PAS 1075 – English Translation

Pipes made from Polyethylene for alternative installation techniques

Dimensions, Technical Requirements and Testing

Foreword

This PAS – Publicly Available Specification serves as a supplement to existing published standards and guidelines and is especially applicable to polyethylene piping for alternative laying methods.

This present PAS lays down the properties, requirements and testing procedures for polyethylene piping, as employed in alternative laying methods. There under, additional requirements are given, which go beyond the minimum requirements of local standards for piping consisting of PE 100 and PAS 1031. This applies in particular to the selection of the raw materials.

The following are the authors of this document:

— Agru-Frank GmbH, represented by Mr. Frank Haizmann

— egeplast Werner Strumann GmbH & Co. KG, represented by Dr.-Ing. Thorsten Spaeth

— Frank & Krah Wickelrohr GmbH, represented by Mr. Stephan Fuellgrabe

— HESSEL Ingenieurtechnik GmbH, represented by Dr.-Ing. Joachim Hessel

— INEOS Polyolefins, represented by Mr. Wolfgang Huszar

— TOTAL Petrochemicals Research, Feluy, Belgium, represented by Dr. Etienne Laurent

— Wavin GmbH, represented by Mr. Volker Koestring

The following persons were also involved in the drafting of this PAS in a consulting capacity:

— Borealis Polyolefine GmbH, represented by Mr. James McGoldrick

— Fachhochschule Aachen (Aachen University of Applied Sciences, Germany, represented by Prof. Dr.-Ing. Gottfried Nonhoff Cert. Eng., expert for plastic piping at the 'Deutsches Institut fuer Bautechnik' (German Institute for Building Construction Technologies).

— Gerodur MPM Kunststoffverarbeitung GmbH & Co. KG, represented by Mr. Heiko Below

— NRM Netzdienste Rhein-Main GmbH, represented by Mr. Marco Schmid

— STRABAG AG, represented by Mr. Ansgar Kortbus

— Tracto-Technik GmbH, represented by Mr. Meinolf Rameil

The publication of the PAS was undertaken by the Innovation and Standardization unit of DIN Deutsches Institut für Normung e.V. The editorial processing and revision of the 'PAS' will be carried out as required, but at the latest after 5 years. Any alteration- and/or supplementary revisory requirements for the following issues can be sent centrally to the email address PAS1075@web.de under the rubric: 'Änderungsdienst PAS 1075' (Revision Services). The authors will take such suggestions into consideration on the occasion of the next revision of the 'PAS'.

Only the authors mentioned above are responsible for the content of the document.

DIN Deutsches Institut für Normung e.V.
Innovation and Standardization
April 6th, 2009

Continued on pages 19 to 33

Contents

0 Introduction

The safe use of polyethylene piping for alternative installation methods (e.g. installation without a sand embedding and possible re-use of the excavated soil for installation in open trenches as well as installation methods without the use of trenching), places appropriate prerequisites on the characteristics of polyethylene piping with regard to their stress crack behaviour.

For this reason, the authors have set themselves the assignment of defining a level of quality for polyethylene piping, where the useful service life is to be at least 100 years.

The contents of this present 'PAS' represent the requirements on polyethylene piping for alternative installation methods including the relative measures for quality control assurance, which already exist on the basis of extensive testing and control.

The quality control- and safety levels described in this present 'PAS' exceed the requirements of any valid existent standards. This present 'PAS' describes the current status of raw material developments as well as the manufacturing- and testing techniques for polyethylene piping for alternative laying methods.

The polyethylene piping described in this present 'PAS' possess fundamentally higher resistance properties in regard to the resistance to slow crack growth in comparison with PE 80- and PE 100 piping to German Industry Standard DIN 8075 ('Stress Cracking Resistance').

The standardised dimensioning for pipes made of PE 100 with regard to permissible service pressure remain applicable for PE 100 pipes intended for alternative installation methods. In this respect, the additional burdening, e.g. from external local point loading are not taken into account in the pressure calculations. Any additional burdening from such sources is taken account of by the herein defined requirements of an enhanced and inherent stress cracking resistance in the piping.

The PE piping suitable for alternative installation methods is manufactured of raw materials, which possess properties of a minimum level of stress cracking resistance of 8,760 hours (1 year) exposure time given for an FNCT test (80 °C, 4 N/mm^2, 2 % Arkopal N-100). Such PE materials are designated as PE 100-RC (Resistant to Cracks).

Materials may only be designated as PE 100-RC when complying with the requirements of PAS 1075 and are certified by an accredited certification body.

1 Areas of application

This present 'PAS' applies to piping made of PE 100-RC using alternative installation methods with enhanced resistance to a slow crack growth ('Stress Cracking Resistance'), which can be manufactured by using either the axial- or spirally wounded extrusion method.

In the view of their properties, the pipes are used for both above ground and buried pipelines, which may be operated as gravity-flow lines or under vacuum or pressure, while taking the static loading of the pipeline into consideration, which is to be considered in each individual case.

The regulations of other relevant guideline regulating bodies are also to be taken into consideration.

The Standards scheduled in Section 2 are also valid in their content in their entirety for piping of PE 100-RC.

