau_{ax,140\,°C} \geq 0.08$ MPa must be verified, in both the aged and the unaged condition.

The aged condition is established with thermal aging with a mean temperature of 170 °C over 1,450 h, while the casing pipe is exposed to room temperature. The foam at the pipe ends was sealed with aluminium adhesive tape to prevent air from penetrating (minimized level of oxidative aging). This accelerated thermal aging in accordance with EN 253 complies with the »in-service« aging at a constant temperature of 120 °C over 30 years, specified in the scope of the product standard. The effect of the air access to the pipe ends after thermal aging is shown in *figure 5*.

The test pieces are 200 mm long pipe sections. The test pieces are taken from both pipe ends, but at least 500 mm from the ends of the foam, exposed at right angles to the pipe axis with a circumferential annular gap through the PE casing pipe and the heat insulation to the medium pipe. The shear stress is applied in the axial direction on the PE casing pipe. EN 253 notwithstanding, only 1 or 2 shear tests per pipe could be performed because of the limited availability of the test material. The individual value and the mean value of both measurements apply as the test result for this inspection.

In this respect it must be pointed out that further aging processes, such as the effect of oxidation and mechanical stresses, are not considered with this test. The constant operating temperatures usually specified by the manufacturers in accordance with EN 253 only allow a statement on the thermal stress. There are no long-time results with regard to EN 253 and AGFW guideline FW 401, increased operating temperatures with simultaneously occurring oxidative effects, mechanical stresses or other processes, which very easily could have a very significant effect.

With the tests at room temperature, all pipes met the requirements before the thermal aging.

All 7 pipes tested also met the requirements after the thermal aging (*figure 6*). This confirmed the expectation that the shear strengths after the thermal aging are lower than the initial values.

With the 140 °C test temperature, the shear strengths before the thermal aging were closer than with the test at 23 °C (*figure 7*). With the pipe from Starpipe, the shear strength in the initial status did not achieve the required minimum value. With the pipes from Starpipe and Isolpus-H, the shear strengths after the thermal aging were higher than in the initial status. This deviating behaviour compared with the other pipe systems can only be explained with varying values along the pipe axis.

A clear shear strength dependency on the density of the heat insulation cannot be determined.

2.6.7 Heat Conductivity

The heat conductivity of the heat insulation is determined with 3 stationary temperature statuses with medium pipe temperatures of 80 °C ±10 K, while the PE casing pipe is exposed to room temperature.

The heat conductivity with a mathematical mean temperature of 50 °C (λ_{50}) may not be greater than 0.033 W/(m·K).

It must be pointed out here that with the draft version for the revision of EN 253, the permissible heat conductivity is expected to be limited to maximum 0.029 W/(m·K).

All pipes met the requirements. With the pipes from Starpipe and Logstor-Z with low densities, the heat conductivity values are also at the lowest because of reduced heat conduction through the cell walls and a higher cell gas volume higher percentage (*figure 8*). The regression line shown in *figure 8* shows the dependency of the heat conductivity on the density in the initial status.

The supplementary heat conductivity measurements performed as part of this inspection after the accelerated thermal aging described above are not normative tests. This type of aging does not permit any statements with regard to a heat conductivity value after a specific usage period or an »end value«; the scope of legality for accelerated aging tests has not been verified for determining heat conductivity.

The measurements were carried out to provide results for possible future comparisons and trend indicators. The results of the measurements on un-aged pipes are provided and confirm an increase in heat conductivity caused by diffusion processes. The range of the heat conductivity values has been reduced when compared with the initial status.

This confirms the assumption that diffusion processes stop long-term comparable cell gas compositions with the same pipe structure. The cell gas composition has the biggest effect on heat conductivity.