Trenchless installation methods are often selected in preference to open trench installation methods, because, as a rule, they save costs both in terms of time and money. In recent years, a variety of installation techniques have achieved 'state-of-the-art' status because of their inherent economic advantages.

Trenchless laying procedures place higher requirements on the piping system to be employed, in comparison with trenched protective sand bedding method.

Those laying methods are described as alternative where diversions are made from prescribed sand bedding regulations in the open trench construction method for PE piping (e.g. compliant with the German W400-2 Regulations of the 'DVGW – Deutsche Vereinigung des Gas- und Wasserfaches' (Gas- and Water Industry Federation)). These procedures are more closely described by the following organisations:

> The German 'GSTT-German Society for Trenchless Technology' describes a variety of trenchless laying techniques in the GSTT Information Sheet No. 20 'Sanierung von Druckrohrleitungen' (Renovation of Pressure Piping Mains), such as the relining process, anti-burst lining, pressure-drawing procedures, etc.

The German regulations of the 'ATV-DVWK – Abwassertechnische Vereinigung – Deutsche Vereinigung fuer Wasserwirtschaft, Abwasser and Abfall' (Technical Waste Water Technical Federation – German Federation for Water Utilities, Waste Water and Refuse) describes in its Section M 160 the milling and ploughing processes.

The 'DVGW – Deutsche Vereinigung fuer Wasserwirtschaft, Abwasser and Abfall' (German Federation for Water Utilities, Waste Water and Refuse) has issued procedural descriptions in the form of worksheets and/or memoranda notices, in the GW 32x Series.

Requirements on pipelines using alternative installation methods have, up to the present time, only been insufficiently described in technical directives. The directives of the 'DVGW – Deutsche Vereinigung fuer Wasserwirtschaft, Abwasser and Abfall' (German Federation for Water Utilities, Waste Water and Refuse) merely define that the piping shall comply with the requirements of the installation method. Authoritative requirements on materials and piping, on the other hand are being described for the first time in this 'PAS' for a minimum service life of 100 years.

2 Normative references

This 'PAS' also includes regulations from the dated or undated requirements of other publications. Such standardised requirements are cited in the text as required and the publications concerned are also indicated therein. In the case of dated regulations, only those subsequent alterations or revisions are included in this 'PAS', wherever these are included by reason of alterations or revisions. In the case of undated regulations, the latest issue of the publications are referred to (including the alterations or revision quoted therein).

PAS 1031	Material Polyethylene (PE) for the manufacture of pressure pipes and -fittings – Requirements and tests
PAS 1065	Spirally wounded pipes made out of polyethylene (PE 100) – tangentially extruded – Dimensions, technical requirements and test
DIN 8075	Pipes made from polyethylene (PE) PE 63, PE 80, PE 100, PE-HD – Dimensions
DIN 16961 -1	Pipes and fittings made from thermoplastics with a profiled wall and smooth pipe inside surfaces – Part 1: Dimensions
DIN 16961 -2	Pipes and fittings made from thermoplastics with a profiled wall and smooth pipe inside surfaces – Part 2: Technical delivery specifications
EN 1555:	Plastics piping systems for the supply of gaseous fuels – polyethylene (PE) Part 1: General Part 2: Pipes Part 3: Fittings Part 4: Valves Part 5: Fitness for purpose of the system
EN 12201:	Plastics piping systems for the supply of water – polyethylene (PE) Part 1: General Part 2: Pipes Part 3: Fittings Part 4: Valves Part 5: Fitness for purpose of the system
EN 13244:	Plastics piping systems for buried and above-ground pressure systems for water for general purposes, drainage and sewerage. Polyethylene (PE). Part 1: General Part 2: Pipes Part 3: Fittings Part 4: Valves Part 5: Fitness for purpose of the system
ISO 16770:	Plastics – Determination of environmental stress cracking (ESC) of polyethylene – Full-notch creep test (FNCT)

3 Technical terms and definitions

For the application of this PAS, the following technical terms and definitions apply, in parallel to the technical terms and conditions of PAS 1031, PAS 1065, DIN 16961 and DIN 8075.

3.1 Material designation

The PE piping materials used for alternative pipe installation methods are PE 100 materials according to PAS 1031, but with a significantly enhanced resistance to slow crack growth ('Stress Cracking Resistance'). Such materials are designated as ***PE 100-RC***. The minimum level for stress cracking resistance is fixed at an exposure time in the FNCT test (80 °C, 4 N/mm^2, 2 % Arkopal N-1 00) of 8,760 hours.

As exposure times over 8,760 hours refer to the area of the thermal ageing of polyethylene at 80°C, extrapolated times > 8,760 (from accelerated testing procedures) are not permissible.

Materials may only be designated PE 100-RC if these meet the requirements of this present 'PAS' and this is confirmed by an accredited certification body.

3.2 Classification of the piping construction

The following piping constructions described represent the current 'state-of-the-art' of technology.

3.2.1 Pipe with dimensions according to DIN 8074 ISO 4065

3.2.2 Plain solid wall pipe of PE 100-RC (Type 1)

In the case of single-layer full walled piping of PE 100-RC according to DIN 8074/ ISO 4065 the entire pipe wall is to be of PE 100-RC.

3.2.3 Pipe with integrated protective layers of PE 100-RC (Type 2)

Double layered piping with integrated protective layer mado of PE 100 or PE 100-RC and having an internal co-extruded protective sheathing consisting of PE 100-RC.

Triple layered piping with integrated protective layer made of PE 100 or PE 100-RC and having an internal and external co-extruded protective layer of PE 100-RC.

The co-extruded layers are fused together in the same extruder tool and inseparably bonded.

The internal layer is a functional protective layer of PE 100-RC and integrated into the construction of the walling. The internal layer and the external wall are co-extruded and are mixed together in the main extrusion flow before exiting the die and are homogenously bonded together. The layering gauge is to be at least 2.5 mm and possesses protective properties against the formation of stress cracking.

3.2.4 Pipe with dimensions according to DIN 8074/ISO 4065 with an additional external protective layer (Type 3)

Piping with dimensions according to DIN 8074 with an external protective layer consists of a core pipe of PE 100-RC and external protective layer of mineral enhanced polypropylene. The minimum gauge of the protective layer should be at least 0.8 mm. The minimum thickness of the protective layer is dependent on the dimensions and in cases of larger dimensions should be appropriately thicker to take consideration of higher impingements. The bonding cohesiveness between the protective layer and the core pipe is to be sufficient to compensate for forces and stresses impinging during the installation operations.

3.3 Influencing factor

Since the complex impinging stresses and stresses deriving from the physical alternative installation methods, are incapable of being precisely described in the statical calculations for the piping, an experimentally evaluated influence factor has to be defined. Wetting agent solutions are employed for an experimental assessment of the influence factor, as the effect of such substances produces a parallel shift in the creep rupture curve to simulate shorter exposure times.

The 'FNCT' (Full Notch Creep Test) has proven itself to be useful in the definition of the impingement factor as against the effect of fluid bathotonic wetting solutions.

The influence factor can also be deemed as an (additional) safety factor[1].

[1] Hessel, J. and Grieser, J.
Verfahren zum Nachweis des Sicherheitsfaktors für Rohre aus Polyethylen unter komplexer Beanspruchung
(Procedure for demonstrating the safety factor for polyethylene piping under complex loadings)
3R international (44) No.: 5/ Pages 277 to 283

4 Testing and supervision

4.1 Generalities concerning testing procedures and testing laboratories

The testing procedures for the quality control assurance of alternative installed PE piping are: FNCT test, point loading test and thermal ageing test. Accelerated testing methods may also be used to shorten the testing time (e.g. ACT).

Remark:

As exposure times over 8,760 hours refer to the thermal effect ageing of polyethylene at 80°C, extrapolated times > 8, 760 (from accelerated testing procedures) are not permissible.

Testing procedures are to be continuously validated in regard to precision and exactness.

An essential part of a validation of long-term testing procedures for the characterisation of stress cracking resistance, is the testing of reference samples.

Test laboratories for testing purposes under this present 'PAS' are to possess experience of at least 3 years of the test procedure concerned, and are to be certified under EN ISO 17025:2005.

4.2 Testing (approval, quality control assurance)

A differentiation is to be made between approval testing and production supervisory testing. In addition, differentiations are made between material testing and component (piping) testing.

Approval testing is in part the subject of more stringent requirements, in order to compensate for any influences from processing and constructional design, for example.

4.2.1 Material approval testing

The testing to be carried out for the initial approval of a PE 100-RC material is listed in PAS 1031 as well as in Table 1a and 1b.

Table 1a – Special 'additive' approval tests on material PE-100-RC to evidence the stress cracking resistance and the resistance to thermal aging

No.	Test	Requirements	Comments
1	Stress cracking test of the raw material*)	> 8,760 hours at 80°C, 4 N/mm², 2 % Arkopal N- 100	FNCT test on 6 separate specimens (orientation-free processing procedure)
2	Point loading test on full walled piping	8,760 hours at 80°C, 4 N/mm², 2 % Arkopal N- 100	3 separate specimens e.g. at 80 °C and/or separate specimens apportioned according to a mathematical model (e.g. Arrhenius)
3	Thermal ageing test	> 100 years at 20°C	Testing at elevated temperatures and proof of a minimum activation energy
4	Notch Test on full walled piping (DIN EN ISO 13479)	> 8,760 hours	Selection possible of defined piping constructions

*) The results of the point loading tests are decisive if contrary results in the FNCT and the point loading tests are obtained.

Remark: In the tests of the stress cracking resistance according to table 1a No. 1, table 2 No. 1 and. table 3 No. 1 no brittle fracture must be observed before the required testing time. In order to achieve brittle fracture the test parameters must be chosen according to ISO 16770 to avoid ductile fracture.
The alternative test parameters must be correlated with at least 3 batches in the point loading test.

The ratio of 2.65 derived from the stress cracking resistance testing of the raw material (Table 1a: 8760 h) and the stress cracking resistance testing of the specimens from the pipe (Table 3: 3300 h) must be confirmed if the adjusted test parameters are used.