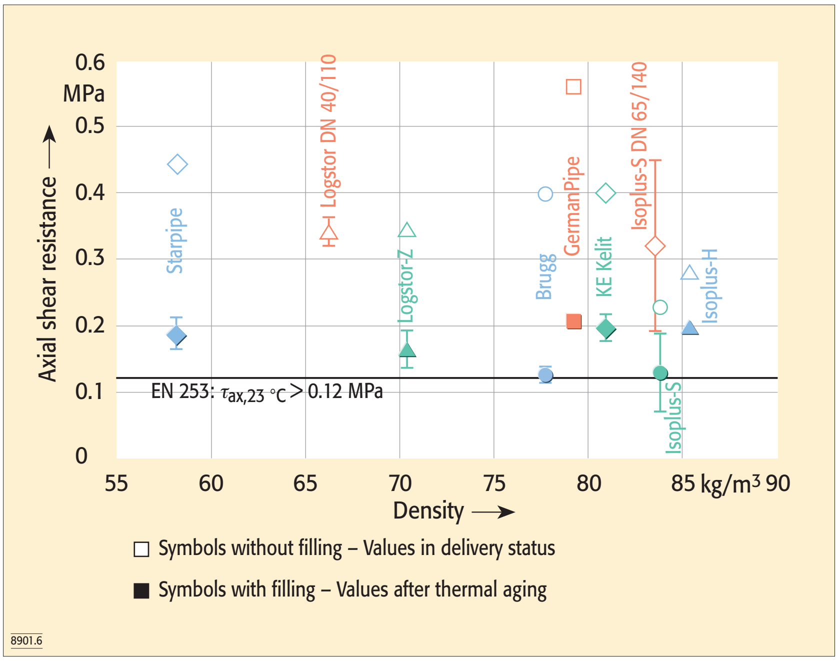

Figure 6. *Axial shear strengths, test with room temperature (23 °C)*

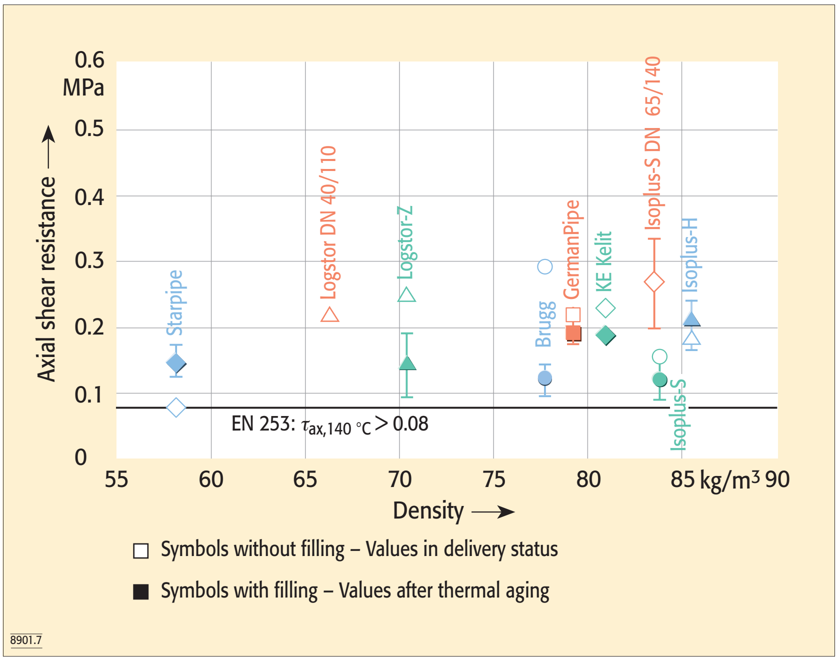

Figure 7. *Axial shear strengths, test at 140 °C*

2.6.8 Impact Resistance

The resistance of the pipes to sudden external force effects is determined with the impact resistance.

A test piece from each of the pipes, which is at least 5 times as long as the external diameter of the PE casing pipe, is tested here with a 3 kg object dropped on it from 2 m.

Before the tests the test pieces are cooled for 3 h at –20 °C. The test must begin within 10 s after the test piece is removed from the cold

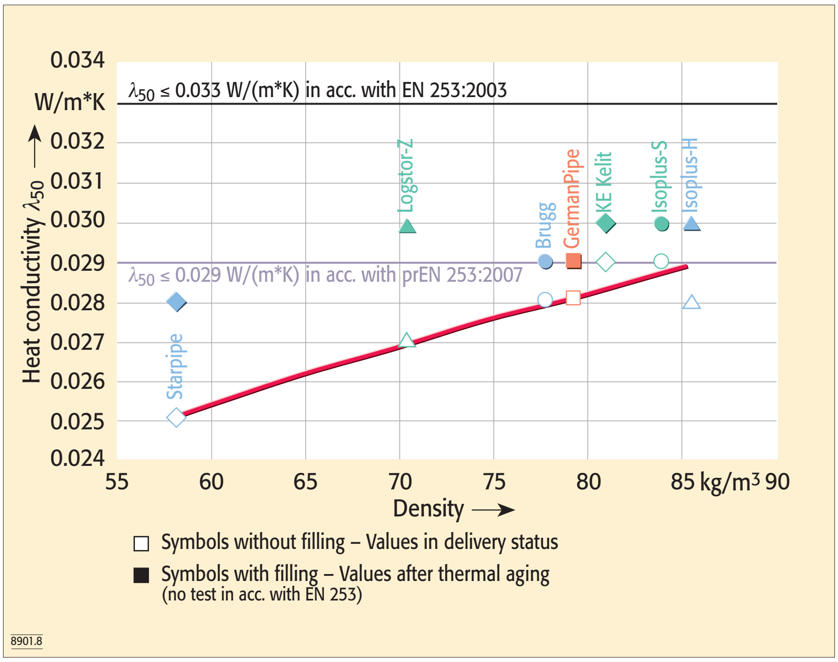

Figure 8. *Pipe heat conductivity*

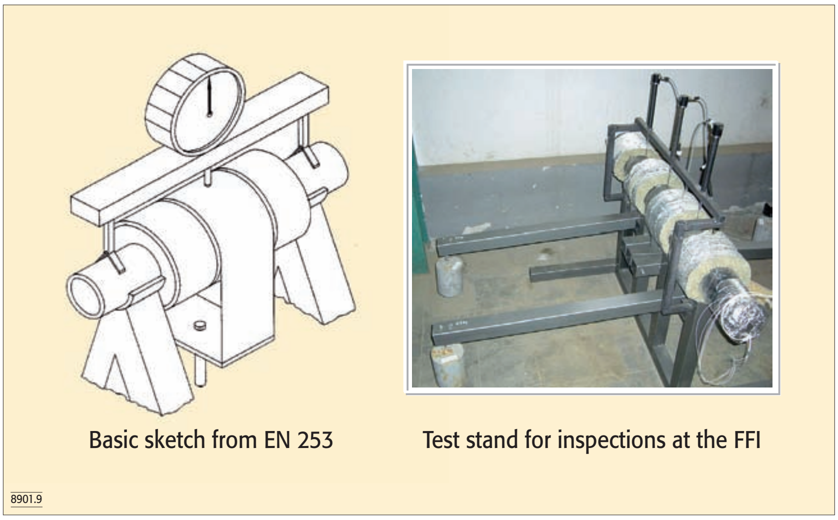

Figure 9. *Set-up for creep behaviour test*

chamber and must be performed as quickly as possible.

After the test the PE casing pipes must not have any visible cracks.

All pipes tested met the requirements.

2.6.9 Radial Creep Behaviour

Test pieces are removed from the centre of the pipe to determine the radial creep behaviour. They consist of a 100 mm test part, and two 50 mm side insulation parts from the original insulation and the PE casing pipe. The insulation parts must be separated from the test part by two cuts, which lead through the PE casing and the insulation to the steel pipe. The test piece must be supported at both ends directly beside the insulation parts. The radial compression stresses are applied via clamps with a force of 1.50 kN, while the medium pipe is exposed to a temperature of 140 °C. This temperature must be maintained for a week before applying the radial compression stresses. The radial displacement of the heat insulation is measured along the line of force in the centre of the test piece and directly on the topside of the PE casing. The test results are determined as the mean values of 3 measurements on 3 test pieces from the same pipe. The total radial displacement between the PE casing pipe and the medium pipe is determined after 100 h and after 1,000 h.