Example:
A testing time of e.g. 424 hours for the specimens from the raw material is required if in the testing of the stress cracking resistance with specimens from the pipe using adjusted test parameters a requirement of 160 hours is obtained (424/160=2.65).

Table 1b – Additional requirements for the PE 100-RC material (in addition to PAS 1031)

No.	Property	Requirement		Test standard
1	Density	Minimum density of the resin (basic density)	≥ 945 kg/m³ (Information from the raw material supplier with nominal value and tolerances)	EN ISO1183 EN ISO1872-1
2	Melt Flow Rate	Information about the MFR-range	Information at 190 °C / 5 kg max (0,2 to 0,4) g/10 min	EN ISO 1133

4.2.2 Quality assurance of the material

The testing for the quality assurance of materials is listed in Table 2.

Table 2 – Special additional tests for the quality control of PE-100-RC materials to verify the stress cracking resistance

No.:	Test	Requirements	Frequency	
			Internal quality control	External quality control
1	FNCT Test	> 8,760 hours at 80°C, 4 N/mm², 2 % Arkopal N-100 (raw material) or in a corresponding test procedure[2], e.g. 320 hours under ACT procedures (raw materials)	Each batch	–
2	Point loading test	8 760 h at 80 °C, 4 N/mm², 2 % Arkopal N-100		Every 3 years if no irregularity is observed
3	Notch Test (DIN EN ISO 13479)	8 760 h		Staggered 1...3 years, if no irregularity is observed

[2] At least 30 test series in 3 decades are required to be tested in which the target value (e.g. 8,760 hours) is to be included. The correlation coefficient shall be > 0.9. The minimum requirement is to be demonstrated with a 'lower confidence limit' of 2.5 %. The correlation is to be certified according to EN ISO/IEC 17025.

4.2.3 Pipe approval testing

The tests for the initial approval of pipes is listed in Table 3.

Table 3 – Testing of polyethylene piping for alternative installation methods and requirements.

No.:	Test	Requirements	Comments
1	Testing of the stress cracking behaviour	> 3,300 hours at 80 °C, 4 N/mm^2, 2 % Arkopal N- 100 (samples machined from the pipe)	2NCT per separate sample on smallest and largest wall thickness + diameter 110, SDR 11 over the cross section of the pipe
2	Point loading test	8,760 hours at 80 °C, 4 N/mm^2, 2 % Arkopal N- 100	3 separate samples, e.g. at 80°C and/or separate samples *(diameter 110, SDR 11)* chosen according to temperature as per mathematical model (e.g. Arrhenius)
3	Penetration test (simulation of a sharp fragment of a burstlined cast iron pipe by 'GG2', see annex A 4)	Remaining wall thickness after 9,000 hours > 50 % of the original wall thickness	Testing conditions as per MAC[3] concept taking into account the stress cracking resistance and the thermal aging

[3] Directive DVS 2203-4; Suplementary sheet 3

4.2.4 Retesting of the pipe

The tests to be undertaken for the quality control ensurement of the piping are shown in Table 4

Table 4 – Quality control testing of the piping

No.:	Test	Requirements	Frequency	Comments
1	Pipe stress cracking test	>3,300 hours at 80 °C, 4 N/mm^2, 2 % Arkopal N- 100 or in correlated testing procedure[4], e.g. 160 hours with ACT procedure (piping samples)	1 × per half year, but at least per manufactured group 1 × annually	2NCT and/or FNCT test on 3 separate samples (piping internal surface being included in the samples)
2	Point loading test	8,760 hours at 80 °C, 4 N/mm^2, 2 % Arkopal N- 100	Manufactured groups 1 and 2 annually, manufactured group 3 once in 3 years	80 °C separate samples

[4] 3 At least 30 test series in 3 decades are required to be tested in which the target value (e.g. 8,760 hours) is to be included. The correlation coefficient shall be > 0.9. The minimum requirement is to be demonstrated with a 'lower confidence limit' of 2.5 %. The correlation is to be certified according to EN ISO/IEC 17025

4.2.5 Test procedures

The descriptions of the testing procedures are given in the annexes to this present 'PAS' (Table 5).

Table 5 – Testing procedures and related annexes

Annex	Testing Procedure
A1	FNCT
A2	2NCT
A3	Point loading test
A4	Penetration test
A5	Thermal ageing test

5 Marking

The minimum marking of the pipe shall comply with the requirements of the directives amended by the certification mark referring to PAS 1075 or the material designation PE 100-RC.

6 Explanations

6.1 General safety level

All requirements mentioned in the PAS 1075 assume a probability of no failure of at least 97.5 % (the "minimum requirement approach"). All tests cover the "worst case" because both thermal ageing and mechanical loading up to the yield stress of the pipes are chosen as limiting values.

6.2 Correlation FNCT – Point Loading Test

The PE 100-RC material and PE 100-RC pipe requirements in PAS 1075 demand that pipes under maximum service pressure and additional point loading do not show any stress cracking before the onset of thermal ageing.

The time to thermal ageing is specified in supplementary sheet 19 of directive DVS 2205-1. The time to thermal ageing is approximately 1 year at a test temperature of 80°C.