A line between these two values is extrapolated in a double logarithmic graph to 30 years and may not exceed 20 mm at this point. The radial displacement after 100 h may not exceed 2.5 mm.

a) Radial Creep Behaviour after 100 h

In *figure 10* the results of 2 test pieces each for 7 pipes at the 100 h point were illustrated. *Figure 11* shows the conclusive results of the 3 test pieces per pipe. The mean values with the pipes from Brugg, GermanPipe, Logstor-Z and Starpipe are characterized by the fact that the radial deformation of each test piece deviates significantly from the other two. With the pipes of GermanPipe, Logstor-Z and Starpipe, each test piece has a deformation of more than 2.5 mm. Noteworthy are the small deformations and the small deviations in the individual results with the pipes from KE Kelit, Isoplus-H and Isoplus-S.

The mean values of all pipes meet the requirements.

b) Radial Creep Behaviour after 1,000 h

Figure 12 shows the results of the 3 test pieces from 7 pipes each for the 1,000 h test time. As expected, the deformations are higher than with the 100 h test time. With the pipes from Brugg, GermanPipe, Logstor-Z and Starpipe, each test piece also has a significantly different radial deformation than the 2 other test pieces. As with the deformation with the 100 h test time, the pipes from KE Kelit and Isoplus-H also feature small deviations here in the individual results. In accordance with EN 253, a limit value for the deformation after 1,000 h is not defined; the mean value for extrapolation must be set to 30 years.

The significantly deviating individual results are by all means usual for plastics tests. They can also be explained with the differences in properties measured along the pipe axis (see section 2.5.3).

c) Radial Creep Behaviour Extrapolation to 30 years in Accordance with EN 253

According to EN 253, the mean values must be provided from the results of the 3 individual measurements per pipe and test time; an individual value that deviates significantly from the other measured values heavily influences the mean value. This is also one of the reasons why, with the exception of the pipe from KE Kelit, all other pipes do not meet the requirement for the creep behaviour to be extrapolated to 30 years. It is interesting to note that the pipe from Isoplus-H has similar mean values for the two test times to the pipe from KE Kelit, however, because of the extrapolation specification, it does not meet the requirement.