Fig. 1 shows the correlation between results in the FNCT (specimens taken from the pipe wall) and results in point loading tests. Thirty measured values taken from industrial assignments are shown in the diagram below.

The lower limit curve was calculated for a probability of failure of 2.5 % (the upper limiting curve was calculated for a probability of failure of 97.5 %).

The minimum requirement in the FNCT of 3300 hours for specimens taken from the pipe wall is given by the intersection point of the lower confidence limit curve and the time when thermal ageing starts (1 year).

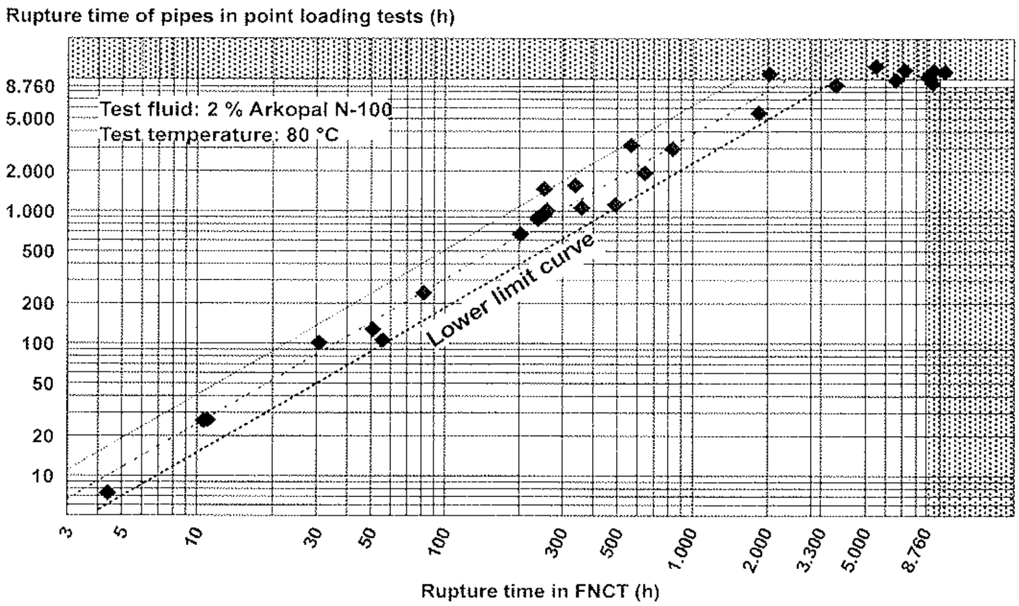

Figure 1 – Correlation FNCT – Point loading test

Annex A 1

Description of the Full Notch Creep Test (FNCT)

General

References: ISO 16770; EN 12814-3; DVS 2203-4 Supplementary sheet 2

1.1 Principle

The resistance to slow crack growth of polyolefins can be determined using the Full Notch Creep Test. The applied stress chosen should be such that it induces a brittle fracture surface according to ISO 16770. The brittle fracture surface shall be at least 30% of the unnotched cross-section

1.2 Preparation of the test specimens

The test specimens for the FNCT shall be cut from the parent material with regard to possible orientations. The test specimens for the FNCT shall be cut with parallel sides. The minimum distance between the clamps and the notch shall be $2 \times a_n$.

1.3 Test specimen notching

The test specimen shall be notched on all four sides in the same plane. The depth of the notch, *c*, shall be 17 % ± 2 % of the measured thickness, *a*.

A notch is produced by pressing a razor blade or a similar tool, which gives an identical result, into the test specimen. It is important to make all the notches coplanar. Test specimens shall be notched at a room temperature of 23°C ± 2°C.

To ensure consistency of results, the razor blade or a similar tool shall be periodically changed.

1.4 Mounting and conditioning

The test specimen shall be loaded free from external torsion and bending effects. The whole test specimen shall be immersed in the test medium. The test specimen shall be conditioned to the test temperature before loading.

1.5. Calculation of the test load (*F*)

$F = A \times \sigma$; where F = test load (N); A = ligament area of the test specimen after notching (mm^2), σ = tensile stress (N/mm^2); a = measured thickness of test specimen; b = width of test specimen c = depth of the notch; with $0.95 \times a \leq b \leq 1.05 \times a$

Key:

1: Clamp

2: Notch

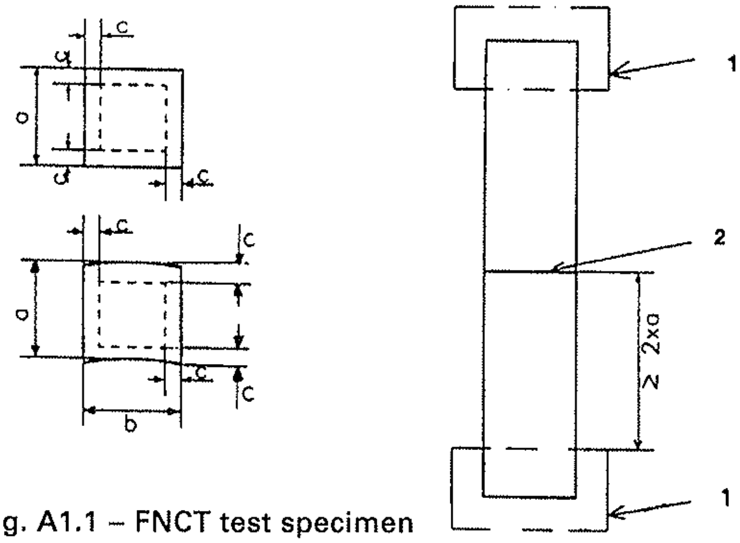

Fig. A1.1 – FNCT test specimen

1.6. Test conditions

The consistency of the test results shall be demonstrated by using reference specimens. The results of the reference specimens per test bath must be available with a frequency of at least 1 specimen per 100 hours over the whole period of testing time.

The specimens are to be loaded by a constant tensile stress of 4 N/mm² ± 0.02 N/mm² in relation to the remaining unnotched cross-sections.

The test temperature has to be kept constant in a range of ± 0.5 K.

The precision of the ligament area has to be ± 16 μm^2.

The tensile creep tests have to be performed on 6 test specimens using an aqueous solutions of ®ARKOPAL N-100 in demineralised water (2/100, w/w). The test fluid has to be stirred during testing in order to prevent separation.

The standard deviation has to be equal or less than 20 % of the geometric mean value calculated from the 6 single values.

The total uncertainty of the FNCT-measurement has to be less than 5 % calculated by the following formula:

$$u_t = \sqrt{\left(\frac{\partial t}{\partial \sigma}\right)^2 \cdot u_\sigma^2 + \left(\frac{\partial t}{\partial T}\right)^2 \cdot u_T^2 + \left(\frac{\partial t}{\partial Kv}\right)^2 \cdot u_{Kv}^2 + \left(\frac{\partial t}{\partial Wv}\right)^2 \cdot u_{Wv}^2 + \left(\frac{\partial t}{\partial M}\right)^2 \cdot u_M^2}$$

were

u_t	Uncertainty of measurement
t	Rupture Time
σ	Stress
T	Absolute Temperature
Kv	Misalignment of the Notch
Wv	Misalignment of the Notch Angle
M	Medium

Annex A 2

Description of the Two Notch Creep Test (2NCT)

General

References: EN 12814-3

The description of the Full Notch Creep Test applies to the Two Notch Creep Test (2NCT) accordingly except for the dimensions of the specimens.

The stripes taken from the pipe wall shall be notched at the machined sides in order to keep the inside and outside wall intact.

The test specimen shall be notched on TWO sides in the same plane.

Annex A 3

Description of the Point Loading Test (PLT)

General

References:

Hessel, J.: Minimum service-life of buried polyethylene pipes without sand-embedding
3R international 40 (2001) Special Plastics Pipes. pages 4-12

3.1 Principle

The resistance to slow crack growth of pipes with external point load can be determined using the point loading test (PLT).

The maximum stress that the pipe material will experience from a point load is the yield stress. Therefore in this test it is ensured that the displacement of the point load into the pipe wall is sufficient to cause yielding of the material at the inside of the pipe.

The required surface elongation at the inner pipe wall (i.e. the above yield elongation) is produced by the displacement of a tool along the radius of the pipe with a tool tip radius of 5 mm.

3.2 Preparation of the test specimens

The pipe dimensions at the location of the point load shall be taken into account when calculating the stress due to internal pressure.

3.3 External loading on test specimen

The test specimen shall be loaded by the loading tool at 23 °C ± 2 K.

The loading tool shall be moved in radial direction only (NO twisting).

The displacement of the loading tool shall produce an elongation at the inside pipe wall which is above the elongation at yield.

The radius of the loading tool tip shall be 5 mm ± 0.1 mm.

3.4 Mounting, conditioning and testing

The test specimen shall be loaded free from external torsion and bending effects at the location of the point load e.g. due to the force from the point loading equipment.

The test specimen shall be filled with the test fluid. The whole test specimen shall be immersed in the test medium with free movement of the end caps.

The test specimen shall be conditioned to the test temperature before pressurizing.

The temperature inside and outside the pipe test specimen shall be kept constant at the test temperature within ± 1 K of the nominal test temperature.

The internal pressure shall be kept constant at the test pressure within ± 2.5 % of the nominal test pressure.

3.5 Evaluation

The failure mode shall be documented.

The time to rupture shall be recorded ± 0.1 h.

Only failure in-between a radius of 4 × wall thickness of the pipe shall be regarded in the evaluation of the test results.

Annex A 4

Description of the Penetration Test

4.1 Purpose of the Penetration Test

The purpose of the penetration test is the simulation of the penetration of a sharp fragment of a burstlined cast iron pipe through the wall of a pipe under internal service pressure.

4.2 Test sample

The test samples used shall be pipes OD 110 mm; SDR 11.

4.3 Test conditions

In order to simulate a sharp fragment of a burstlined cast iron pipe, cylindrical die stamp as per Fig. A4.1 is to be used – as proposed by IKT[5].