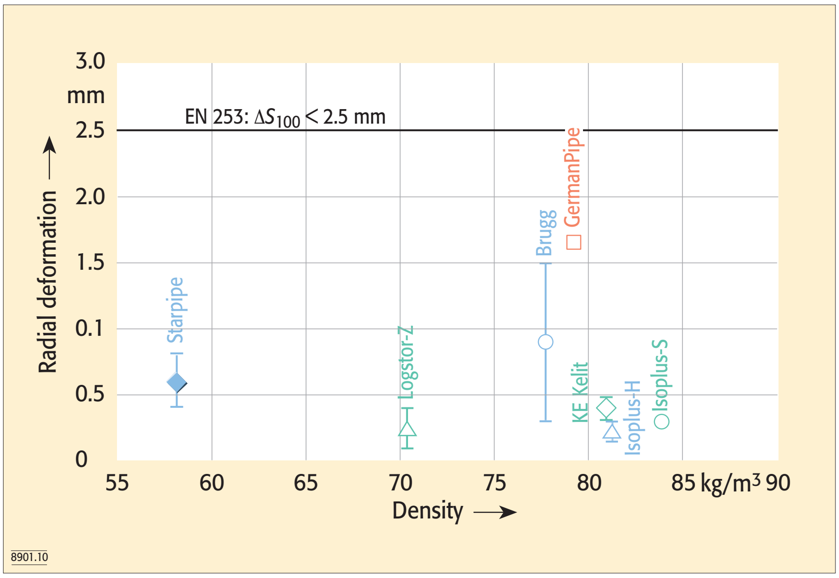

***Figure 10.** Creep behaviour, radial deformation after 100 h (results of 2 test pieces)*

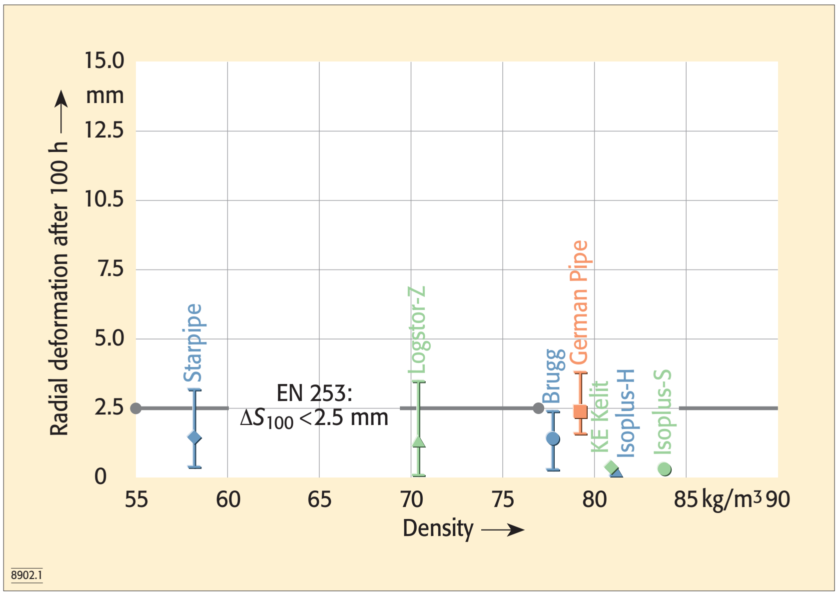

***Figure 11.** Creep behaviour, radial deformation with 100 h test time (results of 3 test pieces)*

d) Radial Extrapolation of the Creep Behaviour as Proposed for the Revision of EN 253

The requirement and the test procedure for proving the permissible radial creep behaviour are expected to change with the revision of EN 253. The test times will be between 1,000 and 10,000 h (previously 100 and 1,000 h); 2 measured values must be recorded during this test period. The creep behaviour to be extrapolated from these measured values to 30 years may not exceed 15 % of the insulation thickness. The radial deformations may not exceed 4.5 mm for the pipes tested with insulation thicknesses of approx. 30 mm.

If we consider the results presented here for the 1,000 h test time and the assumption that the deformation will grow with increasing test time, the pipes from Brugg, GermanPipe, Isoplus-S, Logstor-Z and Starpipe would probably not have passed the test. The pipes from Isoplus-H and KE Kelit would be the most likely to provide positive results.

2.6.10 Surface Conditions at Delivery

The compression on the surface of the pipes may not exceed 15 % of the insulation thickness – measured on the original surface. Scratches on the casing caused by handling and storage may not exceed 10 % of the original section thickness of the PE casing.

All pipes met the requirements.

2.7 Surveillance and Leak Detection Systems

According to EN 14419 and AGFW guideline FW 401, only measuring wires without connections to the pipes may be installed.

These must be arranged in the heat insulation of the pipes so that electrical contact between the individual measuring wires and between the measuring wires and the pipe is not possible. The spacing between the measuring wires and the medium pipe should be at least 10 mm.

The measuring wires can be routed in spacers to ensure axial routing during production and to rule out any electrical contacts.

On the pipe from Brugg a spacing of 9 mm was measured at one point; on the pipe from Starpipe the spacing were only 1 to 5 mm. The wire spacing to the medium pipe in all other pipes is significantly more than 10 mm in places, which means the measuring wires are closer to the PE casing pipe than to the steel pipe.

The continuity of the measuring wires was determined with a loop resistance test on all pipes.

The test to ensure there are no contacts was performed by measuring the electrical resistance at high voltage. All pipes also met the test requirements here.

The measuring wires routed on the front of the pipe components must

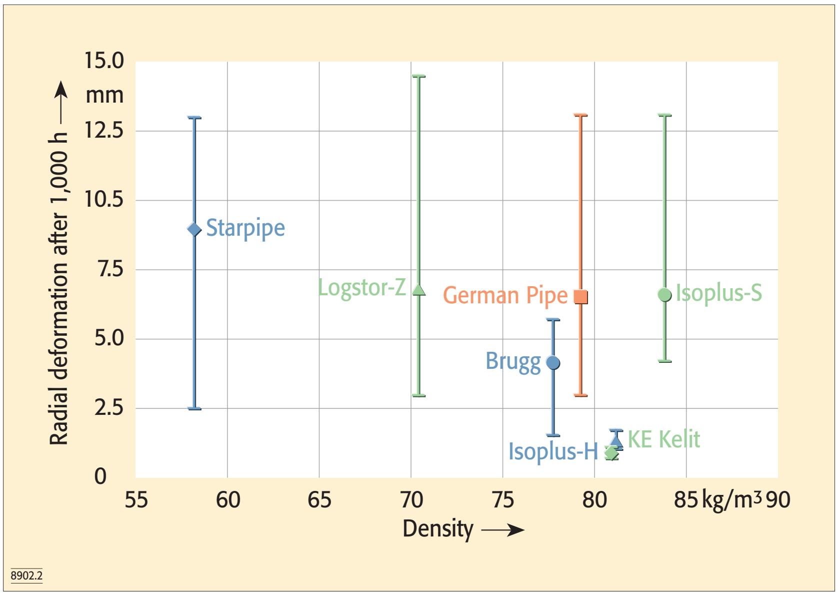

Figure 12. *Creep behaviour, radial deformation with 1,000 h test time (results of 3 test pieces)*

be at least 20 mm longer than the medium pipes.

All pipes met the requirement.

The ends of the measuring wires must be protected against transport and storage damage.

With all pipes the measuring wires lay on the foam ends when delivered, and were protected against unintentional damage from the overlapping PE casing pipes.

3 Summary

Overall not one of the pipes inspected in this quality test met all requirements. All pipes were provided for the tests by network operators from building site deliveries.

The overall results of 8 of the 9 pipes were rated »good« to »satisfactory«. With the pipe from Starpipe there appeared to be a good deal of problems with production and quality assurance.

The heat insulation and bonding properties for discontinuously produced pipes also depend on the point along the pipe axis at which the individual tests were performed. Discontinuous production can result in significantly different property values. As in many cases the property values are only determined at one cross-section surface of the pipe as stipulated by the respective standard or standards, with test results that only barely meet the minimum requirements, the ability to comment and the significance of the results for the entire pipe length must be considered in a critical light.

The purpose of individual requirements is not discussed in the presentation of the requirements, the performance of the tests or the test results. The individual circumstances should be discussed in detail by standards committees.

The authors of this report explicitly recommend that all tests in accordance with EN 253 and AGFW guideline FW 401 (type tests) be repeated in full, on one hand on pipes from one batch inspected in one test centre, and on the other hand to receive the EHP/001 quality mark, and that the type tests be carried out at specified intervals, such as every 2 years, for example. The pipes to be tested must be selected here by the certification authority during the inspection at the production sites.

The manufacturers are asked to ensure that their production is intensively quality assured. Easily avoided deviations from the requirements must be ruled out here (e.g. identification, centre line deviations, positioning of wires for surveillance and leak detection systems) and more long-time tests must be performed on the materials and pipes (e.g. PE elongation at the break, resistance to stress cracking, compression strength, creep behaviour).

Verification at the pipe manufacturers with regard to the completeness and up-to-dateness of the material tests and component tests performed requires improvement from the customer's point of view.