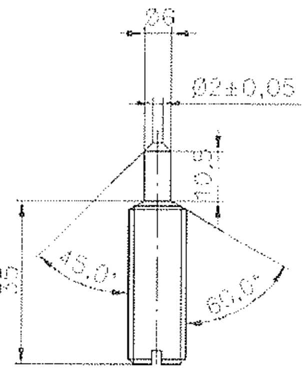

Fig. A4.1 – Dimensions of the 'GG2' test die stamp with blunted spike (diameter: 2 mm)

The test stress in the pipe wall and the associated test temperature is to be calculated from the intersection of the flat branches of the creep rupture curves according to DIN 8075 and the curve representing the start of thermal ageing according to DVS directive 2205-1 supplementary sheet 19 (Fig. A4.2).

In this respect it is to be assumed, that the pipe material in contact with water does not allow stress cracking before the onset of thermal ageing.

The calculated stress values are to be divided by 1.25 (being the lowest safety factor), thus producing the test stress.

The test stress thus represents the highest load during regular service conditions.

[5] Institut für unterirdische Infrastruktur, Gelsenkirchen, Germany (Institute for Subterranean Infrastructures)

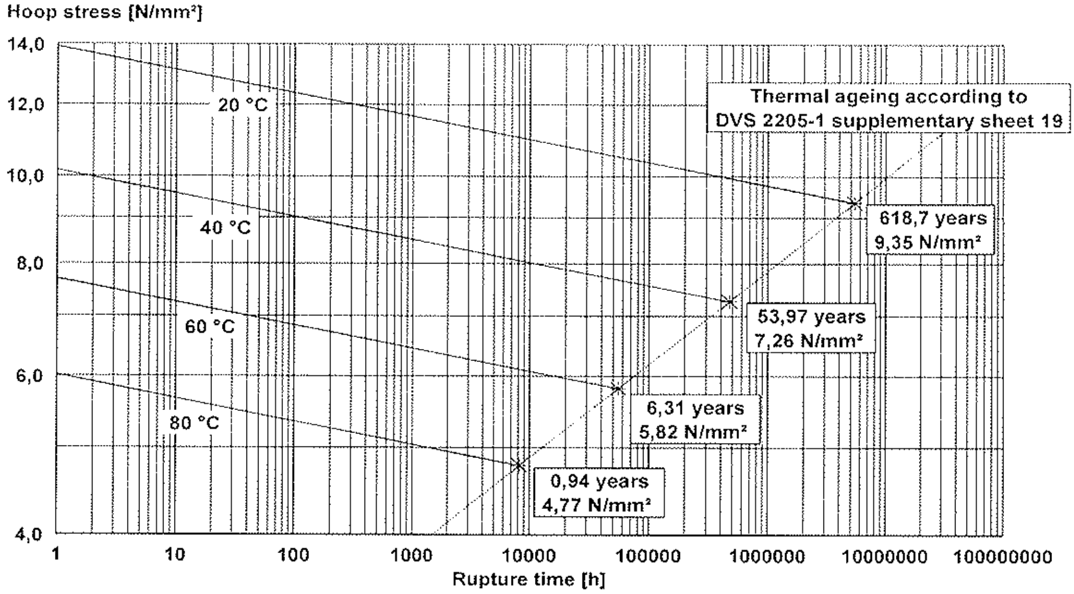

Fig. A4.2 – Intersection between the creep rupture curves of PE 100 (flat 'branches' and the limit curve for the onset of thermal ageing as per DVS directive DVS 2205-1 supplementary sheet 19.

The test parameters selected on the basis of the MAC Procedure lie on a straight line in the Arrhenius plot (Fig. A4.3).

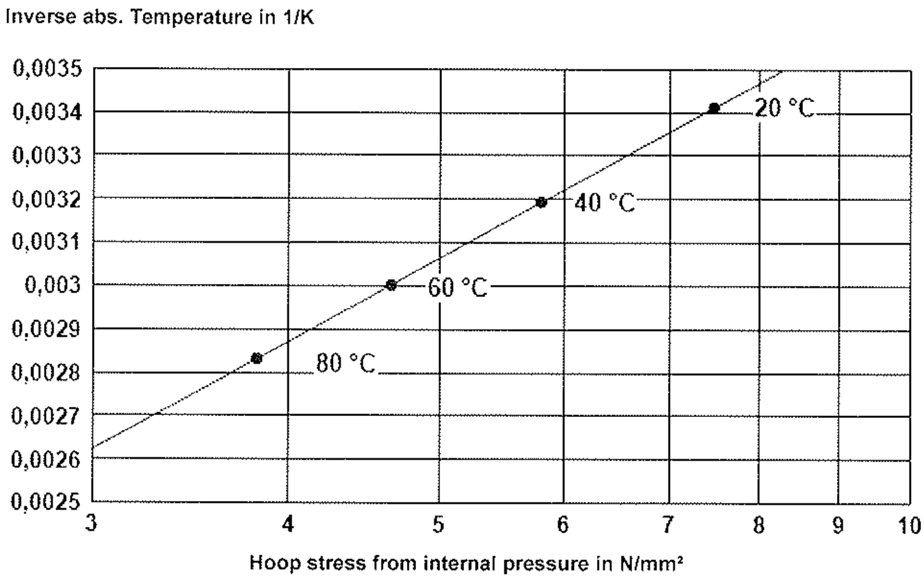

Fig. A4.3 – Illustration of the test parameters in the Arrhenius plot

4.4 The penetration test procedure and interpretation of the results

The displacement of the die stamp is to be 8.18 % of the piping outside diameter, exerted radially at ambient temperature. The die stamp should NOT be allowed to twist.