The authors recommend that the contracting parties and operators of district heating networks also ask the manufacturers of district heating pipes to provide the appropriate proof for evaluating suitability:

- PE casing pipe:
Elongation at break, mechanical long-time behaviour (Constant Load Tensile Test), resistance to stress cracking (Notch Constant Load Tensile Test).
- PUR rigid foam:
Cell structure, foam density, compression strength, water absorption.

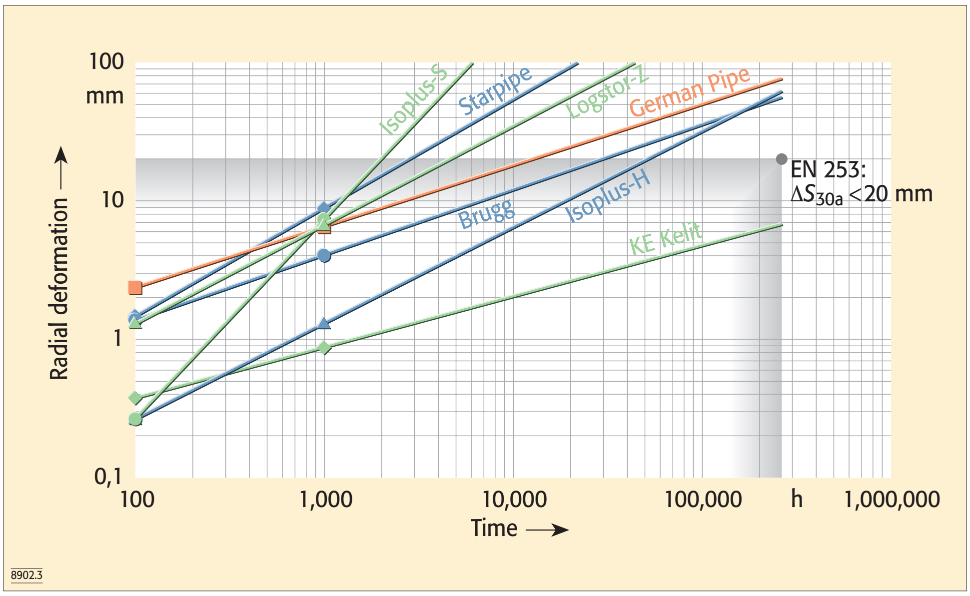

Figure 13. *Creep behaviour extrapolation to 30 years*

• Bonded pipe:
Shear strength at room temperature and at 140 °C, both in a thermally aged and unaged status, heat conductivity, shock strength, creep behaviour.

4 Technical Regulations

• DIN 1626:1984 – Welded circular tubes of non-alloy steels with special quality requirements; technical delivery conditions (withdrawn; replaced by EN 10217).
• DIN 1629:1984 – Seamless circular tubes of non-alloy steels with special quality requirements; technical delivery conditions (withdrawn; replaced by EN 10216).
• EN 253:2006 – District heating pipes – Preinsulated bonded pipe systems for directly buried hot water networks – Pipe assembly of steel service pipe, polyurethane thermal insulation and outer casing of polyethylene.
• EN 253/A2:2006 – Change to section 4.2.1 (steel medium pipe qualities).
• EN 10204 – Metal products – Types of test certificates.
• EN 10216-1 – Seamless steel tubes for pressure purposes – Technical delivery conditions. Part 1: Non-alloy steel tubes with specified room temperature properties. Part 2: Non-alloy steel tubes with specified increased temperature properties.
• EN 10217-1 – Welded steel tubes for pressure purposes – Technical delivery conditions. Part 1: Non-alloy steel tubes with specified room temperature properties.
• EN 14419 – District heating pipes – Preinsulated bonded pipe systems for directly buried hot water networks – Surveillance systems.
• FW 401-3 – Installation and statics of district heating pipes for district heating network. Part 3: Components; straight bonded pipes.
• EHP/001 – Certification guidelines for quality assessment of district heating pipes. ■

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