During the time period of the test, the pipe is to be filled internally with water and immersed externally by the conditioning medium of water at 80 °C, 60 °C and 40 °C. During the test on the pipe at 20 °C, the external medium is to be air or water. The test pressure during the testing time is to be kept constant within a range of ± 2.5 %. The remaining wall thickness below the die stamp is to be measured after a testing time of 9,000 hours.

Annex A 5

Description of the Thermal Ageing Test

5.1 Purpose of the Thermal Ageing test

The thermal stability of the pipe is to be examined for the required service life under consideration of the thermal ageing effect.

5.2 Test samples

OD 32 mm; SDR 11 pipes shall be used with the identical stabilisation as the pipes for alternative installation methods.

5.3 Test conditions

The test conditions under which the circulatory apparatus are to be operated are shown in Table 3. The medium in the apparatus is to be replaced on a weekly basis.

Temperatures:	80 °C, 90 °C, 100 °C, 110 °C
Overpressure:	1,0 bar
Flow velocity:	1 m/s ± $_p$0.2 m/s
Medium:	Drinking water (O_2 content: 6...9 mg/l)
Medium replacement:	Weekly

Table A5.3 – Test conditions for the thermal ageing test

5.4 Performance of the thermal ageing test and interpretation of the results

The determination of the thermal stability of the pipe is to be carried out in an apparatus capable of circulating the test medium. The apparatus is to comprise a stainless steel piping system, to form a closed circuit circulatory ring system to include the inserted test pipes.

The medium is to be circulated through the apparatus and the pipe sample by means of a circulation pump. The flow volume and the flow velocity of the medium can be adjusted by means of a bypass facility. The temperature of the test medium is to be maintained constant by means of a thermostat. In order to be able to operate the apparatus at temperatures greater than 100°C above the steam pressure, the apparatus is to be fitted with a pressurised hot water tank.

The activation energy for the thermal ageing process is calculated using the rupture times and the Arrhenius-law[6]. The onset of thermal aging at the lower confidence limit of 100 years at 20 °C has to be proven by extrapolation.

[6] Directive DVS 2203-4; Suplementary sheet 3

Annex A 6

Description of the External Protective Layer Scratch Test

6.1 Purpose of the External Protective Layer Scratch Test

The scratch depth of a defined blade into the surface of the external protective layer is to be determined under constant load at constant speed.

6.2 Test sample

The test sample used is a pipe containing an external protective layer with a diameter of between 32 mm and 1 200 mm. The minimum thickness of the external protective layer is to be 0.8 mm.

6.3 Test conditions

Scratch speed:	100 mm/min.
Minimum scratch length:	600 mm
Standard climatic conditions:	23/50-2 as per DIN 50014
Conditioning of sample:	24 hours
Blade geometry:	as per Technical Drawing Figure A6.1

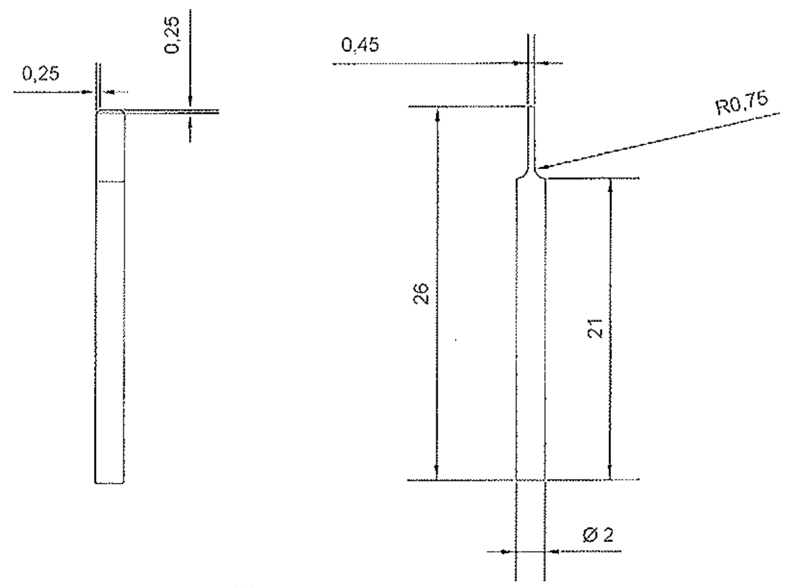

Figure A6.1 – Blade geometry

Load of the blade:

Dimensions	Load
32-90 mm	4 kg
110 – 160 mm	6 kg
> 180 mm	12 kg

6.4 Evaluation and requirements

The scratch depth is to be determined by using a measuring instrument (1/100 mm).

The scratch depth of the blade shall not exceed 75% of the original thickness of the external protective layer.